

Journal of

*Educational Technology
& Society*

Published by

International Forum of Educational Technology & Society



*January 2011
Volume 14 Number 1*

Educational Technology & Society

An International Journal

Aims and Scope

Educational Technology & Society is a quarterly journal published in January, April, July and October. *Educational Technology & Society* seeks academic articles on the issues affecting the developers of educational systems and educators who implement and manage such systems. The articles should discuss the perspectives of both communities and their relation to each other:

- Educators aim to use technology to enhance individual learning as well as to achieve widespread education and expect the technology to blend with their individual approach to instruction. However, most educators are not fully aware of the benefits that may be obtained by proactively harnessing the available technologies and how they might be able to influence further developments through systematic feedback and suggestions.
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The aim of the journal is to help them better understand each other's role in the overall process of education and how they may support each other. The articles should be original, unpublished, and not in consideration for publication elsewhere at the time of submission to *Educational Technology & Society* and three months thereafter.

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Guest Editorial - Creative Design: Scaffolding Creative Reasoning and Meaningful Learning

Chien-Sing Lee¹, Janet L. Kolodner² and Ashok K. Goel²

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Design is a cognitive activity that adds much economic, social and cultural value. Creativity is a desired core competency of individuals and organizations alike. It follows, then, that design and creativity are, or ought to be, among the main goals of learning and teaching. However, we do not fully understand the connections between design and creativity on the one hand, and between learning design and creativity and teaching design and creativity on the other. How, precisely, can design and creative capabilities be promoted in formal and informal education? What are the principles for generating activities and curricula that promote creative design? What scaffolding do learners need to become more creative and to learn to design? How can responsibility for scaffolding be distributed between teacher, peers, and computing technologies?

Information processing theories and technologies impact these issues in at least three fundamental ways. First, we now have the beginnings of information theories of creative design that provide insights into the content, representation, organization, use and acquisition of knowledge. During the 1990's, for example, Kolodner (1994) and Wills & Kolodner (1994) presented a case-based theory of creativity in design while Goel (1997), and Bhatta & Goel (1997) described a theory of creative design that integrates case-based and model-based reasoning. Second, during approximately the same period, constructivist (Savery & Duffy 1996; Jonassen 1999) and social constructivist (Palinscar 1998) theories of learning and teaching became prominent. Third, a new generation of interactive technologies has developed over the past two decade that has the potential for transforming the learning of creative design. These interactive technologies include multimedia technologies and of course the World Wide Web.

The articles in this special issue begin to address the broad issues listed above, taking into account what we know about the reasoning involved in creative design, cognitive and socio-cognitive theories of how people learn, and the affordances of hardware and software technologies. The six papers in this issue answer four core questions: What can we infer from constructivist and socio-constructivist theories of learning about how to help youngsters learn to design and solve problems creatively? What social constructivist practices can be used to promote learning to design, and especially learning to design creatively? How may theories of design, creativity, and creative design inform these practices? How can interactive technologies be exploited to promote such learning?

Lee & Kolodner in "Scaffolding Students' Development of Creative Design Skills: A Curriculum Reference Model" explore the implications of case-based theories of creative design for the design of curriculum that will help high school students learn to design and become more creative designers and problem solvers. Using what we know about constructivist practices and design cognition, they propose a curriculum framework for promoting creative design and describe how it can be operationalized for national and local educational standards. They advocate the teaching creative design within the context of sustainable development projects relevant to the local communities where the high school students live. As stakeholders, it is argued, learners will find the context personally meaningful and be motivated both to do well at achieving project goals and at learning to design and solve problems creatively. Lee & Kolodner's potential reach is global; they envision high school students in cities as disparate as Atlanta, USA, and Kuala Lumpur, Malaysia, working together and learning from each other.

Global outreach aimed at supporting teaching and the development of meaningful learning at the higher education level is investigated in Keskitalo, Pyykkö and Ruokamo's Global Virtual Education (*GloVED*) model. Students from different parts of the world interact with each other in Second Life (SL) to solve a creative design challenge. Analysis suggests that individualized guidance, clear identification of roles, rules and objectives contributing towards effective teamwork, provision of practical examples within contextualized frameworks, critical self-evaluation study, and sufficient time to design and reflect lead to more creative student thinking and better design outcomes.

In “Redesigning a Web-Conferencing Environment to Scaffold Computing Students’ Creative Design Processes,” Bower reports on the evolution of the design of a web conferencing environment over three semesters of college-level education of computer programming. He begins with an information-processing account of creative design based on the interrelated roles of factual, conceptual, and procedural knowledge. He then describes how the web conferencing environment evolved over three iterations from an instruction-based model into a student-led collaborative tool. The final version of the tool also afforded the teacher to better assess students’ mental models and help them correct the models. Bower also extracts some design principles from the empirical study.

The impact of Web 2.0 technologies on learning has been relatively positive in institutions of higher learning and in secondary/high schools. However, their effect on primary school students has been less explored. Woo, Chu, Ho and Li’s case study helps to fill this gap. They have investigated the challenges and potential benefits that a Wiki may bring to students and teachers in a Primary five English language class in Hong Kong and subsequently, identified the Wiki’s key affordances, which can be used to help students improve on their writing abilities. Analyses of students’ collaborative writing projects are positive. Students view the use of the Wiki to learn English as a second language enjoyable, helpful in building teamwork and in improving writing skills.

Sullivan also investigates ways to promote creative design among young learners. However, instead of providing them with information technology, she asks them to solve robotics problems together, identifies the discourse practices that led to key understandings, and traces the conditions under which these understandings led to creative solutions. This work provides key insights into design of learning spaces where creativity, and especially collaborative creativity, can be promoted.

Finally, the article by Vattam, Goel, Rugaber, Hmelo-Silver, Jordan, Gray, and Sinha pulls together an interdisciplinary team of computer, cognitive and learning scientists to investigate how to help middle school students (grades 6 to 8; ages 12 to 14) understand natural complex systems. They propose scaffolding that makes the functional abstractions and the invisible causal behaviors of such systems visible to the students. Such functional understanding is critical to explaining how complex systems work and to developing solutions to problems that occur with such systems, including prediction, monitoring, diagnosis, and redesign. A software system called ACT (the Aquarium Construction Toolkit) helps middle school students reason about structures, functions, and behaviors in aquarium systems, providing a model for designing software that can scaffold systems thinking around other natural (and designed) complex systems.

These selected papers have provided a diverse range of possibilities for modeling ecosystems and creative experimentations; providing rich testbeds for exploration and collaboration. We hope that you will enjoy this special issue.

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Scaffolding Students' Development of Creative Design Skills: A Curriculum Reference Model

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ABSTRACT

This paper provides a framework for promoting creative design capabilities in the context of achieving community goals pertaining to sustainable development among high school students. The framework can be used as a reference model to design formal or out-of-school curriculum units in any geographical region. This theme is chosen due to its individual, community and global impact. Learning activities are designed to promote incremental learning of creative reasoning as students iteratively work towards solving environmental goals in their communities. To inculcate thinking from multiple perspectives, students take on a stakeholder role, analyze cases from around the world with similar problems, generate new ideas, predict their counterparts' arguments, evaluate their own arguments based on their counterpart's points of views, and refine their own ideas/arguments corresponding to goals. For adaptation of the curriculum over a variety of communities while maintaining the main structure and the support for learning the science and for learning creative design skills, modularity is adopted in content and the sequencing of strategies and tactics. If practices are beneficial and widely accepted, they can be included as a part of the meta-reference model and instantiated/cascaded into future reference and individual classroom models. We conclude with implications for instructional design.

Keywords

Twenty first century skills, Instructional design, Creative design scaffolds, Case-based reasoning, Learning-by-design

Introduction

What does it take to develop productive members of society who will regard learning as a lifelong process and who can excel in society whether locally or internationally? This is a crucial question in the minds of every society. According to the US-based Partnership for 21st Century Skills (Saltrick, 2009), students who are prepared to excel will regard the knowledge that they learn in different subjects not as silos of knowledge but as knowledge that intertwines to contribute to a greater whole. They will think in terms of “systems” and connections rather than regard each subject area separately. They should also have sufficient cognitive diversity to develop innovative solutions to complex problems (Leonard, 1998).

In general, the claim is that the more innovative or creative thinkers are, the better citizens and more productive members of society they will be. Our goal, consistent with societal needs for citizens who are creative thinkers, is to find ways to promote development of creative thinking skills. We want to understand how to integrate the learning of such skills into the everyday curriculum of schools, as we want our solution to be accessible to all young students. To promote widespread incorporation and scalability of activities that promote creativity, we believe that activities and scaffolds that will support learning to be creative must be designed in a way that retains core curricular structure and in a way that is easily adaptable to different communities and subject areas.

What we mean by “creativity” is the ability and disposition to work around constraints while achieving design challenges or solving problems. There are many other definitions of creativity that have been proposed. We propose this definition as a description of the everyday creativity required to be a productive member of a society. Within that context, we want to promote the communication, collaboration, flexibility and adaptability, self-monitoring, and systems thinking skills that promote creativity. Our major goal and design focus, is to design and implement a curriculum framework for reference modeling the promotion of creative thinking (along with promotion of other important skills and practices within that context) based on previous curriculum studies. We hope that this framework can subsequently be tested, adopted, adapted, refined and shared by communities of practice spanning multi nationalities.

Problem 1: How can we help students develop creative thinking skills?

Solution 1: Learn from cognitive science and learning sciences communities to develop means of promoting creative thinking.

The cognitive science and learning sciences communities tell us that to learn complex skills, one has to practice them and reflect on one's reasoning across a variety of contexts and applications (see, e.g., Bransford, Brown and Cocking, 2000). With the right scaffolding, the experience of learning in the context of doing affords having experiences that can be reflected on to learn skills and affords deliberative repetition of important skills that leads to incrementally becoming more expert at carrying them out. For example, Learning by Design (Kolodner et al., 2003) helps middle schoolers learn scientific reasoning and the kinds of communication scientists do in the context of learning science content. Project-based science (Marx, Blumenfeld, Krajcik, & Elliot Soloway, 1997; Edelson & Reiser, 2006) and implementations of Problem-Based Learning (Barrows & Feltovich, 1987; Savery & Duffy, 1995; Hmelo & Barrows, 2006) do the same. In each of these approaches, students learn content, domain-specific skills, and more general communication and collaboration skills in the context of answering some interesting question or achieving some engaging design challenge. Our assumption is that these same approaches can be used to help youngsters become more creative, and we have designed a curriculum unit to be used to make this happen.

As mentioned earlier, reflection on learning experiences can help students to become progressively more expert in reasoning across different contexts. Hence, in this paper, we have looked specifically into how we can afford more meaningful and effective collaborative reflection from multiple perspectives as espoused by cognitive flexibility theory (Spiro, Coulsen, Feltovitch & Anderson, 1988) and how to use these multiple perspectives to help students evaluate and refine their own reasoning and view their efforts as parts of a socio-economic-legal-environmental ecosystem.

Problem 2: How to retain the core curricular structure and yet enable easy adaptation to different communities?

Solution 2: Include modularity in strategies and tactics to complement the core curricular structure and learn from prior work on reference modeling

Content, strategies and tactics can be modularized. We refer to prior work on reference modeling to create adaptable curricula for different communities while retaining the core curricular structure. A reference model is built up from the commonalities identified in various models and how these commonalities relate to each other within a specific environment. Hence, a reference model functions like a super class / core reference which can be instantiated to different environmental contexts. Commonalities can be in terms of entities or processes. Examples of the use of reference models in designing learning are found in Lee, Koper, Kommers and Hedberg (2008).

Approach

In this descriptive study, we use what we know about how people learn; especially how people learn from design activities (Papert, 1991; Schank, Fano & Jona, 1993; Kolodner, 1994; Kolodner et al., 2003; Resnick, 2007; Pepler & Kafai, 2008), to describe the implementation of a curriculum unit that can be used to promote the learning of creative reasoning in the context of solving environmental problems in the students' own communities. Such a curriculum unit can be integrated into science classes, technology classes, or extra-curricular learning environments. We hope that after it has been evaluated and iteratively revised, the lessons learned from its design and enactments will serve as principles for developing other such units and, indeed, for integrating the learning of creative reasoning throughout the school curriculum.

As for reference modeling, we have designed a curriculum unit that could fit into a U.S. high-school science class as the reference model and instantiated/adapted it to the Malaysian context. Our designed curriculum unit is intended as a first pass, to be refined over time as it is implemented in a variety of learning environments.

We proceed by outlining the literature we draw on and the suggestions it makes about designing a curricular approach to helping youngsters learn to think creatively. Then we present our designed curriculum unit and why we believe our approach can be successful.

Foundations

Creativity and creative design

We presented our working definition of creative reasoning above: the reasoning required to work around constraints while solving problems or achieving design challenges. Our understanding of what it means to be a creative thinker comes from the second author's work on processes involved in creative design. With respect to generating ideas, the creative designer or problem solver spends time thinking about solutions to similar problems and how they might be applied in the new situation (Kolodner, 1994). Then, while evaluating proposed solutions, the creative reasoner asks a variety of questions about those alternatives, in the process deriving new criteria and constraints, elaborating and reformulating proposed solutions, and generating new alternatives and new evaluation criteria from those already proposed:

- a) function-directed questions (the degree to which a function is met);
- b) derivation-driven questions (questions derived from prior design-solution-reformulations);
- c) outcome-related questions (use of prior outcomes to predict current outcomes – what-if alternatives); and,
- d) constraint-related questions (the degree to which the proposed solution fits).

The full process Wills and Kolodner (1994) propose is shown in Figure 1. The process integrates reasoning needed to solve problems and achieve challenges with the iterative evaluation, explanation, and redesign processes required for creativity.

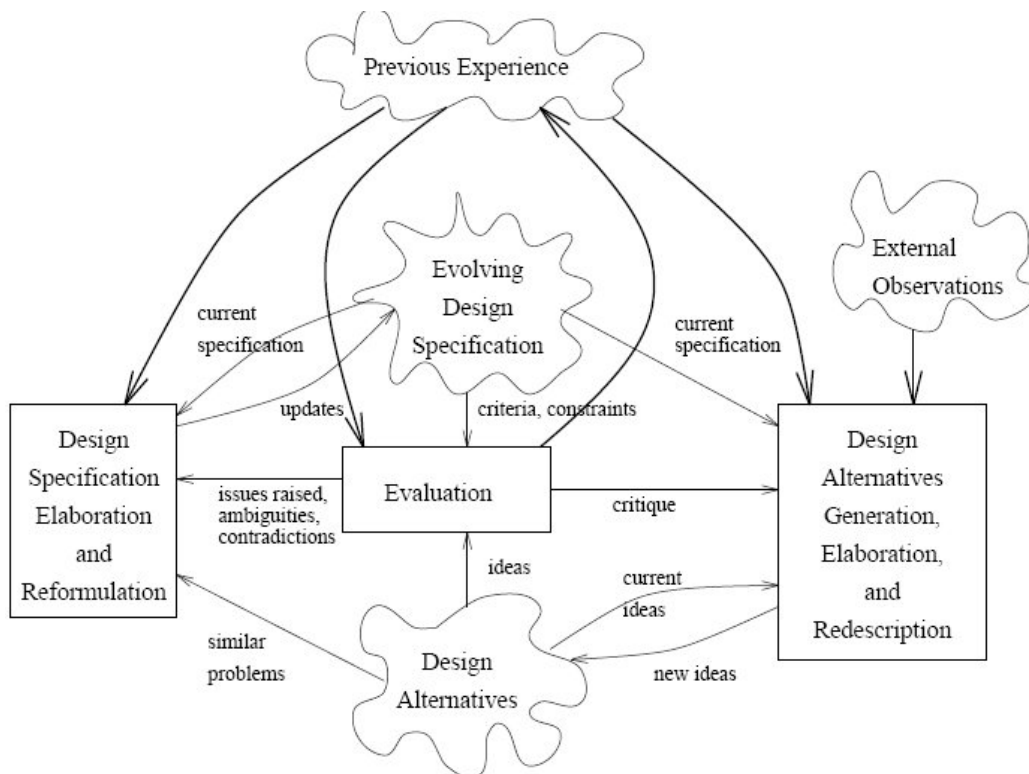


Figure 1. Creative design process

This analysis tells us what needs to be learned to reason creatively: how and when to identify criteria and constraints (design specification in the figure); how to use criteria and constraints as evaluation criteria; how and when to generate alternative solutions, and especially how to use cases and one's own experiences to do that; how to use

evaluation results to elaborate and reformulate alternative solutions (called design alternatives in the figure) and criteria and constraints; and how to identify when one has a good enough solution. The question we must address is this: how can we help students learn these skills and practices? The Learning Sciences literature gives us clues.

Goals as contextualization and self-regulation scaffolding

For meaningful learning to occur, students need, first, a reason for learning; second, to engage in a set of learning activities that can help them to achieve their learning goals; and third, proper scaffolding and other aids to help them derive targeted content and skills from their experiences. Savery and Duffy (1996) note that when students have goals, they can act as a primary pivot around which context, content and learning activities can evolve. Csíkszentmihályi (1997) points out that when students are engrossed in achieving personally meaningful goals, they will achieve a state of “flow” that can only come about from active interaction between the learner and his/her learning environment. All of these researchers tell us that once someone has a goal, the physical, social and emotional environment they are engaging in will suggest and motivate generation of new goals and subgoals. As people generate, evaluate, and refine alternative solutions to challenges they aim to achieve, they identify knowledge and skills they need to learn, setting up new goals for themselves.

It thus makes sense to design learning activities centered on goals that students are likely to take on as their own. One example of a goal-based curriculum design is Schank, Fano, Bell and Jona’s (1993) goal-based scenarios (GBS). Goal-Based Scenarios build on the cognitive model suggested by case-based reasoning (Schank, 1982; Kolodner, 1994), which suggests that learning from experience happens through repeated practice of skills and use of knowledge across a variety of contexts. According to this model, a learner is constantly applying patterns of reasoning from previous experiences, noticing what works and does not work in these applications, explaining successes and failures as much as possible, and updating memory based on those explanations. Designing an effective Goal-Based Scenario requires choosing a mission for students to achieve that will require their repeated use of targeted skills and content. The mission should have a cover story that helps students enter into the mission and take on its goals. It gives them roles, and it sets up situations in which they will carry out skills and apply targeted content. Scaffolding to help students generate alternative ways of achieving goals, evaluate alternative solutions, and reflect on their reasoning and progress is then embedded into this structure.

A second approach to learning through achieving goals that we draw on is Learning by Design (LBD; Kolodner et al., 2003). Like goal-based scenarios, LBD derives from the cognitive model underlying case-based reasoning and proposes that students take on a mission through which they will repeatedly practice and debug targeted skills. Its focus is on learning through engaging in design activities, and it takes seriously the idea of sharing one’s ideas and creations with an interested audience. In addition, LBD proposes classroom activity structures and sequencing of activities designed to help a teacher manage a classroom of young designers, to give students reasons to want to share their ideas and reasoning with other students, to help students reflect productively and provide scaffolding for each other, and to help teachers facilitate classroom discussions in ways that will allow students to grasp the learning affordances of the activities they are engaging in.

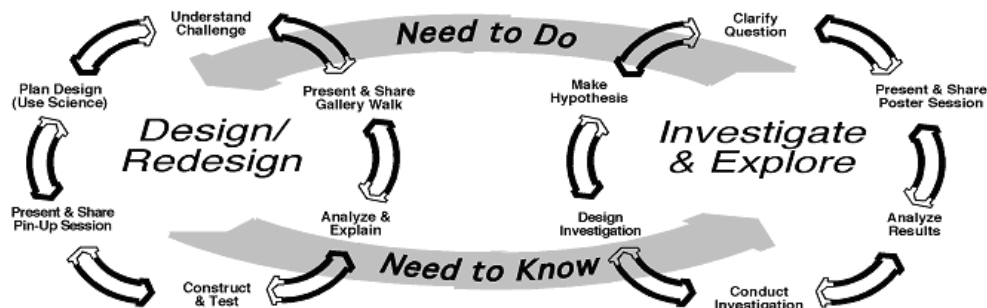


Figure 2. Learning-by-Design Cycles

LBD’s way of sequencing classroom activities is shown in Figure 2. There are two cycles – a design/problem solving/redesign cycle and an investigation/exploration cycle. A design challenge is used to promote generation of design subgoals and learning subgoals. When students identify a need to learn something new in order to achieve the

challenge, activity moves into the investigation/exploration cycle. When learning goals are achieved, activity moves back to achieving the design challenge. Along with these activities, the class also keeps track of their progress on a class project board, where they record their ideas, what they need to learn more about, and what they have learned. The cycle provides opportunities for engaging in and reflecting on each of the skills and practices listed in the previous section as important to creative reasoning. Because communicating and collaborating are built into the sequencing, students naturally propose and defend their ideas.

Cases as adaptation scaffolds

One area not addressed in the foundations above is how to scaffold generation, evaluation, and adaptation (or reformulation) of ideas. We turn to case-based reasoning (Kolodner, 1994) and the idea of case libraries for this. A case is an interpretation of some real-world event. Case-based reasoning is reasoning that makes direct access to cases – either one’s own interpreted experiences or those of others that have been reported to the reasoner.

Previous cases can be used to provide suggestions to proceed in a new situation and how to get around common obstacles. They can also be used to guide evaluation, especially for identifying new evaluation criteria (those that have been used before), developing evidence to inform decision-making, and developing predictions about the way solutions-in-progress will work. In addition, the work of Spiro and colleagues (Spiro, Coulsen, Feltovitch & Anderson, 1988) suggests that use of multiple perspectives through cases can contribute towards development of “cognitive flexibility.” Cognitive flexibility (CFT) refers to the ability to think through a problem from multiple perspectives even when one has not encountered such a problem before. Spiro and colleagues tell us that cognitive flexibility is developed through repeated practice interpreting and using a set of cases to explain multiple situations.

For the unit we have developed, a vital resource for students is a case library of environmental incidents and solutions from around the world. Each case shows an environmental problem that arose or was anticipated in some location in the world, means that were taken to alleviate or postpone the problem, and what happened as a result. Specific cases are assigned for reading and application at different times in the unit. Subsequent discussion with the whole class centers on the ideas, strategies, or evaluation criteria suggested by the case and how to use cases to help with creative reasoning.

Scaffolding development of creative design skills: A curriculum unit on the theme of sustainable development

Application of GBS and LBD

As a first pass, we have built on the combination of Goal-Based Scenarios (GBS) and Learning by Design (LBD) to design the sequencing for a sample curriculum unit. We have proposed a curriculum unit focused on the interdisciplinary theme of sustainable development. Sustainable development means creating the kinds of solutions to everyday problems, both big and small, that impose the least damage on the environment, leaving the world a habitable place for future generations. In the professional world, solving problems in a sustainable way requires integrating ideas from ecology, environmental science, economics, sociology, and politics. With respect to high-school students (our target students), solving problems in a sustainable way means to use what they know of these areas to come up with the best solutions they can.

Schools increasingly involve students with solving these kinds of problems and learning the ecology and environmental science associated with sustainable development. So, we can envision the unit we develop being used in a classroom. Alternatively, it can be used in an after-school program with students already interested in these issues. We have designed the first version of the unit for students in the city of Atlanta, Georgia, USA, and we show how it can be adapted for communities around the world.

Currently, we do not include in the sequencing of specific activities students engage in to learn necessary science. Readers should assume that as students engage in the activities we describe below, they will identify science content they need to learn and that they will engage in activities appropriate for learning that content.

The principles used to construct our curriculum unit are as follows:

- a) Students are asked to undertake the mission of addressing environmental problems in their communities.
- b) Students work in small groups and as a class during the problem-solving process. They may also interact with experts in their community and with other students around the world who are engaged in addressing environmental problems in their own locales.
- c) Students follow a sequence similar to the LBD cycles to achieve their mission.
- d) Pin-up sessions and gallery walks (sharing opportunities) are used extensively as avenues for students to discuss the solutions they are proposing, the obstacles they are encountering while trying to achieve the mission, the tactics and strategies they are using to work around constraints/obstacles, better solutions and better ways of working towards solutions, and the strengths and weaknesses in their reasoning.
- e) As in LBD, students identify science content they need to learn as a natural part of the reasoning they engage in while undertaking their mission. Activities for learning science content are inserted into the classroom activities when those needs arise.

More specifics are presented in Table 1.

Table 1. Description of modules and corresponding strategic scaffolds

Module	Modules description
1	<ul style="list-style-type: none"> - The mission context (sustainable development as a concept, and a set of environmental issues in their community) is introduced: to apply sustainable development concepts and concepts from successful problems and solutions in different parts of the world to creatively address issues in Atlanta’s sustainable development project, the Beltline project. Students come to understand the importance of sustainable development and some consequences of local environmental issues. - Strategies: Watch a video on President Obama’s inaugural speech (authentic, immediate relevance) and articulate about sustainable development and stakeholder roles.
2	<ul style="list-style-type: none"> - How some organizations are already addressing these challenges and missions – locally and around the world in similar places; they are introduced here to the notion of urban planning. - Strategies: identify suitable evaluation criteria and constraints facing the Beltline project (these will be used/added/deleted/modified throughout subsequent module)
3	<ul style="list-style-type: none"> - How smart urban planning contributes towards sustainable development - Strategies: <ul style="list-style-type: none"> o Investigate and explore what urban planning is and use urban planning principles and a case in Washington D. C. to generate potential solutions to issues for Atlanta’s Watershed Management Department. o Design/generate possible solutions and constraints, evaluate feasibility and interestingness of solutions, tradeoffs, rank top three solutions o Identify ways of getting around some of the constraints (e.g., through partnership one can raise money that would not be available otherwise; to help students realize that partnership means lots of different things).
4	<ul style="list-style-type: none"> - How good the alternatives are – students evaluate the solutions different groups have proposed - Strategies: <ul style="list-style-type: none"> o Students discuss how having alternatives and understanding multiple perspectives from different stakeholders’ perspectives contribute to working around constraints o Redesign their initial proposed solution in view of legal guidelines by using LBD to investigate and explore strategies introduced in Module 3. o Redesign, present justifications in pin-up sessions o Go through gallery walk - refine sub-goals (if necessary) and revise design, identify and elaborate on what they need to investigate next
5	<ul style="list-style-type: none"> - More in-depth discussions on what other successful cases are telling us – based on cases from around the world, they continue evaluating and reformulating their solution alternatives - Strategies: <ul style="list-style-type: none"> o Investigate and explore 2 longer successful cases in Boulder and Portland o Iterate through design and redesign LBD strategies introduced in Modules 3 and reinforced in Modules 4
6	<ul style="list-style-type: none"> - How the learner himself/herself can contribute towards his/her community – they identify the roles they can play in moving a small number of these alternative solutions forward.

	<ul style="list-style-type: none"> - Strategies: <ul style="list-style-type: none"> o Students apply, evaluate, create/design the parks for their own communities using a 3D modeling toolkit o Apply investigate and explore, design and redesign strategies.
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Enabling reference modeling while retaining core curricular components

We want to create modules that could easily be adapted for use in a variety of locales. There are two reasons why this is important to us. One reason is so that any module we create for promoting creative thinking can be scaled up for broad use. Our second reason is that there is reason to believe that if students in different places interact with each other as they are solving environmental problems in their own locales, students might have additional reasons to engage and have more opportunities to learn different strategies and tactics for creative reasoning.

Reference modeling framework

Table 2 below shows our proposed framework for reference modeling. Instructional design is divided into pre-, during- and post-instruction. These three phases are mapped to the commonly accepted generic model for instructional design, i.e., the ADDIE: analysis, design, development, implementation and evaluation (Strickland, 2006). Hence, pre-instruction involves analysis of the students' contextual environment and the design of learning strategies. Development of learning materials ensues from these phases for different platforms (face-to-face/blended/virtual). Evaluation of the actual instructional design implementation concludes the learning session. Contextual relevance parameters are from an earlier work on reference modeling in the US (Lee & Blank, 2009).

Table 2. Reference modeling framework

US curricula meta-reference model					
Goals (GBS)					
Themes					
Pre-instruction	Analyze	Contextual relevance: <ul style="list-style-type: none"> - National and state standards - Students' needs (prior and future knowledge) - Students' environment (motivationally challenging?) - Differentiation (regular classroom?) 			
	Design	Critical thinking (LBD)		Creative thinking	
		Investigate & explore: Goal-based filtering <ul style="list-style-type: none"> - relevance of issues - ambiguities - contradictions 	Design & redesign: Goal-based evaluation <ul style="list-style-type: none"> - constraints & stakeholders - evaluation criteria? 	Learning from examples (CBR) <ul style="list-style-type: none"> - design solutions to overcome constraints - CBR guiding questions 	Learning from multiple perspectives (CFT) <ul style="list-style-type: none"> - different roles - predictive counter-arguments, evaluation and refinement
	Develop	Multimedia learning materials			
During instruction	Implement	In the classroom/virtual			
Post-instruction	Evaluate	<ul style="list-style-type: none"> - Objectives achieved? - Students engaged? - Creative outcomes? - What did students learn about the creative process? 			

Modular instantiations and adaptations of tactics from the US curriculum to the Malaysian curriculum

The goals of sustainable development in any part of the world will be more or less similar. The problems specific to each city or country however, will differ. Examining the differences in Module 3 in the Atlanta and Kuala Lumpur (KL) curricula illustrate more directly some of the ways we propose to adapt the Atlanta curriculum module to meet

the needs of Kuala Lumpur students. Since the Malaysian students will be using US successful projects as case studies, there is an added learning objective in the Malaysian version of Module 3 -- students consider what and how to transfer the successful solutions from the US to the KL city. There are more activities in the Malaysian curriculum as there is a need to guide students from a teacher-centered mode of learning to a project-based learning mode. The different activities in Module 3 are shown in Table 3 below.

Table 3. Instantiation and adaptation of tactics in the US and Malaysian curricula (Module 3)

ADDIE	US curriculum	Malaysian curriculum
Analyze	<p>Contextual relevance:</p> <ul style="list-style-type: none"> - National and state standards - Students' age: 16 - Students' needs: <ul style="list-style-type: none"> ▪ Prior knowledge: ▪ Target knowledge: ▪ Future knowledge: - Common mode of classroom learning: Student-centred (project-based learning) - Students' environment: Average performing suburban high school, moderately motivated - Differentiation: Regular classroom 	<p>Contextual relevance:</p> <ul style="list-style-type: none"> - National and state standards - Students' age: 16 - Students' needs: <ul style="list-style-type: none"> ▪ Prior knowledge: ▪ Target knowledge: ▪ Future knowledge: - Common mode of classroom learning: Teacher-centered (lecture style) - Student-centered style to be implemented: project-based learning - Students' environment: Average performing suburban high school, moderately motivated - Differentiation: Regular classroom
Design	<ol style="list-style-type: none"> 1. In small groups, read article on effects of urban sprawl in various parts of the US. 2. Identify problems, effects and solutions in the article. 	<ol style="list-style-type: none"> 1. In small groups, read and discuss about flash floods in KL. 2. Identify how flash floods and stormwater management are related. 3. Read article on effects of urban sprawl in various parts of the US and identify how urban sprawl is related to stormwater management. 4. Identify problems, effects and solutions in the article. 5. Determine which issue(s) in the US is <i>relevant to the issue(s) in KL, resolve ambiguities and contradictions</i>)
	<ol style="list-style-type: none"> 3. Identify the stakeholders and discuss how stakeholders influence the decision-making process and achievement of the goal. 4. Explore the meaning of working around constraints. 5. Discuss examples. 	<ol style="list-style-type: none"> 6. Identify the stakeholders in the US and in the Malaysian scenarios and discuss how stakeholders influence the decision-making process and achievement of the goal. 7. Explore the meaning of working around constraints. 8. Discuss examples.
	<ol style="list-style-type: none"> 6. Read article on smart growth in Washington D. C. 7. Analyze and interpret factors leading to success/failure and reasons behind them 	<ol style="list-style-type: none"> 9. Read article on smart growth in Washington D.C 10. Analyze and interpret factors leading to success/failure and reasons behind them
	<ol style="list-style-type: none"> 8. Read new info on Atlanta Watershed department's initiatives 9. Compare and contrast how Washington D. C. and Atlanta have managed their stormwater management problems (<i>determine relevance of issues to the goal for these districts and to the students' goals, resolve ambiguities and contradictions</i>) 10. Determine suitable evaluation criteria to 	<ol style="list-style-type: none"> 11. Read new info on Atlanta Watershed department's initiatives 12. Read and discuss KL's specific initiatives on stormwater management in line with the water-sensitive urban design approach and strategies 13. Compare and contrast how Washington D. C. and Atlanta have managed their stormwater management problems (<i>determine relevance of issues to the goal for these districts and to the</i>

<p>determine which practices in D.C. can be used in Atlanta</p> <p>11. Evaluate problems, solutions and outcomes.</p>	<p><i>students' goals, resolve ambiguities, contradictions)</i></p> <p>14. Determine <i>suitable evaluation criteria</i> to determine which practices in D.C. and Atlanta can be used in KL.</p> <p>15. Evaluate problems, solutions and outcomes.</p>
<p>12. Generate alternative solutions</p> <p>13. Identify possible <i>constraints</i> e.g. <i>legal, different stakeholders' interests</i>, to the proposed solutions</p> <p>14. Evaluate possible solutions to <i>work around the constraints</i></p> <p>15. Determine best three solutions based on feasibility and interestingness</p> <p>16. Present and share to the class, get feedback and refine proposed solutions</p>	<p>16. Generate alternative solutions</p> <p>17. Identify possible <i>constraints</i> e.g. <i>legal, different stakeholders' interests</i>, to the proposed solutions</p> <p>18. Evaluate possible solutions to <i>work around the constraints</i></p> <p>19. Determine best three solutions based on feasibility and interestingness</p> <p>20. Present and share to the class, get feedback and refine</p>

The KL curriculum can be used as a reference model for other cities in Malaysia. Instantiations and adaptations from the KL curriculum to another city in Malaysia are shown in Table 4. Only national standards are shown in Table 4 as Malaysia has only one standard, i.e. the national standards.

Table 4. Instantiation and adaptation of tactics from the KL curriculum to another Malaysian city (Module 3)

KL curriculum	PJ curriculum
<p>Contextual relevance:</p> <ul style="list-style-type: none"> - National standards: - Students' age: 16 - Students' needs: <ul style="list-style-type: none"> ▪ Prior knowledge: ▪ Target knowledge: ▪ Future knowledge: - Common mode of classroom learning: Student-centered (project-based learning) - Students' environment: Average performing suburban high school, moderately motivated - Differentiation: Regular classroom 	<p>Contextual relevance:</p> <ul style="list-style-type: none"> - National standards: - Students' age: 16 - Students' needs: <ul style="list-style-type: none"> ▪ Prior knowledge: ▪ Target knowledge: ▪ Future knowledge: - Common mode of classroom learning: Teacher-centered (lecture style) - Student-centered style to be implemented: project-based learning - Students' environment: Advanced performing suburban high school, highly motivated - Differentiation: Regular classroom
KL curriculum	PJ curriculum
<ol style="list-style-type: none"> 1. In small groups, read and discuss about flash floods in KL. 2. Identify how flash floods and stormwater management are related. 3. Read article on effects of urban sprawl in various parts of the US and identify how urban sprawl is related to stormwater management. 4. Identify problems, effects and solutions in the article. 5. Determine which issue(s) in the US is <i>relevant to the issue(s) in KL, resolve ambiguities and contradictions)</i> 	<ol style="list-style-type: none"> 1. In small groups, read and discuss about flash floods in KL. 2. Identify how flash floods and stormwater management are related. 3. Read article on effects of urban sprawl in various parts of the US and identify how urban sprawl is related to stormwater management. 4. Identify problems, effects and solutions in the article. 5. Determine which issues in the US and KL are <i>relevant to the issues in PJ, resolve ambiguities and contradictions)</i>
<ol style="list-style-type: none"> 6. Identify the stakeholders in the US and in the KL scenarios and discuss how stakeholders influence the decision-making process and achievement of the goal. 7. Explore the meaning of working around constraints. 8. Discuss examples. 	<ol style="list-style-type: none"> 6. Identify the stakeholders in the US and in the KL scenarios and discuss how stakeholders influence the decision-making process and achievement of the goal. 7. Explore the meaning of working around constraints. 8. Discuss examples.

<p>9. Read article on smart growth in Washington D.C. 10. Analyze and interpret factors leading to success/failure and reasons behind them</p>	<p>9. Read article on smart growth in Washington D.C. 10. Analyze and interpret factors leading to success/failure and reasons behind them</p>
<p>11. Read new info on Atlanta Watershed department's initiatives 12. Read and discuss KL's specific initiatives on stormwater management in line with the water-sensitive urban design approach and strategies 13. Compare and contrast how Washington D. C. and Atlanta have managed their stormwater management problems (<i>determine relevance of issues to the goal for these districts and to the students' goals, resolve ambiguities, contradictions</i>) 14. Determine <i>suitable evaluation criteria</i> to determine which practices in D.C. and Atlanta can be used in KL. 15. Evaluate problems, solutions and outcomes.</p>	<p>11. Read new info on Atlanta Watershed department's initiatives 12. Read and discuss whether PJ has any specific initiatives on stormwater management similar to KL's. 13. Compare and contrast how Washington D. C., Atlanta and KL have managed their stormwater management problems (<i>determine relevance of issues to the goal for these districts and to the students' goals, resolve ambiguities, contradictions</i>) 14. Determine <i>suitable evaluation criteria</i> to determine which practices in D.C., Atlanta and KL can be used in PJ. 15. Evaluate problems, solutions and outcomes.</p>
<p>16. Generate alternative solutions 17. Identify possible <i>constraints</i> e.g. <i>legal, different stakeholders' interests</i>, to the proposed solutions 18. Evaluate possible solutions to <i>work around the constraints</i> 19. Determine best three solutions based on feasibility and interestingness 20. Present and share to the class, get feedback and refine</p>	<p>16. <i>Generate alternative solutions</i> 17. Identify possible <i>constraints</i> e.g. <i>legal, different stakeholders' interests</i>, to the proposed solutions 18. Evaluate possible solutions to <i>work around the constraints</i> 19. <i>Predict the counterparts' goals and arguments by simulating their roles</i> 20. <i>Evaluate own proposed solutions based on counterparts' goal, possible arguments and possible outcomes</i> 21. <i>Refine own proposed solutions and predict possible outcomes</i> 22. Determine best three solutions based on feasibility and interestingness 23. Present and share to the class, get feedback and refine</p>

Implications for instructional design practice

We need to focus reflections on ADDIE design and practice to encourage more critical and creative thinking. We have shown how in the analysis phase, contextual relevance focusing on national (and state) standards, students' needs and relevance of learning can highlight the symbiotic relationship between the students' immediate environment and the students and afford contextual associations between goals and plans. This makes the mission context more meaningful. Furthermore, affordance of contextual associations between goals and plans highlights the taxonomical relationships in knowledge building. In turn, these taxonomical relations can be used to search for similar contents or strategies across curricula and domains. The benefits to multinational curricula are easier contextualization of lesson planning and easier (and faster) navigation access to relevant content.

In the design phase, critical thinking skills such as goal-based filtering skills should be emphasized, whereby students need to learn how to differentiate relevance of issues to their goal and subgoals and subsequently, how to identify and resolve ambiguities and contradictions. In line with LBD, these activities are iterative and collaborative, with students working in small groups and constantly interacting with the whole class. Multiple iterations however, may take up a lot of class time, which sometimes, is not easily available. As such, the teacher can first model the identification of constraints and possible ways of working around the constraints through an example and subsequently, model how to determine suitable evaluation criteria. As students progress through iterations of design, modeling can progressively fade so that students can independently use their own ingenuity to determine what

constraints they are likely to face, how they can overcome these constraints and how to determine/refine their own evaluation criteria to determine what they need to know more about in order to reach a suitable and optimal decision. Furthermore, iterations may need to focus only on the key components. In our example above, the key components are identifying and working around constraints, and determining evaluation criteria. Focusing on key components may help students to realize which activity is core and which supportive in achieving a goal. Realizing which activity is core or supportive relative to a goal may enable the student to be flexible in his/her reasoning process. Realizing that flexibility in reasoning is allowed may encourage the student to explore based on his/her own intelligent guess and think more independently.

In addition, to inculcate creative thinking, examples need to be provided at the initial stages as launching pads from which students can brainstorm and design alternatives. Guiding questions (such as function-, derivation-, outcome- and constraint-directed scaffolds) should feature prominently across many strategies and tactics. Which type of scaffold is to be used depends on the strategy and the students' mastery level (advanced, average or weak). Hence, there will be different types and different number of creative thinking questions/driving questions. For example, function-directed questions will be most prevalent in all learning activities due to its goal-orientation and contribution to self-regulation. Derivation-directed questions encourage inductive, deductive and systems thinking.

After the first iteration, learning activities need to help students to look at the problem from different perspectives. The aim is to help students realize that all cause-effect relations occur in an ecosystem and that they as a stakeholder are part of this ecosystem interrelating with and affecting other parts of this ecosystem. Hence, students need to predict whom and what their actions will have impact on and reason and adjust accordingly. An example is by simulating the counterpart stakeholder's goals and arguments and using these to evaluate and refine their own goals and arguments.

Subsequently, to adapt learning to different environmental contexts, strategies and tactics can be instantiated from the meta-reference model to the reference model and subsequently, the individual classroom models. This should save lesson-planning time. However, in multi-national curricula, adaptations are common due to different environmental, socio-economic and legal contexts. Hence, flexibility and simplicity in design should be catered for. In addition, if teachers and students' evaluations of lessons are factored into the learning system, these would be very helpful in highlighting best practices that can be emulated. At a more advanced and personal level, learning strategies and tactics can be personalized to students' knowledge states (mastery level), learning styles and preferences as elaborated on in Sampson, Karagiannidis and Kinshuk (2002).

Strategies and tactics shown in Tables 3 and 4 can be added, adapted or deleted. The modularity of strategies and tactics fits well with the modularity of learning objects (Verbert & Duval, 2004). Each learning object consists of different media, which can be reused across domains and lessons. Hence, for any development of content (media in learning objects), clear indications of the inherent taxonomical interrelationships among the different parts of the learning objects should be provided for in order to allow reusability of these learning object parts to different strategies and tactics across domains.

In terms of formative evaluation, it may be worthwhile to place more emphasis on reflecting and evaluating the processes by which students improve in their creative capabilities, i.e., how much students have improved with regards to investigate and explore (goal-based filtering), design and redesign (goal-based evaluation), learning from examples and learning from multiple perspectives. This is so that students become aware that the process is more important than the creative output. Thus, they should not rush to quickly come up with an output and in the process prematurely dismiss alternative solutions, which may lead to better solutions. Subsequently, summative evaluation will consider the process, the creative artifact at each iteration and the final artifact.

Conclusion

We have presented a description of a curriculum reference model drawn from several literatures, in designing our approach to learning creative reasoning: what we know about how people learn, especially how they learn skills; the skills involved in reasoning creatively; what we already know about how to help people learn to be creative; and approaches to promoting skills learning, including design-based learning, Goal-Based Scenarios, and project-based

learning. We have also woven the curriculum around goal-oriented systems thinking and the development of scientific reasoning, creative thinking and collaborative learning skills.

Our next steps are to test our approach using a design-based study to improve on the curriculum and the methodology. In later enactments, we hope to have students in Kuala Lumpur and Atlanta interact with each other as they are achieving their missions. This, we hope, will both increase engagement and promote broader and/or deeper learning. We hope that this framework will be put to the test, adopted, adapted, refined and shared by communities of practice of multi nationalities.

Acknowledgement

The Fulbright Commission funded the development of the sustainable development curriculum between Atlanta city and Kuala Lumpur city. The National Science Foundation funded earlier work on LBD.

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Exploring the Meaningful Learning of Students in Second Life

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ABSTRACT

This study reports a case study in which a pedagogical model, namely the Global Virtual Education (GloVED) model, which is based on the teaching-studying-learning process (TSL process) and the characteristics of meaningful learning, is developed and used to evaluate students' meaningful learning experiences during the Global Virtual Collaboration Project (GVCP) course in spring 2009. During the course, using collaboration technologies, global student ($N = 54$) teams solved a creative design task. The data were collected and analyzed using various methods. The results suggest that the GVCP course supported the process characteristics of meaningful learning and its outcomes, although the individual, critical, and interactive characteristics were not fully realized. In addition, Second Life (SL) did not contribute to the realization of the goal-oriented, collaborative, conversational, and immersive characteristics. Several implications can be drawn from the results with respect to creative design.

Keywords

Meaningful learning, Teaching-studying-learning process, Pedagogical model, Creative design, Second Life

Introduction

The educational potential of virtual worlds, such as Second Life (SL, also referred to as a multi-user virtual environment), has been widely recognized and discussed among educators in recent years, although the instructional strategies in SL are still in their infancy (Edirisingha, Nie, Pluciennik, & Young, 2009; Jarmon, Traphagan, Mayrath, & Trivedi, 2009; Mayrath, Sanchez, Traphagan, Heikes, & Trivedi, 2007; Warburton, 2009). SL can be described as a three-dimensional (3D) shared place, where thousands of participants can simultaneously collaborate with each other via avatars — the students' representations in the virtual world — in a non-competitive manner (Ondrejka, 2008; Warburton, 2009). In SL, participants can unleash their imagination and creativity by creating objects, identities, and knowledge, and by breaking physical, geographical, generational, and professional boundaries (Ondrejka, 2008). As noted, there is a new kind of educational potential in virtual worlds.

The purpose of this study is to take an educational perspective to a global virtual course in the field of engineering. The aim of this study is to develop a pedagogical model, namely the Global Virtual Education (GloVED) model, and use it to evaluate the students' meaningful learning experiences in the Global Virtual Collaboration Project (GVCP) course. The model is based on the ideas of the teaching, studying, and learning (TSL) process (Kansanen, Tirri, Meri, Krokfors, Husu, & Jyrhämä, 2000; Uljens, 1997), the characteristics of meaningful learning (Ausubel, 1968; Jonassen, 1995; Löfström & Nevgi, 2007; Ruokamo & Pohjolainen, 2000), and previous pedagogical models (Hakkarainen, 2007; Tissari, Vahtivuori-Hänninen, Vaattovaara, Ruokamo, & Tella, 2005). In this research, the characteristics of meaningful learning are used to describe the study process. A pedagogical model can be viewed as “a plan or pattern that can be used to shape curriculums (long-term courses of studies), to design instructional materials, and to guide instruction in the classroom and other settings” (Joyce & Weil, 1980, p. 1). The aim of this pedagogical model is to help teachers and researchers in planning, realizing, and evaluating education to enhance students' meaningful learning experiences.

The GVCP course was conducted at the Helsinki University of Technology (HUT, Espoo, Finland); the University of Twente (Enschede, The Netherlands); Columbia University (New York, NY, USA); and the Indian Institute of Technology Madras (Chennai, India) in spring 2009. Altogether, 54 students participated in the GVCP course. The course aims to provide students with an opportunity to learn how to collaborate on and solve real business problems in SL. During the course, multiple methods were used to collect and analyze data. An introduction to the theoretical background, the GloVED model, research question, and the methods follow. Finally, the results are presented and discussed.

Theoretical background

Previous research on the educational use of Second Life

Several studies have argued that the value of virtual worlds lies in their ability to provide students with a greater sense of presence and belonging (Edirisingha et al., 2009; Holmberg & Huvila, 2008; Omale, Hung, Luetkehans, & Cooke-Plagwitz, 2009; Salmon, 2009; Warburton, 2009) compared to more traditional text-based learning environments, where feelings of isolation and loneliness are commonly highlighted (Löfström & Nevgi, 2007). Due to the attractive appearance, the existence of avatars, and a shared place, as well as the possibility of communicating synchronously, SL has succeeded in capturing the interest and motivation of most learners (Holmberg & Huvila, 2008; Mayrath et al., 2007; Omale et al., 2009). Sometimes we can even talk about an immersive experience (Delwiche, 2006; Edirisingha et al., 2009; Salmon, 2009). In SL, it is also possible to do things that might be difficult or even impossible to do in real life (Ondrejka, 2008; Salmon, 2009; Twining, 2009). For example, students can explore different cultures by going to locations that are otherwise elusive. As noted, SL provides great opportunities for experiential, inquiry, and authentic learning (Jarmon et al., 2009; Salmon, 2009; Warburton, 2009).

SL has also been noted as a functional environment for collaborative learning (Salmon, 2009). For instance, creating one's own world in SL helps students learn how to collaborate and solve problems (Delwiche, 2006; Ondrejka, 2009; Warburton, 2009). Studies have also shown that students prefer working in groups in SL, and this collaborative activity may lead to the creation of a community of practice (Jarmon & Sanchez, 2008; Mayrath et al., 2007). Previous researchers have also noted that the barrier to participating in discussions in SL is lower than in real life. In addition, the interaction between students and teachers is more spontaneous and direct, since all the participants are able to be simultaneously present in the same place and see each other (Edirisingha et al., 2009; Holmberg & Huvila, 2008; Omale et al., 2009). The array of communication tools in SL also makes participating in communication easier (Jarmon et al., 2009). However, there are also contradictory results of students' collaboration in SL. For instance, communities are not always easy to find, and participation in these communities can be difficult (Jones, Morales, & Knezek, 2005; Warburton, 2009).

There are certain issues that educators must consider while planning to use SL in education. Several authors have noted that it takes time to get acquainted with the environment (Delwiche, 2006; Mayrath et al., 2007; Ondrejka, 2008; Salmon, 2009; Warburton, 2009). Therefore, a strong scaffold and support are needed. According to Omale and associates (2009), technology was "a distraction rather than an enabler" (p. 492). The authors supposed that the participants were so overwhelmed by the environment that they were distracted from their actual learning tasks. As results have shown, learning in SL is not necessarily enhanced. Therefore, SL must be used in a pedagogically appropriate way, and students' activities must be well structured in order to promote meaningful learning and meet learning goals.

GloVED model

Generally, this research builds on the socio-constructivist and socio-cultural perspectives of learning (Lave & Wenger, 1991; Vygotsky, 1978). According to these views, learning is seen as a tool-dependent and social phenomenon, whereas interpersonal knowledge is seen as achieved by its social construction and use of cultural artefacts. The GloVED model is based on the idea of the TSL process (Kansanen et al., 2000; Uljens, 1997), the characteristics of meaningful learning (Ausubel, 1968; Jonassen, 1995; Löfström & Nevgi, 2007; Ruokamo & Pohjolainen, 2000), and previous pedagogical models (Hakkarainen, 2007; Tissari et al., 2005). The special characteristics of the students, SL, and the course content are also considered. The GloVED model is presented in Figure 1.

Overall, the TSL process implies that teaching does not necessarily lead to learning, but that students' activity is needed before learning can be attained (Kansanen et al., 2000; Uljens, 1997). Here teaching is viewed as teachers' activities that aim to promote students' meaningful learning by using different kind of strategies (Kansanen et al., 2000). In this research, 17 characteristics of meaningful learning are used to describe the studying in this context. These characteristics are selected from theories and results of previous research (e.g., Hakkarainen, 2007; Jonassen, 1995; Löfström & Nevgi, 2007; Ruokamo & Pohjolainen, 2000; Tissari et al., 2005). We argue that course organizers should emphasize these selected characteristics in order to promote students' meaningful learning in SL.

However, it should be noted that these characteristics partially overlap and are interconnected (Jonassen, 1995). In the GloVED model, learning includes the expected outcomes of the GVCP course (cf. Hakkarainen, 2007), which are elaborated in more detail in the course’s description.

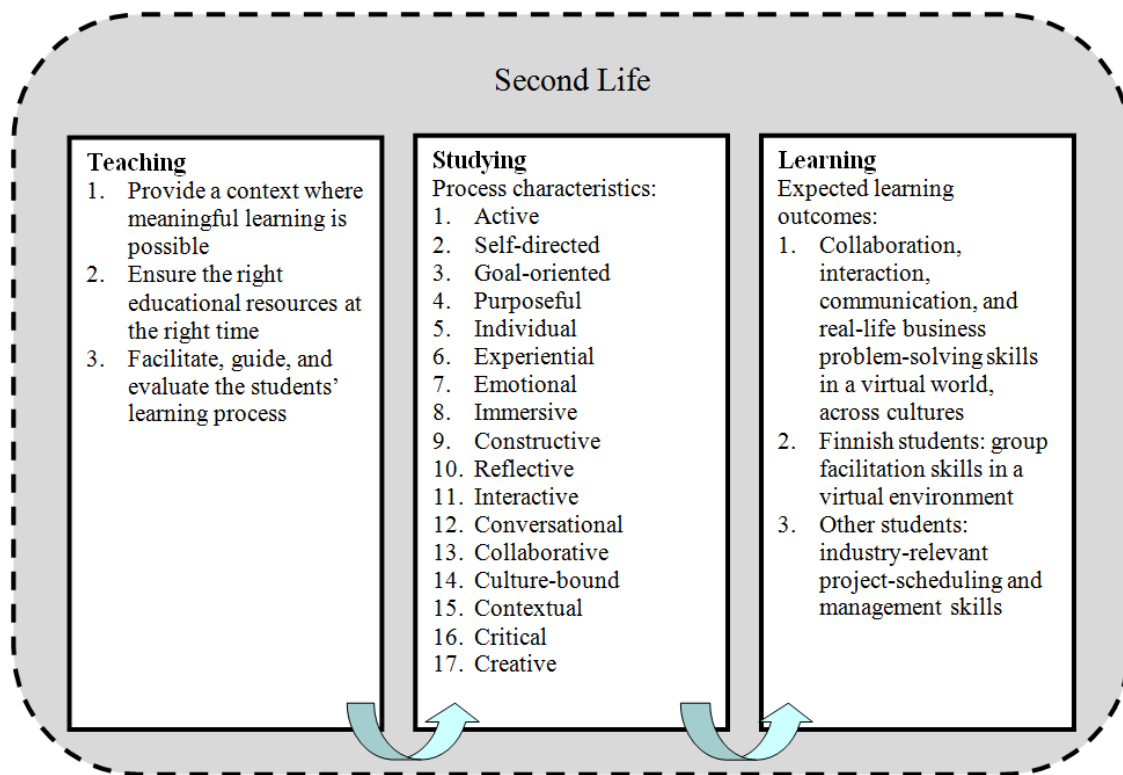


Figure 1. The GloVED model

Active and self-directed characteristics indicate that students should engage in finding, evaluating, and constructing knowledge (Jonassen, 1995), while also being responsible for planning, executing, and evaluating their own learning. Consequently, instruction involves supporting these processes. Intertwined with previous characteristics are goal-oriented and purposeful characteristics, which mean that students have a goal and purpose for their learning (Jonassen, 1995). Therefore, it is important that both the learning environment and the teachers support this student activity. Learning is also individualistic in that learners enter the learning environment with individual characteristics (De Corte, 1995; Karagiorgi & Symeou, 2005). Thus, it is important that teachers take students’ characteristics into account as well as provide individual guidance and feedback for all the students (Karagiorgi & Symeou, 2005). Experiential characteristics imply that students have the opportunity to use their own experiences as starting points in learning, as well as gain new ones, which are then used to further enhance the learning and knowledge construction (Kolb, 1984).

Emotions are always intertwined with learning (Damasio, 2001). Previous research has indicated that SL is an engaging and immersive environment, and may therefore result in greater motivation and learning (Holmberg & Huvila, 2008; Twining, 2009). However, extreme immersion may also lead to addiction, and thus students should be warned of this possibility (Delwiche, 2006). According to Jonassen (1995) constructivist characteristics mean that “learners accommodate new ideas into prior knowledge (equilibrating) in order to make sense or make meaning or reconcile a discrepancy, curiosity, or puzzlement” (p. 60). Intertwined with the constructivist characteristics is reflection, which implies that students articulate what they have learned and reflect on the process and decisions (Jonassen, 1995).

Interactive and conversational characteristics imply that when studying takes place in SL, the conversations and avatar interactions play a vital role in creating a shared understanding of the subject matter. Therefore, the orientation of the environment as well as successful communication and dialogue should be emphasized (Delwiche, 2006; Holmberg & Huvila, 2008; Mayrath et al., 2007; Ondrejka, 2008; Salmon, 2009; Warburton, 2009). Studying

collaboratively means that students work in groups in which the students exploit each other's knowledge and skills, provide feedback and support, and model and imitate each other's behavior (Jonassen, 1995). According to Karagiorgi and Symeou (2005), this also means that learners can develop, compare, and understand multiple perspectives on an issue. Learning is bound to the surrounding culture and its wider contexts as the culture-bound and contextual characteristics indicate (Vygotsky, 1978). Therefore, in order to promote learning transfer, learning tasks should be situated in a meaningful and real-world context or simulated through case-based or problem-based examples of the real world (Jonassen, 1995; Karagiorgi & Symeou, 2005).

In learning, students should be encouraged to critically evaluate their own learning, their acquired information, and the learning environment (Hakkarainen, 2007), as well as explain and defend their decisions (Karagiorgi & Symeou, 2005). Critical thinking is also intertwined with creative thinking. In creative learning and creative design, students should be encouraged to create novel and unexpected connections between concepts based on previous knowledge and existing ideas (Eysenck, 1994; Howard, Culley, & Dekoninck, 2008). According to Kolodner and Wills (1993), creative design involves "a process of generating and considering several alternatives, weighing their advantages and disadvantages, and sometimes incorporating pieces of one into another" (p. 95). It is also agreed that creative design process involves different kind of phases (Howard et al., 2008; Kolodner & Wills, 1993). The learning environment should also inspire creativity (Kangas, 2010). SL has been noted to enhance creativity and playfulness, for example, by letting students explore the world, create their own spaces and avatars, perform different roles, improvise as well as test different hypotheses (Jarmon et al., 2009).

Research question

Based on the theoretical background presented above, the research question of this study is as follows: From the students' point of view, what were the process characteristics of meaningful learning that were realized during the TSL process in a virtual world?

Case: The global virtual collaboration project course

Set-up and participants

The HUT students are majoring in business process networks, whereas the students from the three other universities study civil engineering. The course took place January through May 2009. During the course, students worked in global teams to solve a real-life scheduling and management problem for a civil engineering business project, for example, construction of a bridge in New York City or a building in India. This can be seen as a collaborative creative design task. However, the task of the Finnish students differed from that of the other students: the Finnish students' responsibility was to facilitate the creative design process of their teams, and not to take part in the actual subject-matter problem-solving. The students were divided into six teams: three had Finnish facilitators. The other three teams solved their problems without facilitators. In each team, there were two to three members from each civil engineering school, and the three facilitated teams had an additional two students from HUT.

Before the in-world activities began, participants attended lectures related to topic areas (e.g., facilitation of virtual teams and cross-cultural project management) as well as were trained how to work in SL. The teams interacted by holding weekly team meetings in SL. At the end of the course, the teams had to write an end report presenting their solution to the problem and an analysis of their teamwork process. Additionally, the Finnish students wrote a memo regarding each team meeting, as well as reflection essays in which the students analyzed their own learning. The Finnish students also held weekly face-to-face peer meeting sessions throughout the course.

Course goals

Through gaining experience in virtual interaction, the students were expected to learn methods and solutions for collaborating virtually, as well as to study the use of virtual applications and coordination of virtual teamwork. The students had also the opportunity to discover cultural differences and overcome cross-cultural challenges, and were expected to learn virtual team-building skills and how to create team spirit.

In addition to these common expected learning outcomes, the students had some task-specific expected outcomes. The Finnish students' goal was to gain skills and knowledge concerning facilitation in a virtual context. In contrast, the civil engineering students should have learned about the interdependency of tasks in the scheduling and management of construction projects, as well as different scheduling and project management methods.

Second Life (SL)

After initial analysis and testing of several virtual teamwork tools such as Webex and Windows Live Meeting, SL was chosen as the platform for the student teams' interaction, since SL was expected to enhance the collaboration between the students and the students and the teaching staff as well as the students' curiosity, motivation, emotional involvement, and creativity (e.g., Delwiche, 2006; Edirisingha et al., 2009; Jarmon et al., 2009; Salmon, 2009; Twining, 2009). In addition, interest in virtual worlds, especially SL, in university education (Edirisingha et al., 2009; Jarmon et al., 2009; Mayrath et al., 2007; Warburton, 2009) and in corporate life (e.g., IBM) is increasing, so the decision to use and test SL was made.

SL was used as the only interaction channel for the global teams in the course. This implies that the students were instructed to use SL for all their team communication needs, and the use of other tools, such as e-mail, was prohibited. In SL, communication occurs through voice and text chat, of which the former was considered to be the preferred form of communication during the course. However, some technical difficulties with voice chat were anticipated, which is why text chat was accepted as the reserve option.

Each student team had its own group workspace in SL. In addition to the six team rooms, the course house included an auditorium where the students could meet course staff and hold presentations. Since file-sharing is not possible in SL, the students were provided with a file-sharing tool (Windows Live Sync).

Technological resources that supported creative design and collaborative problem-solving were designed and introduced to the course's SL learning environment. Each team room in SL had a tool called a team wall as a fixed feature. On the team wall, the groups were able to look at their team calendar and the broadcasts of each other's computer desktops, or edit a whiteboard. Team members could broadcast their own content to the team wall using a tool called screen broadcaster. The rooms with the facilitated groups also had process screens. These were used by the Finnish students to assist their task of facilitating. Each individual student avatar was given a communicator tool to help with team interaction. In addition, students used different kinds of tools (AutoCAD, Autodesk Revit, NavisWorks) to create the design models.

Data collection and analysis methods

Data were collected using multiple measures from the students ($N = 54$) participating in the GVCP course. In order to answer the research question of this study, we analyzed student-reflection essays, end reports, and questionnaires. The Finnish students reviewed their learning in reflection essays ($N = 6$), and all six teams returned jointly written end reports. These were received in May 2009. Questionnaires were sent to the participating students through a web-based survey after the course in April 2009. However, only 23 students (a response rate of 43%) returned the questionnaire; therefore, the results are not generalizable. The questionnaire consisted of 54 Likert-type items (a five-point scale ranging from *disagree* to *agree*), with questions related to the process characteristics of meaningful learning and eight questions to gather the students' background information. The process characteristics were operationalized partly by using existing operationalizations by Nevgi and Löfström (2005; see also Hakkarainen, 2007). In Table 1, the examples of the operationalizations of the process characteristics of meaningful learning are presented.

Qualitative data were analyzed using the content analysis method (Brenner, Brown, & Canter, 1985), whereas quantitative data were analyzed using SPSS 15.0 for Windows. The following phases constituted the analysis: 1) reading the students' end reports and reflection essays, 2) closely analyzing the qualitative data, and creating tentative categories based on the first coding and reflecting the research questions of the study (the characteristics of meaningful learning comprise the main categories of this study), 3) specifying the categories based on the second coding and then comparing them with the theoretical background, and 4) analyzing the quantitative data. Because

only 23 students returned the questionnaire, there were limitations in the statistical procedures that could be performed; therefore, only descriptive data from the questionnaire have been reported. The mean age of the respondents was 26 years. Students who answered the questionnaire did not have prior experience with SL or other virtual environments.

Table 1. Examples of the operationalization of the process characteristics

Process characteristics	Statement in the questionnaire
Active and self-directed	The students' role was to actively find, evaluate, and apply information.
	The students directed their own study process during the sessions.
Goal-oriented and purposeful	I was able to achieve my own personal goals.
	Teachers oriented students toward a learning goal.
Individual and experiential	I felt that it was possible for me to study according to my own personal style.
	I was able to utilize my own experiences as starting points for learning.
Emotional and immersive	I was emotionally involved in the studying.
	It was fun to study with Second Life.
	I forgot everything else while studying in Second Life.
Constructive and reflective	I was able to utilize my prior knowledge related to the course's content.
	I was able to reflect my own learning during the course.
Interactive, conversational, and collaborative	I was able to interact with the environment and other avatars.
	Small group conversations helped me to learn.
	Second Life supported interaction and communication within the group.
Culture-bound and contextual	The course took the students' cultural background into account.
	The course promoted the learning of skills needed in the real business world.
Critical and creative	Studying developed my critical thinking skills.
	Studying in the course encouraged creative thinking.

Results

From the students' point of view, what were the process characteristics of meaningful learning that were realized during the TSL process in a virtual world?

When students were asked whether they thought that their role was to actively find, apply, and evaluate information, 90.9% moderately agreed or agreed, while none disagreed. This is also essential in creative reasoning, since a certain quantity of knowledge must be gained in order to complete the design (Howard et al., 2008). Also crucial in creative reasoning and design are the continual interpretation and use of information for creating high-quality outcome (Howard et al., 2008; Kolodner & Wills, 1993). This was acknowledged by the non-facilitated team, which stated their model would have benefitted from review by other team members: "In order to get a very high quality model, the Americans would have had to send the model back and forth for multiple iterations and 'checks' by the Indians" (End report, team 4). In addition, 81.8% of the students moderately agreed or agreed that they directed their own learning during the course. The activeness and self-directedness of students appeared in the determining of goals and activities, information seeking, problem-solving, solving of technical problems, modeling the construction projects, scheduling, and evaluating their teamwork process. According the students, their level of activity also depended on the class schedule, students' readiness to use SL, and other team members' subtasks, as this excerpt illustrates: "Due to the time needed to contact the site, get a response from the project manager and send the files, it took over 2 weeks before the US team had the schedule they needed to begin modeling in SimVision" (End report, team 4).

Students' assignments showed that the real-life business problem aided goal-oriented and purposeful studying. In the GVCP course, students had two roles, since the Finnish students' responsibilities included facilitating collaboration and creative problem-solving by solving conflicts and technical problems, summarizing the discussions, questioning, and ensuring that everybody had understood what was decided, as well as negotiating the working rules, overall goals, and subtasks (cf. Cross, 1997). Other students were responsible for the actual construction project, and so it was important that every team knew what to do and how to proceed. Goal follow-up usually occurred during the weekly team meetings in SL, as this team describes: "Meetings began by having each team discuss any pressing issues, followed by project updates and future work schedule" (End report, team 3). The excerpt also describes the

incremental nature of creative design well (Simina & Kolodner, 1997). Things that complicated the achievement of the learning goals were a tight schedule for the course, occasionally ambiguous project goals as well as poor usability of SL and the other tools (e.g., file sharing). This team had difficulties in particular with voice chat:

The greatest problem encountered the lack of voice communication. IIT-Madras was not able to set up this feature with their program, which forced the teams to communicate through text chat, making the meetings run slower and decrease the interaction between team members (End report, team 3).

Although students did not seem to have prior experience with virtual collaboration or the use of SL, 78.9% of the students agreed or moderately agreed that they were able to apply their own experiences during the course. In addition, gaining new experiences on how to collaborate and facilitate virtual teams in SL was important for students, as this student described: “. . . (SL) offered me a unique chance to get acquainted with a new way of working” (Reflection essay, student 4). In addition, the following team understood the idea of the global project work: “There were initial difficulties in understanding the drawings, but it helped us how a global project is supposed to be” (End report, team 5).

It has been noted that the global virtual team context raised a variety of emotions among the students. The frustration with the communication difficulties, as well as the fear and insecurity brought on by the new technology, was balanced by the joy of success and the feelings of trust and belonging. The following excerpt is a good description of the emotional roller-coaster that students experienced: “Personally, my feelings swung from frustration and despair to exhilaration during the course. However, the course was highly motivating at all times: I was able to learn many new things as well as practice some formerly learned in a new setting” (Reflection essay, student 1). As noted, the course promoted emotional characteristics quite clearly. The questionnaires also revealed that students were quite motivated ($M = 3.59$; $SD = 0.908$) and studying with SL was fun ($M = 3.91$; $SD = 0.811$).

Constructiveness of learning appeared, for example, in the weekly team meetings in SL, where team members discussed and reconciled issues in order to adjust differing opinions and subtasks into a coherent solution, which is essential in creative design (cf. Cross, 1997; Kolodner & Wills, 1993). Reflection was encouraged by letting the Finnish students reflect upon the learning process through peer meetings and reflection essays. Other students reviewed their learning process in end reports, although deep reflection was not encouraged. Nevertheless, according to the students’ own responses, the students felt that they were able to reflect on their own learning during the course ($M = 4.50$; $SD = 0.512$).

The course assignments supported conversational and collaborative characteristics, since the assignments were based on collaborative effort and communication through SL. The real-life problems required constant exchanging of opinions and information, collaborative reasoning, and negotiation from the students. The questionnaires also revealed that students felt that they belonged to the group ($M = 4.50$; $SD = 0.816$) (cf. Holmberg & Huvila, 2008), and that conversations in these small groups helped the students learn ($M = 4.14$; $SD = 0.793$). However, the collaboration and teamwork experiences varied among the teams. Students acknowledged several prerequisites for successful collaboration, such as the following: careful planning and establishing of the goals and roles clearly and early enough; motivation finishing the tasks; group problem-solving; regular, well-planned meetings and intense participation; and respect and appreciation from team members among others. The following excerpt shows the experience of the facilitated team who had a successful collaboration: “Team spirit seemed to be quite high within each global team, as well as for the group as a whole. Whenever the challenge was confronted, the spirit was positive and all the teams tried to solve the challenge together” (End report, team 3). This team had adopted a very straightforward facilitation style, including discussing and solving conflicts promptly with all the team members, although they also stated that the team worked well without planned process, since all its members were motivated to finish the task. Other successful facilitation strategies included questioning, which helped to bring the quiet members into the discussion, mediating the information to all team members as well as creating an agenda for each team meeting, thus ensuring that all the points were covered. In addition, a positive attitude helped in creating team spirit.

On the other hand, there were also contradictory experiences, as the following excerpt shows: “the other team members could even not agree within their team of the work they could perform and the assumptions that should be made, which resulted in productivity losses and lengthy arguments” (End report, team 6). This non-facilitated team suffered from disagreements and a lack of communication. According to this team, a facilitator would have been beneficial. However, another team succeeded in its teamwork without a facilitator. That particular team realized the importance of goals and regular meetings early on, which may have led to the team members’ successful

collaboration: “Executing a global project required intense planning and participation of all players. To accomplish this, each individual have been assigned responsibility for separate tasks, before collaborating findings throughout the project and final report” (End report, team 5).

In addition to communication difficulties, technological problems complicated collaboration and conversation within the team. Since voice chat was unreliable, students needed to depend on text chat, which was challenging to use. In line with previous research (Edirisingha et al., 2009), the flow of conversation in text chat was difficult to follow since questions and answers were submitted to chat simultaneously, as this student described: “Typical to our chats was overlapping of speakers due to delay in responding by typing. Two or more dialogues were ongoing at the same time which made it first difficult to follow each of the simultaneous threads in the team’s dialogue” (Reflection essay, student 4). New tools (such as a communicator tool and a team wall) were developed and implemented in order to facilitate group communication in SL. However, these tools, and the additional features offered by SL, were not used very efficiently: “The avatars were not used for nonverbal communication” (End report, team 3).

The contextual characteristics of meaningful learning (Jonassen, 1995), were supported since, after the course, students felt that studying with real-life problems had prepared them for new tasks ($M = 4.43$; $SD = 1.089$), and that the course had promoted their learning of skills (cf. Figure 1) needed in real life ($M = 3.68$; $SD = 1.086$). However, there were also problems with real-world tasks, including confidentiality and viability problems. For example, some companies were not ready to reveal all the details that would be necessary in order to solve the creative design case. Learning is also culture-bound (Vygotsky, 1978), and differences were noticed among the four cultures, for example, goal and reflection orientations varied among the students as well as the differences in terminology related to the subject matter. These all posed challenges to global teamwork. However, the effect of national culture was somewhat diluted when communicating in SL: “The cultural differences weren’t as glaring in a virtual setting but they became apparent during certain situations” (End report, team 3).

SL supported the use of imagination and creativity (cf. Jarmon et al., 2009; Kangas, 2010). Students had the opportunity to decorate their global team rooms and design the appearance of their avatars: “. . . had an Iroquois hairdo and red outfit that looked like long johns” (Reflection essay, student 1). However, students also felt that their task enabled creative thinking ($M = 4.38$; $SD = 0.957$), since it required assessment of the tasks, design model, and information as well as knowledge co-construction in order to create consensus for the final report (cf. Cross, 1997; Howard et al., 2008). Creativity was also emphasized every time students needed to invent a new way of working when a planned tool or software did not work or when other conflicts arose: “. . . to invent new ways of document sharing” (Reflection essay, student 4).

The collaborative nature of the activities may be a factor in why student individuality was not strongly emphasized. As the characteristic implies, it would have been useful to find out students’ individual characteristics at the outset, because then it would have been easier to provide individual guidance for each student (Karagiorgi & Symeou, 2005). This was strongly acknowledged by the students: “I think that any virtual work should address the participants’ different backgrounds, and be prepared to educate the competencies needed for those less experienced” (Reflection essay, student 1). In addition, only the Finnish students had the opportunity to express their individual opinions during their peer meetings as well as in the reflection essays. However, students were able to select a real-life case based on their own interests and motivation.

Immersion into 3D virtual space in SL was not emphasized, since the teams generally met there once a week. However, the students stated that a feeling of presence was stronger in SL because of the avatars, and this may be the reason why students experienced a greater number of feelings of trust and belonging (Edirisingha et al., 2009; Holmberg & Huvila, 2008), as this team described: “It was noted that the interface of Second Life may have positive impacts on the development of trust compared to more traditional channels of virtual communication” (End report, team 3). In addition, the critical characteristic was not particularly encouraged during the course, although feedback was collected from the students and they were encouraged to analyze their collaboration processes. Despite the extensive tutorials on how to work in SL and how to use the developed software tools, the students were somewhat confused during their interaction with the environment at the beginning, and thus interactive characteristics were not emphasized enough. According to the students, both virtual and physical instruction would have been beneficial:

Maybe there could be an introduction session with the course people present both in physical and virtual, showing and explaining how the virtual environment works, allowing to practice the

interaction in a safe and encouraging environment before being in the real situation (Reflection essay, student 1).

In addition, many teams stated that weekly meetings were not enough to complete the work, and occasionally, the national teams tended to work together too much without interacting enough with the whole team.

Discussion and conclusion

The results suggest that the problem-based GVCP course supported the process characteristics of meaningful learning and its outcomes, although we should emphasize the individual, critical, and interactive characteristics more in a future running of the course. In addition, SL did not contribute to the realization of the goal-oriented, collaborative, conversational, and immersive characteristics.

Our results suggest several implications, which could be useful for educational practitioners, especially if they have plans to utilize virtual worlds while teaching. The students' individual characteristics should be addressed more properly in order to provide individual guidance and scaffolding (Delwiche, 2006; Mayrath et al., 2007; Ondrejka, 2008; Salmon, 2009; Warburton, 2009). A physical and virtual orientation to the environment is important, since it helps students' actual puzzlement with tasks later on. In addition, technological issues must be dealt before the course starts, and students should be offered enough options if the primary technology fails to work. In the future, we should also pay attention to students' interaction with each other by stressing the importance of clear roles, rules, and objectives as well as emphasizing everyone's responsibility for the teams' work and the quality of the design outcome. In order to have suitable schedules to finish the tasks, it would be better if the students negotiate the meeting schedules by themselves. These suggestions are crucial for students' meaningful learning, especially for the individual, interactive, goal-oriented, collaborative, conversational, and immersive characteristics, and also help in creative design. In addition, the critical characteristics should be addressed more effectively, for example, students should be encouraged to study practical examples within a theoretical framework, and a critical evaluation of one's own learning would be advantageous for each student. This would have helped students to understand the solution and the process in terms of their own knowledge, and helped them to create new learning goals (Simina & Kolodner, 1997). In addition, providing enough time to review and complete the design by all the team members would have contributed to the quality of the students' design models. However, it was not the purpose of the research to analyze the quality and creativeness of students' work, since such a critique would have required judgment from a field expert (Howard et al., 2008).

However, this study has its limits. Our data are quite scant, since only the Finnish students wrote reflection diaries, and the quantitative analysis of questionnaires is simply descriptive. Therefore, the results of this study should be interpreted and adapted carefully. Future research is also needed. We will continue the development of the model and the GVCP course based on these research results and the design-based research method. In particular, we need to consider how we can support those characteristics that were not fully realized during this course. In the future running of the course, the development of new software and experimentation with other virtual teamwork tools will also continue.

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Redesigning a Web-Conferencing Environment to Scaffold Computing Students' Creative Design Processes

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ABSTRACT

Based on a three-semester design research study, this paper argues the need to redesign online learning environments to better support the representation and sharing of factual, procedural, and conceptual knowledge in order for students to develop their design capabilities. A web-conferencing environment is redesigned so that the modalities facilitate more socio-constructivist pedagogies whereby students co-construct knowledge and share their design thinking. The design-based research methodology explicates how redesign not only allowed more effective student representation and sharing of the different levels of knowledge required for abstraction to occur, but also enabled better teacher assessment and, hence, remediation. On the basis of the emerging findings of the study a set of principles for designing web-conferencing (or other online) environments to support creative design learning is proposed.

Keywords

Creative design, Web-conferencing, Technology, Learning design, Design-based research, Interface design

Introduction

Modern technologies provide teachers with new opportunities to create engaging and effective learning (Oliver, Harper, Wills, Agostinho, & Hedberg, 2007). Contemporary web-conferencing systems such as Adobe Connect (Adobe Systems Inc., 2010), Wimba Classroom (Wimba Inc., 2010) and Elluminate Live (Elluminate Inc., 2010) allow rich-media tools to be integrated, offering novel possibilities for instantiating synchronous online learning. Voice-over IP, text chat, whiteboards, screen-sharing, communal note areas, and so on provide a powerful suite of tools with which to present information, model processes, and share concepts.

Computer programming is a design-based field that depends upon the capacity of programmers to work creatively. It is a unique domain in that it is highly structured in terms of the underlying syntax and semantics, yet highly creative in terms of the solutions that can be produced. Based on a three-semester design-based research study of teaching computer programming in a web-conferencing environment, this paper reports on how the pedagogies, tasks, and interfaces utilized in online environments can be redesigned to effectively support students' creative design thinking and sharing.

Literature review

Creative design

Design can be defined as devising “courses of actions aimed at changing existing situations into preferred ones” (Simon, 1996, p. 111). Löwgren (1995) distinguishes between creative design and engineering design, with creative design being a more personal and unpredictable process resulting in the creation of many parallel ideas and concepts, whereas engineering design involves finding solutions to precisely defined problems. Importantly, in an attempt to dispel negative connotations associated with creative design processes and promote its intellectual rigor, Wolf, Rode, Sussman, & Kellogg (2006) point out that rather than being diametrically opposed, engineering design often involves elements of divergent and artistic production while creative design often contains structured practice and scientific reflection. That is to say, all design involves elements of creativity and science.

The way in which people represent and exchange design information has been proposed to critically affect the success of collaborative design processes. Carroll, Thomas & Malhotra (1980) found a significantly improved performance in a temporal design task when a visual representation was used. The arrangement of physical spaces has been observed to affect the success of design teams (either positively by providing natural ways to share created knowledge, or negatively by physically distancing designers), causing researchers to conclude that online

collaborative systems needs to facilitate effective switching between communicating and acting (Leiva-Lobos, De Michelis, & Covarrubias, 1997).

Based on an analysis of car design software and practices, Tano (2003) observed that different types of representations are more or less appropriate for different types of creative design thinking. Abstract sketches were found to be more appropriate for reflective cognition, and high reality renderings were more suitable for experimental cognition (Tano, 2003). In another study, the conception phase and the deliverable preparation phases of a creative design process were performed in entirely different ways (Leiva-Lobos et al., 1997). When considered in the light of designing online learning environments to support design processes, different interface designs may be more or less appropriate based on the phase of development and the type of thinking being engaged.

This design-based research study explains how the pedagogical approach, type of task, and interface of an online collaborative learning environment was redesigned in order to better support creative design processes.

Pedagogies for supporting creative design

There is a variety of pedagogies for supporting creative design ranging from transmissive to more student-centred approaches. Expert modelling is an instructional technique whereby the teacher demonstrates a to-be-learned process and uses explanation to offer students a “cognitive apprenticeship” (Collins, Brown, & Holum, 1991). This allows teachers to impart subject-matter knowledge, thought processes, problem-solving techniques, and a range of other capabilities that underpin creative design. Instructional approaches such as this are considered by some to be more appropriate when students are yet to form understandings about a particular topic (Magliaro, Lockee, & Burton, 2005). However these more transmissive approaches generally do not take maximum advantage of the benefits derived from more student-centred pedagogies, which include the active engagement of students, support from peers, and the ability to socially construct meaning (Hedberg, 2003; Jonassen, 2000; Land & Hannafin, 2000).

Computer-supported collaborative learning (CSCL) is sub-discipline of computer-mediated communication (CMC), which focuses on how online technologies can be used to design learning experiences whereby students share ideas and negotiate meaning (Jonassen, Lee, Yang, & Laffey, 2005). When groups are provided with collaborative technologies rather than being the recipients of online instruction, they have the capacity to co-construct meaning and distribute cognition between them (Hollan, Hutchins, & Kirsh, 2000; Wilson & Myers, 2000). Such constructionist approaches are argued to improve learning by virtue of engaging participants in personally meaningful productive pursuits over which they exercise a large degree of control (Willett, 2007). The real-world, ill-defined, and complex nature of authentic tasks posed in collaborative learning environments is espoused to improve student motivation and help transfer learning to other contexts (Herrington, Oliver, & Reeves, 2002).

The synchronous and multimodal capacities of many contemporary online learning environments afford new possibilities for moving from instructional pedagogies towards more social and construction-based learning as a way of developing students’ design capabilities.

Types of design knowledge

In accordance with both cognitive science (Byrnes, 2001) and contemporary models of learning (Anderson & Krathwohl, 2001), creative design thinking can be seen to be based on a range of different levels of knowledge:

1. Factual creative design knowledge — discrete pieces of elementary information, required for people to design and solve problems within a discipline
2. Procedural creative design knowledge — the skills to perform design processes and execute design procedures
3. Conceptual creative design knowledge — interrelated representations of more complex knowledge forms, including schemas, categorization hierarchies, and explanations of design constructs.

All three of these levels of knowledge are both essential and inseparably interrelated for developing creative design thinking. An understanding of creative design concepts arises from performing creative design processes, which are based upon items of factual knowledge. For instance, in the field of computer science, an understanding of how to

design a drawing program depends in the ability to perform all the steps to write to the drawing canvas, which is based upon an understanding of the syntax of the code relating to plotting points on the screen.

The process of building from facts to more abstract concepts based on performing processes has been described by Ahanori (2000) in the Actions-Process-Object model (see Figure 1).



Figure 1. Ahanori's (2000) Actions-Process-Object model of abstraction and its relationship to factual, procedural and conceptual knowledge

As people perform sequences of actions as part of problem-solving processes, they form objects of knowledge that can then be used as inputs into other contexts (Aharoni, 2000). By writing computing code that draws points on a canvas to form an image, people can then abstract the concept of “drawing,” which can then be used to solve larger problems. It is this process of abstracting principles that is critical to effective learning because it allows concepts to be applied to other situations (Hazzan, 2003). Based on the Action-Process-Object model of abstraction, it is necessary to iteratively develop students’ factual, procedural, and conceptual design knowledge so that they may be able to apply their skills creatively in other contexts.

Multimedia learning effects

Several “multimedia learning principles” (Mayer, 2005) inform how online interfaces can be redesigned to better support creative design learning. Examples include:

- The “multimedia effect” — people learn more effectively from words and pictures than from words alone (Fletcher & Tobias, 2005)
- The “modality effect” — presenting some content in visual mode and other parts in auditory mode can lead to more effective learning than using text to supplement visual information (Low & Sweller, 2005)
- The “split-attention effect” — people learn more effectively when related words and pictures are located spatially or temporally close to one another (Ayres & Sweller, 2005)
- Symbol System Theory — matching the modality to the nature of the information being communicated can reduce the level of elaboration and recoding required for learner comprehension (Salomon, 1994).

The explanation for these effects is based upon cognitive science, in particular:

- There is a limit to the amount of information people can process at any one time (Cognitive Load Theory, see van Merriënboer & Ayres, 2005).

- People have the ability to process visual and auditory information somewhat simultaneously (dual-processing capabilities, see Pavio, 1986).

The way in which modalities are arranged in combinations or “clusters” has a considerable impact on the way information is interpreted (Baldry & Thibault, 2006). Designing environments for the development of creative design capabilities in part depends on ensuring that the way in which modalities are combined enables effective communication of processes and concepts.

Creative design and computer science

Computer programming is a design science. Depending on the level of expertise of the programmer, different approaches to design may be employed, from more procedural (bottom-up) approaches by novices to more functional (top-down) approaches by experts (Rist, 1995). For students to learn how to successfully design programs, they must first understand how to perform lower-order programming processes such as writing syntactically correct code, detecting and correcting flaws, predicting the effect of program segments, and applying programming concepts (Bower, 2008a; Fuller, et al., 2007).

Designing effective computer programs relies on the capacity of programmers to abstract their knowledge beyond the local, concrete representations they hold (Robins, Roundtree, & Roundtree, 2003). Kurland, Pea, Clement, & Mawby (1989) propose that the supporting computing students to abstract concepts is the key to their effective development. There is some evidence to show that design concepts can to some extent be learnt independently of the syntax and semantics that actualize them, although the capacity to put them into practice is necessary to be able to construct creative solutions (Fay & Mayer, 1994). Understanding design patterns underpins extensible and flexible programming (Gamma, Helm, Johnson, & Vlissides, 1998), and being able to design creatively using such abstractions is arguably the essence of computer science. Thus supporting students to abstract programming concepts is critical to developing their design capabilities.

Developing and assessing creative design thinking

In this study, Biggs & Collis’ (1982) Structure of Observed Learning Outcome (SOLO) taxonomy is used to measure the structure and sophistication of student representations of their mental models. Depending on the type of pedagogy applied, the level of knowledge involved in the task, and the nature of the interface provided, students present creative design thinking at different levels of the SOLO taxonomy:

- Prestructural — no correct response item in relation to a problem
- Unistructural — a single correct response item in relation to a problem
- Multistructural — several correct response items but not an entire set and not entirely interrelated with one another
- Relational — an entire set of fully interrelated response items in relation to a problem
- Extended abstract — a complete set of fully interrelated response items that are also interrelated to other information beyond the bounds of the concept or process being considered.

With respect to creative design, a “response item” could be considered either a piece of design knowledge or a step in a creative design process. If teachers do not provide students with the opportunity to represent creative design processes and concepts at the level of structure being addressed then students cannot practise or develop their creative design capabilities, and the teacher cannot adequately assess student understanding. In order for this to happen in online environments, the pedagogies, tasks, and tools must be selected to support representation at the level of structure being shared and assessed.

Method

This study applied a design-based research methodology across three semesters of an online introductory computer programming course to analyze how a web-conference-based learning environment could be redesigned to better

facilitate co-constructed design and learning. Design-based research involves iterative cycles of problem analysis, theory-based solution development, evaluation in real-world settings, and the development of situated design principles (Reeves & Hedberg, 2003). The difference between predictive and design research approaches is summarized in Figure 2.

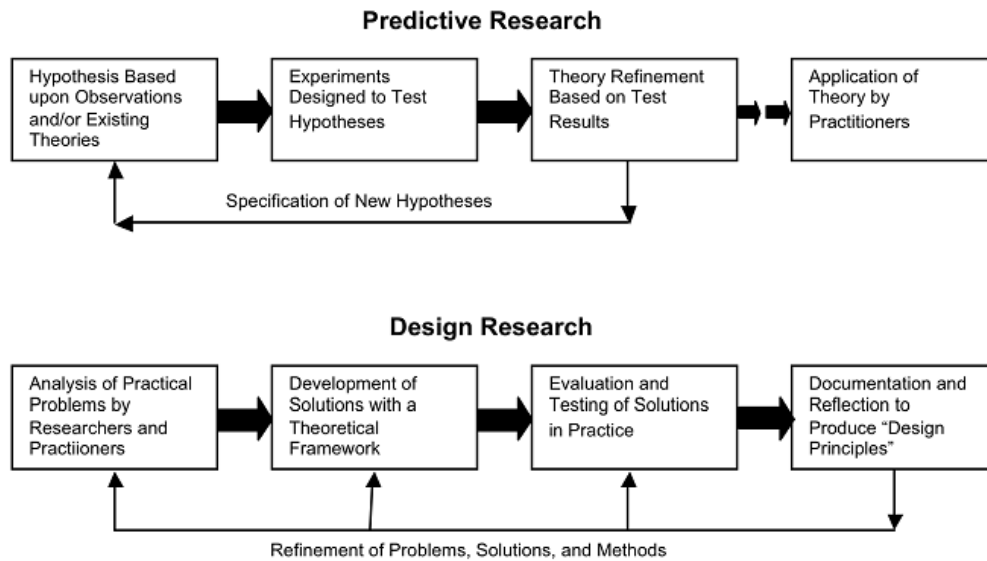


Figure 2. Difference between predictive and design research approaches (Reeves & Hedberg, 2003)

Design-based research was selected in this study for its capacity to cater to the real-life complex educational setting, to integrate theoretical principles with cycles of in-situ iterative reflection, and to shape grounded yet generalisable design principles (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2004; Collins, Joseph, & Bielaczyc, 2004). Design-based research enables the use of any and all types of data to arrive at effective designs (Gorard, Roberts, & Taylor, 2004; Wilson, 2004), which allowed the teacher’s observations as well as students’ interactions, contributions, discourse, and feedback to inform the redesign of the environment.

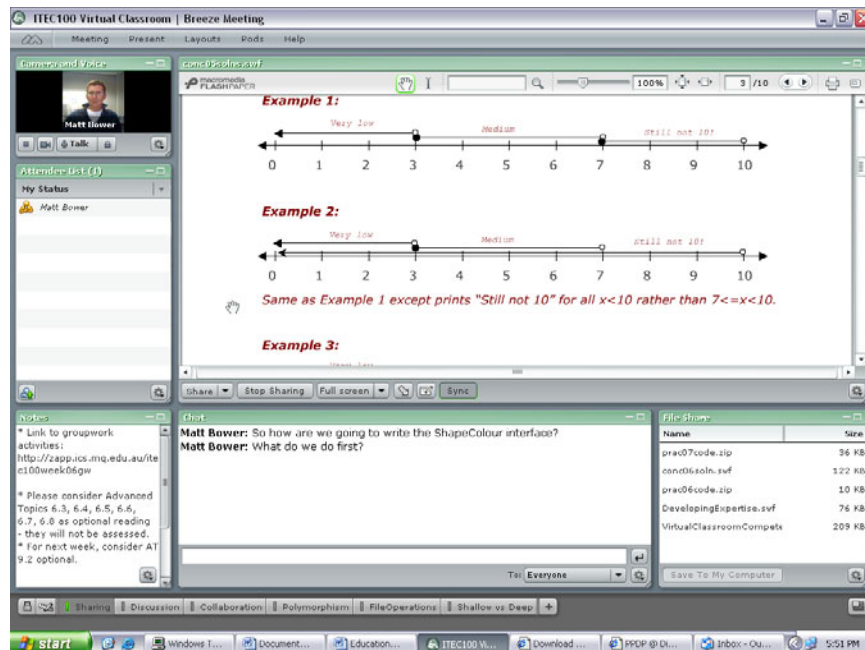


Figure 3. An Adobe Connect Meeting interface, showing (clockwise from top left) Camera and Voice, Document share, File Share, Chat, Notes and Attendee List Pods

The web-conferencing platform

The Adobe Connect Meeting platform (Adobe Systems Inc., 2009) is a web-conferencing system that provides the flexibility to tailor the interface to meet the requirements of the learning episode (see Figure 3).

Designers can select from a range of tools, including those to display PowerPoint presentations, broadcast webcam and voice, screen-share, exchange text chat and files, vote, write shared notes, and collaboratively draw on a whiteboard. Each of these tools (or pods) can be instantly resized, dragged-and-dropped, created or deleted, allowing the designer ultimate flexibility in the tools that are provided and the way that they are arranged. The platform also allows several layouts to be pre-designed within one room and all meetings to be recorded.

The context

This research focused specifically on collaborations in the two-hour weekly online classes for an introductory software development subject at Macquarie University. The subject aimed to teach students the basic skills of computer programming as well as develop their capacity to design effective and creative solutions using computing constructs. The unit of study covered basic programming syntax and semantics, objects and classes, polymorphism and inheritance, applets and GUIs, arrays and ArrayLists, as well as error handling and file operations. The language used to develop these capabilities was Java (Sun Microsystems Inc, 2010).

Students who undertook the introductory programming subject were graduate students from a discipline other than computing who wished to extend their IT knowledge and skills. There were 26 students who enrolled across the three semesters, of which 20 completed the unit. Of these 20 students, ten were enrolled in 2005, Semester 2; seven in 2006, Semester 1; and three in 2006, Semester 2. Of the 26 students, 9 were female and 17 were male.

The method

The approaches to redesigning the learning environment across the three iterations can be summarized as follows:

- **Iteration 1:** The approach to teaching was predominantly transmission based, including long periods of teacher explanation and presentation of solutions relating to tutorial and practical exercises. In some cases a degree of interaction was afforded using audio to ask students questions and having students respond using text chat. The default layouts of the web-conferencing platform, or minor variations thereof, were applied. This iteration offered a baseline for the design-based research analysis.
- **Iteration 2:** The learning activities and web-conferencing environment were redesigned to facilitate student participation in creative design processes. Tasks required students to contribute their design ideas and create computer programs. There was greater use of screen-sharing and Note-pod tools to enable students to collaboratively perform programming processes, though text chat was used to mediate the majority of discourse.
- **Iteration 3:** Greater emphasis was placed on students sharing their conceptual understanding of program designs, either before, during or after collaborative programming processes were performed. The web-conferencing environment was redesigned, often spontaneously, to incorporate whiteboards so that students could represent their mental models in visual form. As well, pervasive use of audio by students was used to facilitate collaboration.

Recordings of these lessons were captured and analysed ex-post facto to identify factors that affected the success of the learning episodes. These reflections on the process of enactment were recorded in a reflective journal and added to the project database along with other relevant data (such as student programs and correspondence that occurred outside the virtual classroom). Both successes and failures were documented, with the failures seen as making an important contribution to understanding teaching and learning in the web-conferencing environment.

The observations contained in the reflective journal notes along with lesson artefacts and student feedback were then used as a basis for redesign, in accordance with design-based research processes (Gorard, Roberts, & Taylor, 2004; Wilson, 2004). The influence of both tactical (within semester) and strategic (across semester) redesigns on collaboration and learning were added to the project database through their inclusion in the reflective journal. Validation of effects occurred by repeated observation either within or across iterations, or both. Data triangulation between recording of lessons, learning artefacts, and student feedback was also used to establish the effectiveness or

otherwise of approaches. Applied principles for teaching and learning in web-conferencing environment were then derived by distilling repeated effects as they applied to supporting and developing creative design capabilities.

Results

Descriptions of key observations and particular learning episodes have been provided to illustrate the design research process. Vignettes are used to depict critical incidents and effects with relation to the pedagogies, types of knowledge being addressed, and the interface designs applied. While it is not possible to include all data and analysis in this paper, a more complete portrayal of the study is available online (Bower, 2008b).

Iteration 1

In the first iteration, standard interface layouts, or minor variations thereof, were used. The two main pedagogical strategies used to develop students' design capabilities were both teacher dominated: broadcasting exemplar solutions and demonstrating programming processes. An example of broadcasting exemplar solutions is illustrated in Vignette 1.

Vignette 1

The screenshot in Figure 1 illustrates how the teacher broadcast the Week 1 tutorial solutions. The pedagogy was transmissive, the task involved predominantly factual knowledge, and the interface only supported text-chat contributions by students.

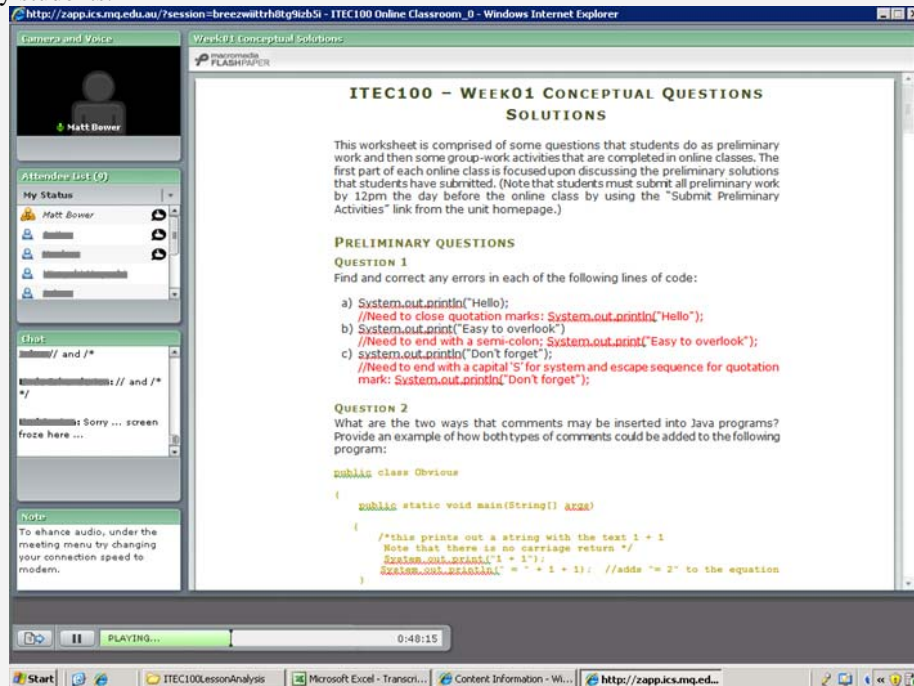


Figure 1. Teacher broadcasting exemplars to students using the standard web-conferencing interface

The teacher-centred pedagogy restricted students' ability to practise and represent their thinking. The task requiring only factual responses to unauthentic text-book style questions resulted in closed responses. The use of text chat inhibited the extent to which information could be interrelated or extended contributions could be made. At best, the text chat allowed a multistructural understanding to be demonstrated by virtue of students' contributing multiple pieces of information relating to the concept. It could not allow a relational understanding to be shared since students did not interrelate all items of knowledge in the same way that they would have if they were applying the information creatively as part of a problem-solving process. The teacher-centred pedagogy, the limited task, and the interface supporting only text-chat contributions did not support the expression or development of creative design thinking.

In Iteration 1, a teacher-dominated “modelling” approach was also applied in practical programming activities. This is exemplified in Vignette 2.

Vignette 2

Figure 2 shows how the teacher modelled programming approaches by broadcasting their screen and used audio to provide insight into underlying thought processes being performed. While the task was more authentic, students could only make text-chat suggestions about how to design the computer program and ultimate control over the process resided with the teacher.

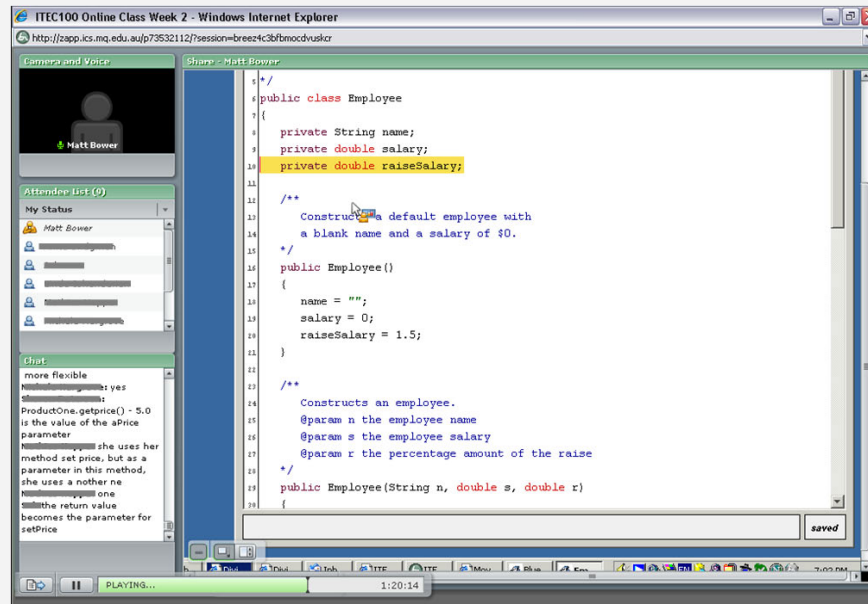


Figure 2. Basic screen-sharing approach to model programming processes

This approach was useful during the early stages of the course when students had little or no design-process knowledge. The screen-sharing and teacher audio enable the teacher to offer students a cognitive apprenticeship on how to edit, compile, and debug program code. However the approach once again only allowed students to demonstrate a multistructural understanding by virtue of contributing several text-chat comments. The approach did not allow a relational understanding to be evidenced because the teacher was completing procedural aspects and intermediary steps in the design process.

The screen-sharing provided a modality that was able to dynamically represent the process information being shared, thus representing information in a “cognitively efficient” form (in accordance with Symbol System Theory, Salomon, 1994). However the teacher was the major contributor of creative-process information.

Iteration 2

Based on observations from Iteration 1 indicating low levels of student contribution and teacher-dominated lessons, the learning environment was redesigned in Iteration 2 to engage more student-centred learning. This included groupwork activities where students were required to design solutions to problems in small teams. For instance, Vignette 3 illustrates how students used desktop-broadcasting to share process knowledge about how to write programs.

Vignette 3

For this activity students were divided into groupwork rooms and asked design a program that created cylindrical TinCan objects, which could return their own volume. The student-centred pedagogy and the authentic task enabled students to demonstrate their creative design capabilities.

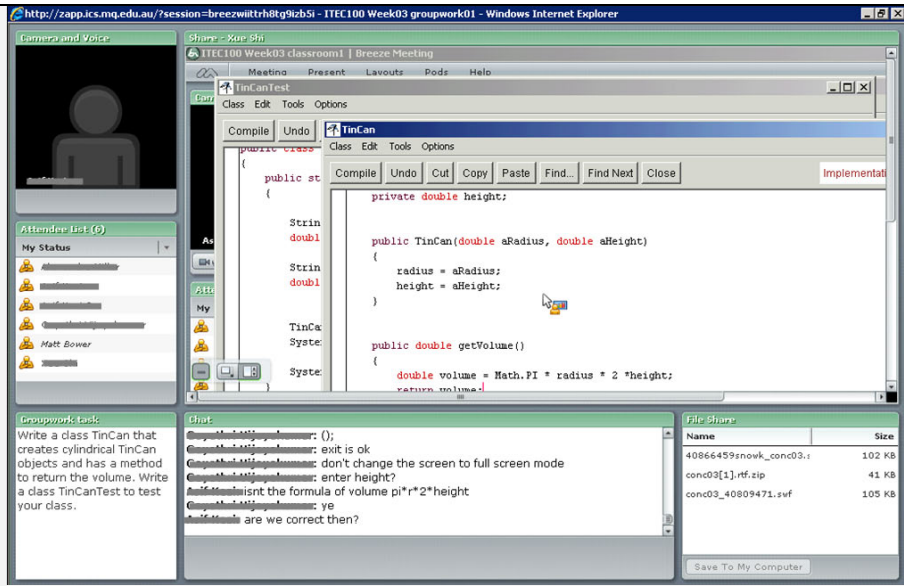


Figure 3. Students using screen-sharing to perform group programming

Figure 3 shows how one student was able to broadcast their desktop and other students could contribute suggestions using text chat. This time the teacher could assess a relational understanding by virtue of students being able to correctly perform and sequence all steps of the design process. However in this episode, the people broadcasting their screen struggled to communicate with the rest of the group because using text-chat collaboration rather than audio resulted in “split-attention” (Ayres & Sweller, 2005).

In Iteration 2, the capacity to utilize multiple Note-pod areas afforded the potential to create more cognitively and collaboratively efficient interface designs (as exemplified in Vignette 4).

Vignette 4

In this exercise, students were divided into groupwork rooms and required to merge a “circle resize” program with a “circle re-centre” program, combining functionality and removing any redundancies. The web-conferencing interface was redesigned so that the resize and re-centre programs were displayed in Note pods, and a third Note-pod column was provided for students to write their combined program (see Figure 4).

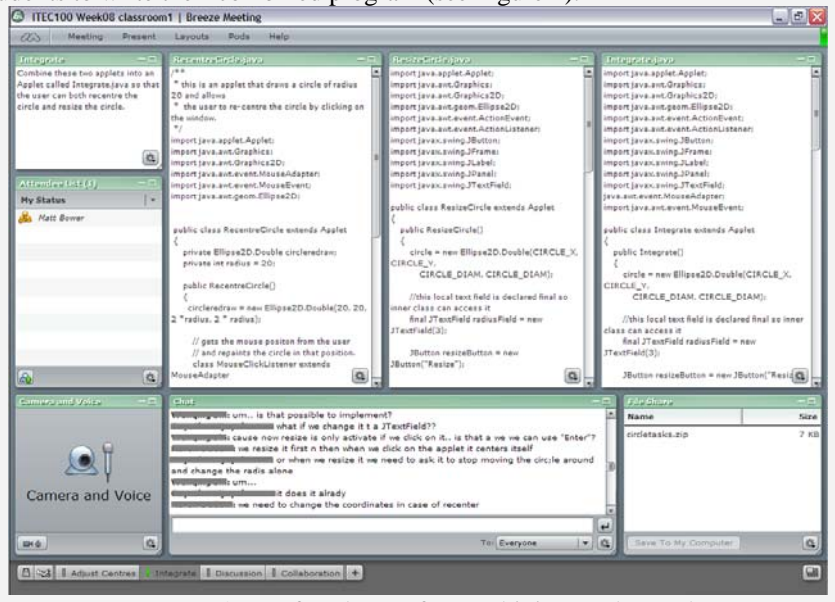


Figure 4. Interface layout for combining applets task

The student-centred pedagogy and authentic task allowed students to demonstrate and share their creative-process thinking. The layout integrating all the relevant information in the one interface, overcame the need to navigate back and forth between program files. The interface supported high levels of student contribution and was available for the teacher to review for diagnostic purposes. For instance, the teacher was able to determine that group 1 was unsure about how to solve this problem, making some progress but not understanding where some of the code from `RecentCircle` should be inserted into `ResizeCircle`. On the other hand, inspection of the group 2 virtual classroom revealed a complete (relational) understanding of how the program should be designed. However, the fact that all communication was mediated using text meant that it was difficult for everyone to follow who was making contributions, and visual concepts relating to the design were not able to be shared.

Iteration 3

Based on issues identified in the previous semester, Iteration 3 was characterized by greater use of whiteboards to facilitate the exchange of conceptual creative design knowledge. As well, audio was pervasively used to facilitate more efficient groupwork collaboration.

Vignette 5 demonstrates how a whiteboard was utilized to strengthen students' conceptual design knowledge.

Vignette 5

In response to student difficulties with nested array program design, a whiteboard was used to support conceptualisation of program operation. With the guidance of the teacher, students dynamically represent the state of variables and arrays while they stepped through the program (see Figure 5).

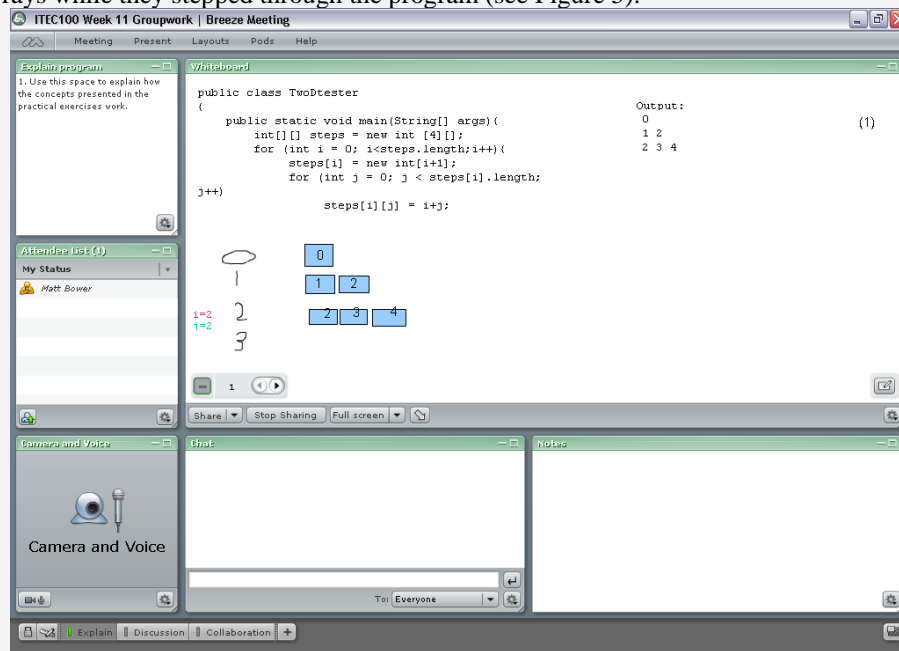


Figure 5. Using a whiteboard to support guided representation of a design concept

The pedagogy required students to represent their understanding in the solution space. The task, while less authentic in nature, directly responded to student misconceptions. Integrating a whiteboard into the interface allowed students to represent their understanding of the concept in a dynamic way so that the level of student comprehension was immediately evident to the teacher. Student comments indicated that communicating aspects of the concept visually as well as in words enabled them to form a more complete understanding, in accordance with the multimedia effect (Fletcher & Tobias, 2005). The contribution-based pedagogy and the interface supporting the sharing of conceptual knowledge had enhanced their understanding of the design pattern.

Audio was used pervasively throughout this iteration in an attempt to support more efficient collaboration. Audio was observed to allow student groups to contribute more discourse in less time than text chat, and those contributions could be made with greater ease. Using audio in small group situations enabled easier coordination of activity because students could contribute to the whiteboard or Note pods at the same time as they were speaking (which was not possible for text chat). For example, in Vignette 5 students were able to contribute to the whiteboard at the same time as they discussed the design concepts. Utilizing audio for student-centred tasks also reduced split-attention caused by monitoring and contributing to two visual channels at once (Note pod and text chat or whiteboard and text chat), thus allowing people's dual processing capabilities to be utilized (modality effect, Low & Sweller, 2005).

Iteration 3 was characterized by spontaneous redesign of interfaces to support the changing collaborative needs of the evolving conversation. This is exemplified in Vignette 6.

Vignette 6

For this activity students were required to design a flexible program that allowed multiple copies of an image to be drawn on a canvas. The pedagogy was student-centred in so far as they were responsible for constructing the solution. The authentic task required students to integrate their conceptual knowledge of object reuse with their procedural knowledge of how to write programs. A purpose built web-conferencing interface had been designed with the entire program code (main method and drawing object) displayed in the two Note pods along the right hand side of the interface so that split-attention was avoided (see Figure 6).

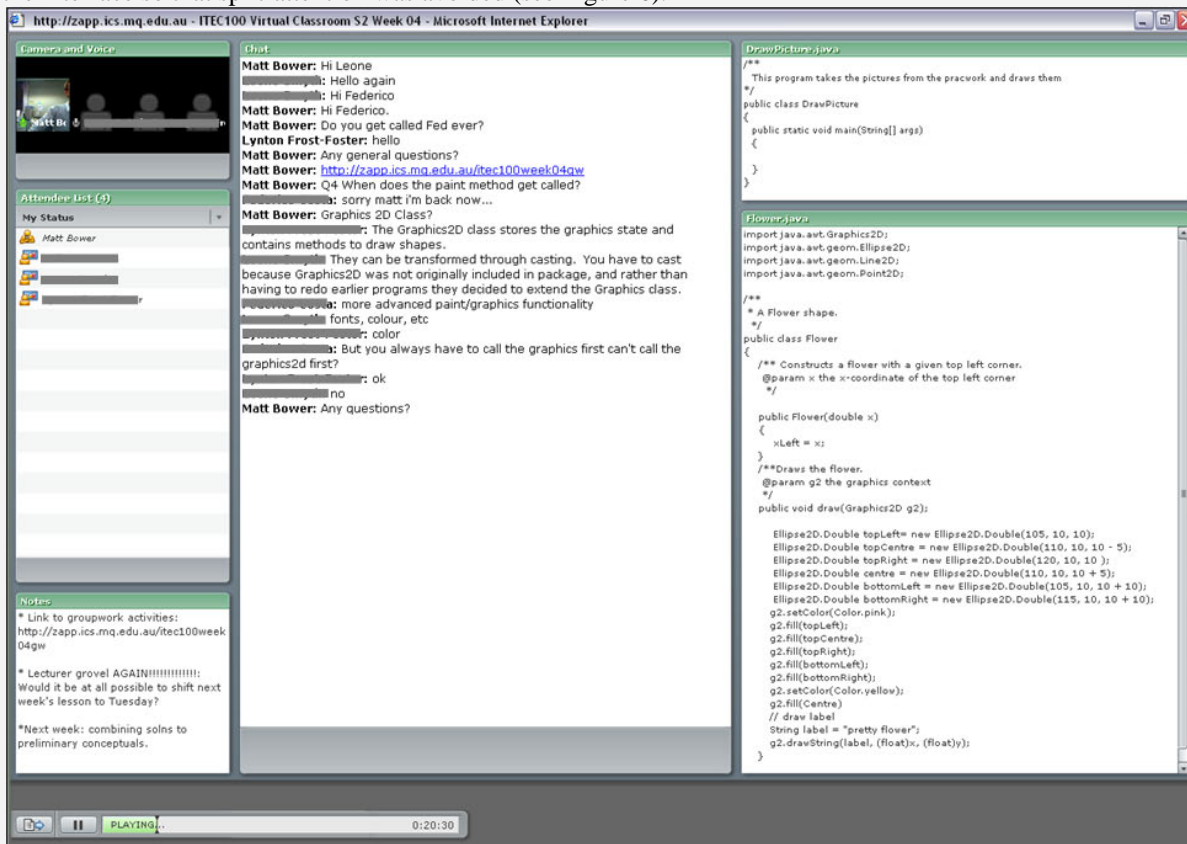


Figure 6. Initial design of the applet image drawing episode

Student progress and questions indicated that there was uncertainty about how the coordinate system of the image being drawn could be flexibly related to the coordinate system of the canvas. This prompted the teacher to adjust the web-conferencing interface mid-episode so that a whiteboard could be used to represent conceptual information (see Figure 7).

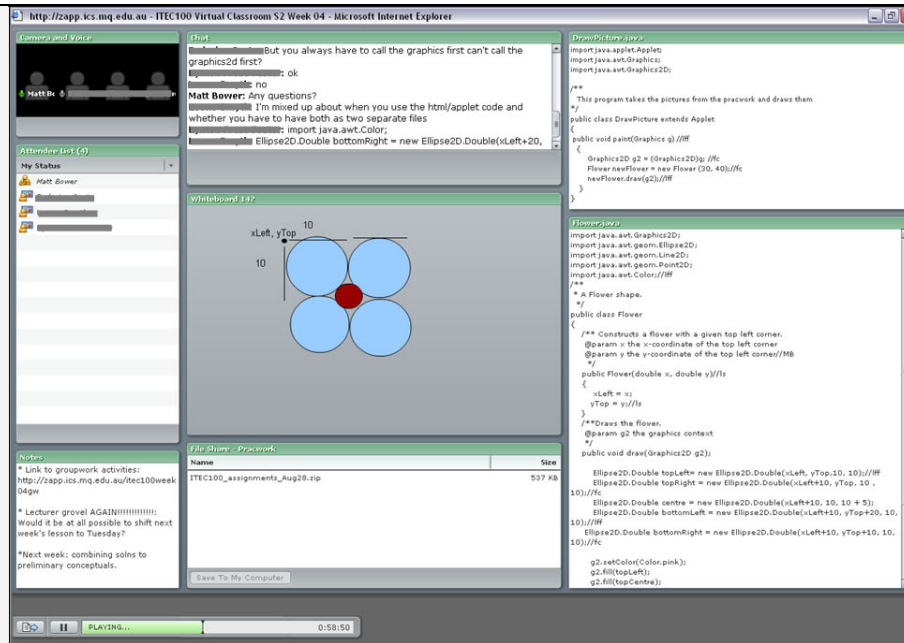


Figure 7. Dynamic adjustment to interface enabling effective conversational approach

As well as supporting the teacher's explanation, the whiteboard allowed students to represent their amended conceptions so that the teacher could gauge whether they had developed accurate mental models. The picture adjacent to the program code enabled students to relate the conceptual knowledge represented in the diagram to the programming process occurring in the Note pods. This supported the development of students' abstractions by relating phases of the Action-Process-Object cycle (Aharoni, 2000). Students then collaboratively adjusted the flower program to correctly incorporate the provision of x and y coordinates in the object constructor. The teacher could immediately assess a relational understanding had been achieved. By improving the program design to be flexible rather than hard coding the image coordinates it was then possible to quickly write a program that could draw multiple copies of the image across the canvas (see Figure 8).

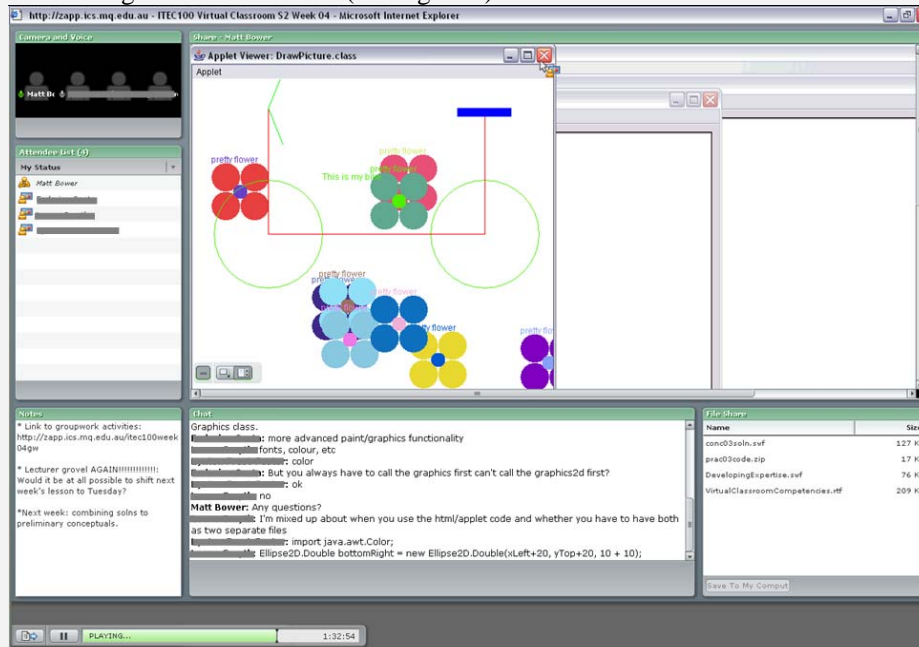


Figure 8. Dynamic adjustment to interface to represent design output

Note that this involved a transition to another interface design, this time a screen-sharing layout, in order to effectively represent the program output.

While the descriptions and examples above cannot fully explicate the design-based research process, observations, and results, it does provide an indication of the type of analysis that was conducted and the nature of the data collected. A more complete analysis is available online for readers who may be interested (Bower, 2008b).

Principles for scaffolding creative design learning in online environments

On the basis of observations drawn from the three iterations of the design-based research project, the following set of recommendations for developing students' creative design capabilities in online environments are proposed.

Adopt student-centred collaborative pedagogies to support the revelation and sharing of creative design thinking

Student-centred collaborative activities enable students to practise and share their creative design capabilities. For instance, by requiring students to collaboratively construct solutions to the “circle combine” and “flower paint” activities, the students are provided with the opportunity to actively apply their creative design knowledge and learning from one another. Because students more fully reveal their mental models through their solutions and conversations, the teacher can more accurately assess student understanding and provide remediation if required. For instance, in the circle combine activity, the teacher was able to gauge both the specific misconceptions held in one group and that the other group had achieved a relational understanding. In contrast, the more teacher-dominated approaches in Iteration 1 restricted the amount of contribution that students could make and thus the quality of response that the teacher could provide.

Apply authentic tasks in order to engage all levels of creative design thinking

More authentic tasks incorporate all stages of the Action-Process-Object cycle and thus support an integrated understanding of factual, procedural, and conceptual design knowledge. For instance the more authentic “tin can” and “flower paint” programming activities required students to integrate their factual (syntactic), procedural (programming processes), and conceptual (design pattern) knowledge. In contrast, the text-book style task in Vignette 1 at best allowed only factual knowledge to be shared and developed. Authentic tasks require students to work on a concrete problem, thus engaging their declarative and procedural knowledge. As students attempt to apply design patterns from other episodes to the current context and develop abstractions from their problem-solving attempts, conceptual thinking is engaged. Performing this in a public space allowed the abstraction process to be shared by all participants, allowing the evolving nature of students' underlying mental models to be revealed. As a result more authentic tasks also provide the teacher with greater insight into the accuracy of student schema and the form of remediation that may be required.

Select modalities that best suit the desired form of representation

Different representational possibilities are afforded by different modalities, and the modality of representation should be selected to match the collaborative and cognitive requirements of the learning episode. Following are some examples:

- Text chat — effective for simultaneous sharing of factual information among members of a large group of contributors (for instance, when several participants are making suggestions about the next step when writing a computer program)
- Audio — affords rapid contribution of extensive descriptions by one person (for instance, a team leader) or rapid turn-taking among a members of a small group of users (who may be collaboratively designing)
- Note pods — useful for organizing textual information among multiple users where sequencing, editing, copying, and deletion are required (for instance, collaborative authoring of a solution)
- Screen-sharing — suitable for sharing process-based information with relation to computing (such as performing a programming process)
- Whiteboard — effective for supporting shared representation and development of conceptual knowledge (for instance, drawing diagrams to represent the schematic design of a program)

Designing multimodal clusters according to multimedia learning principles to improve cognitive efficiency

Different modalities offer not only different individual possibilities for representing, but also different possibilities in combination as “multimodal clusters” (Baldry & Thibault, 2006). The design of effective multimodal clusters was observed to rely upon application of multimedia learning principles. Examples include the following:

- Using whiteboard diagrams to embellish audio explanations to support clearer formation of mental models (multimedia effect)
- Use of audio (rather than text chat) in combination with visual modalities (such as Note pods, whiteboards or screen-sharing) to leverage people’s dual-processing capabilities (modality effect)
- Placing related information such as program files and diagrams in close physical and temporal proximity (avoiding split-attention)
- Using modalities that accurately match the nature of information being presented, such as screen-broadcasting for programming processes, so that minimal recoding of that information is required (symbol system theory).

These principles provide strategies in response to claims by Carroll et al. (1980) and Leiva-Lobos et al. (1997) that the way in which people represent and exchange design information can critically affect the success of design endeavours.

It should be noted that while this study only reports on the design-based research findings elaborated in Bower (2008b), feedback from students verified the above principles in the following ways:

1. Active and authentic learning exercises better supported their learning (Bower, 2009).
2. The selection and arrangement of tools based on multimedia learning principles resulted in significantly superior interfaces (Bower & Hedberg, 2009).

Conclusion

The capacity to design creative solutions depends on the acquisition of underlying factual, process, and conceptual understanding. In order to develop students’ creative design capabilities it is critical that environments are designed to facilitate the effective contribution and exchange of knowledge at the level being addressed (factual, procedural, and conceptual). It is imperative that students are provided with the opportunity to represent their mental models in order for ideas to be more effectively shared with their peers and their level of understanding to be more accurately assessed.

Based on an analysis of teaching and learning computer programming in a web-conferencing environment this paper presents principles for designing online learning environments to better support creative production. These include applying student-centred and collaborative pedagogies to increase the amount of activity and contribution, utilising authentic tasks that provide students with the opportunity to integrate all levels of creative design thinking, selecting modalities that best support the type of collaboration and level of design knowledge being engaged, and clustering modalities in cognitively efficient forms in accordance with multimedia learning effects. Within this framework, ongoing adjustment of the environment may be required to support the emerging collaborative and cognitive requirements of a learning episode.

Multimedia and socio-constructivist learning principles can be used to support all stages of the action-object-process model of abstraction. In this study, the redesign of the learning environment involved a movement from instructive to student-centred pedagogies, whereby students performed collaborative design processes using screen-sharing and negotiating design concepts using shared whiteboards. Pervasive use of audio by students enabled more effective discourse around creative design artefacts. Supporting operation at and movement between the different levels of knowledge encourages abstraction of design capabilities and allows students to more easily apply their skills in other problem-solving situations. It is intended that the principles for redesigning online learning environments to facilitate abstraction of creative design concepts will support educators in developing the creative design capacities of their students in other educational settings.

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Using a Wiki to Scaffold Primary-School Students' Collaborative Writing

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ABSTRACT

This small-scale case study explores the challenges and potential benefits of a wiki for students and teachers in a primary-five English-language class in Hong Kong. The study examined how the wiki's key affordances might help in scaffolding students during their collaborative writing projects. The study found that the use of a wiki in a class of primary-five students in a Chinese primary school where English is taught as a second language (L2) was perceived positively. Students enjoyed using the wiki, and the overall perception was that it helped foster teamwork and improved writing. The tracking functionality of the wiki gave in-depth information about the types of edits the students were making and helped the teacher to provide necessary support and feedback, scaffolding their editing process. Findings from this study may help illuminate how Web 2.0, specifically wikis, can help scaffold primary-school L2 writers in collaborative learning.

Keywords

Wikis, Collaborative writing, Affordances, L2 Writing, Scaffolding, Primary school

Introduction

The current technology-driven educational setting emphasizes the integration of Web 2.0 technology in language teaching and learning (Education Bureau, 2007; Richardson, 2009), and teachers are being pressured to integrate technology into their teaching. This study aims to address research problems at both a theoretical and a practical level. At the practical level, how can we integrate Web 2.0 technology (e.g., wikis) into daily English-language writing lessons with primary-school students? What are the benefits and potential of this technology for teachers and students in Hong Kong, where English is taught as a second language (L2)? Does wiki technology enhance students' writing and, if so, in what way? How can we harness the power of collaborative technology into an effective teaching tool?

At the theoretical level, many studies have started to appear on the application of Web 2.0 in education involving collaborative tools called wikis. The studies examine the application of wikis and explore their usage potential, the effects they have on student learning, and their effectiveness when used with appropriate instructional practices. They occur across different subject disciplines, including English language, geography, engineering, and library and information science, at both the tertiary and the secondary level (Chu, 2008; Engstrom & Jewett, 2005; Mak & Coniam, 2008; Nicol, Littlejohn, & Grierson, 2005). However, whether or not these findings are applicable to young learners at the primary school level and whether they are transferable to young L2 learners needs further investigation.

A case-study approach was used to explore the challenges and potential benefits that a wiki may bring to students and their teacher in a local Hong Kong upper-primary English-language class. The findings may help illuminate the potential of Web 2.0, specifically wikis, for helping to scaffold young L2 writers in creative reasoning and meaningful learning. The notion of "scaffolding," rooted in the Vygotskian concept of "zone of proximal development," was coined by Wood, Bruner, and Ross (1976) and refers to teacher and peer support that enables learners to attain a higher level of achievement than they would be able to do by themselves. Our study investigated the students' and teachers' perceptions about wiki's key affordances and how they helped scaffold young L2 learners in their writing through teacher and peer social interaction and collaboration.

Literature review

Literature on collaborative learning in second-language (L2) acquisition strongly supports the importance of social interaction and collaboration in L2 learning (Saville-Troike, 2006) and writing (Hyland, 2003). Most of the literature views technology-supported collaborative learning using computer-mediated communication in L2 learning in a

positive light (Jones, Garralda, Li, & Lock, 2006). New technologies have had a tremendous impact on the teaching and learning of writing in the last few decades (Goldberg, Russell, & Cook, 2003; Hyland, 2003), and there are both advantages and disadvantages in using technologies for L2 writing. Although some researchers have been critical of computer-aided/assisted instruction in language learning (Angrist & Lavy, 2002), generally, the literature seems to point to web-based collaborative learning as potentially promising technology in language learning as well as in writing (Goodwin-Jones, 2003).

Gibson (1986) first coined the term “affordances” as what the environment offers and provides as perceived by the subjects living in it. Similarly, Norman (1998) describes affordances of a tool as both the perceived and actual properties of a tool that determine how it can be used by the user. For technology implementation to be effective, the affordances provided by a wiki and the affordances required by a learning task need to match (Bower, 2008). In computer-supported collaborative learning (CSCL), Kirschner, Strijbos, Kreijns, and Beers (2004) distinguish three types of affordances: educational, social, and technological. Both educational and social affordances are characterized by two factors: (1) a reciprocal relationship between the learner and the environment, and (2) a perception-action coupling. Social affordance should also encourage learners to engage in activities and generate social interaction. Technological affordance is concerned with technical design and its usability in allowing the users to learn, access, and control the device for task accomplishment.

Many studies with wikis have shown that: (a) the easy accessibility, simplicity and transparency of wiki pages helps learners to share information and resources among their team members and across groups, and makes it easier for students to work at their own pace (Nicol et al., 2005); (b) students have positive perceptions about how wikis can improve collaborative group work and the quality of their work (Chu, 2008); and (c) the effectiveness of wiki application in learning and teaching depends on careful planning and training of both students and instructors to familiarize them with the technology, on class size, and on motivating students to learn from one another based on appropriate instructional design (Engstrom & Jewett, 2005).

These are some of the ways in which wikis may help to scaffold students’ collaborative writing through a platform of sharing, peer-commenting, and co-constructing (Richardson, 2009). All of these studies, however, have been at either the tertiary or the secondary level, and it is not clear whether or not they can be applied to primary school L2 writers using wikis. To address the research gaps, an overarching research question was proposed: How does the use of wikis help scaffold L2 writers during collaborative writing in an upper-primary English-language classroom? Three sub-questions helped to guide data collection: (1) What are the perceived benefits and challenges for students and teachers using wikis for a collaborative writing? (2) What are the key affordances in the use of wikis that help scaffold students in collaborating actively during the co-construction of their writing assignments? (3) How might a wiki’s tracking system help teachers scaffold students in their editing?

Conceptual framework

The literature in the three broad areas of (1) collaborative and cooperative learning, (2) L2 learning and writing, and (3) technology-supported collaborative learning seems to indicate that the common prevailing learning theories in these paradigms tend to be mainly from constructivism (Gros, 2001; Parker & Chao, 2007) and from a sociocultural perspective (Crook, 1994; Hyland, 2003). In CSCL, specific learning theories developed from constructivism and sociocultural paradigms include knowledge building (Scardamalia & Bereiter, 2006), the process-oriented method (Strijbos, Martens, & Jochems, 2004), and expansive learning based on activity theory (Engstrom, 2001). While the application of wikis in education is an innovation and learning theories are continuing to evolve, researchers have found that wikis support learning approaches from collaborative learning and social constructivist paradigms (Bruns & Humphreys, 2005; Parker & Chao, 2007).

Collaborative learning regards learning as an active, constructive process, in which knowledge is not just transmitted but is jointly created in an inherently social context where students work in groups or together with teachers within an authentic situation using high-order thinking and problem-solving skills (Smith & MacGregor, 1992). In CSCL, Gros (2001) defined collaborative learning with three underlying theories: (a) constructivism, (b) cultural-historical theory, and (c) situated-cognition.

1. Constructivism originated from Piagetian theory and highlights individual knowledge construction with respect to social interaction.
2. Cultural-historical theory originated from Vygotskian psychology, and argues that internal cognitive change is affected by social interaction, in which scaffolding is provided through adults or capable peers.
3. The theory of situated-cognition advocates that new knowledge should be learned within a specific context so that learning can be applied to a new situation (Brown, Collins, & Duguid, 1989).

Social constructivist learning environments promote complex and realistic problem-solving skills in order to engage students in collaborative and individual knowledge building through group collaboration and interaction, and in which the teacher facilitates, manages and provides guidance (Bruns & Humphreys, 2005).

Methodology

A case-study design using both quantitative and qualitative data was chosen to explore how wiki technology helps to scaffold L2 writers in the complex and continuously changing dynamics of a real-life classroom context where the researcher has little control over the occurring events (Yin, 2009).

Participants

A class of 38 primary-five students and their English teacher were selected for this case study by purposeful sampling. The school was selected from Chinese primary schools of mid to high level in terms of students' ability to write in the English language. This was to ensure that the primary-five students of ages ten to eleven were able to write a minimum of 100 words in English so that a sufficient quantity of writing could be produced to examine the effect of the collaboration using the technology.

Intervention program

The students and their teachers participated in an intervention program for approximately six weeks, only during their English writing lessons. The intervention program was designed with the integration of a wiki into the existing English-language curriculum (HKCECES, 2008) in collaborative writing. For its user friendliness, the teacher chose one of the wiki tools now renamed PBworks (<http://pbworks.com/academic.wiki>). To scaffold the students in their writing, the teacher asked students to co-construct their writing on PBworks pages created for each group and to exchange constructive feedback and comments through its platform guided by teacher-provided wiki rules. The students worked collaboratively in mixed ability and gender groups of four to six to produce a non-fiction text on a topic of their choice from different animals and illustrate their work with photos and graphics. The lessons were planned for both face-to-face learning situations in the classroom or the computer laboratory and for online learning outside their normal classroom. The teacher helped scaffold students' writing by providing a genre framework and timely feedback, which included teaching skills such as critically evaluating and extracting appropriate information from the Internet and encouraging students to paraphrase and summarize main ideas. For ethical reasons, the intervention program was offered to other classes and their English teachers on a voluntary base. However, this study focused on just one classroom.

Data collection and analysis

The data were collected and examined through a triangulation method using multiple sources of evidence, including student and teacher questionnaires given after the intervention program, a semi-structured interview with the teacher, focus-group discussions with selected students, and students' editing information recorded in the wiki system. The teacher questionnaire consisted of open-ended questions, while the student questionnaire consisted of both open-ended and closed questions. Responses to closed questions were recorded on a five-point Likert scale to measure the participants' perceptions, the wiki's key affordances, and the learning outcomes. Overall, closed questions yielded Cronbach's α reliability coefficient of 0.70, which was over the minimum 0.60 generally recommended for internal

reliability in psychology (Aron, Aron, & Coups, 2006). The interview and focus-group discussions were conducted after the questionnaires to probe further into the respondents' answers for clarification.

Qualitative data from open-ended questions in both student and teacher questionnaires, transcribed interviews, and student focus-group discussions was coded according to categories of affordances by Kirschner et al. (2004) to examine the key affordances involved in this study. The participants were asked to cross-check the transcription for accuracy. Edited information generated by different groups as recorded in the wiki system was analyzed and sorted by types of revision. The types of revision were categorized using an adapted version of Mak and Coniam's (2008) four identifiers used with Hong Kong secondary students: (1) adding ideas, (2) expanding ideas, (3) reorganizing ideas, and (4) correcting errors (e.g., grammar, spelling, and punctuation). Group writings were analyzed using a score sheet adapted from Lo and Hyland's (2007) study on Hong Kong primary-five students' composition writing. To maximize the accuracy of coding by categories and marking group writing, two raters coded and marked independently. The correlation between results of the two raters was more than .96 in each case.

Findings and discussion

Student and teacher perceptions

Data from student questionnaires concerning students' perceptions of the use of a wiki in their group writing helped to address the sub-research questions 1 and 2. For the closed-ended questions, the students were asked whether they enjoyed using the wiki (Q1), whether the wiki helped them work better as a team (Q2), whether the wiki helped them write better (Q3), whether commenting on the wiki helped in improving their writing (Q6), and whether the wiki was useful for group work online (Q7). Table 1 shows how students rated their responses using a five-point Likert scale from 1, "not at all," to 5, "very much so," where 3 is the mid-point. All the questions had ratings over 3 from the lowest of 3.5 (Q2) to the highest of 3.8 (Q6 and Q7). Data from student questionnaires indicated that students' perceptions of the use of a wiki in their group writing were generally positive, which is supported by Chu's (2009) findings that primary-four students regarded the positive use of information technology in their inquiry project-based learning.

One of the highest positive responses concerned how peer comments posted on the wiki platform helped in scaffolding the students' writing (Q6). This was also echoed in the students' responses to the open-ended questions: "We write comments to correct our mistakes," and "Others can give comments to me and help me make it better." All the sample quotes have been translated and edited.

Table 1. Students' perceptions of a wiki

Question items	Mean Rating (SD)	Median	N
Q1 Enjoy using PBwiki	3.6 (.75)	4.00	38
Q2 Work better as a team	3.5 (.80)	3.00	38
Q3 Write better in groups	3.6 (.88)	4.00	38
Q6 Commenting on PBwiki improves writing	3.8 (.72)	4.00	38
Q7 Useful for group work online	3.8 (.73)	4.00	37

The teacher's perceived benefits from the open-ended questionnaires provided some answers to the sub-research question 1. The teacher mentioned that the students found wiki's shared platform for exchanging ideas and sharing information they had collected from the Internet very convenient and motivating: ". . . students will be more motivated to find the information they look for from the Internet" and "They will exchange their ideas via the platform as well, as it is more efficient and convenient".

Figure 2 shows how actively the students exchanged their ideas on the wiki platform as recorded in its tracking system. The frequency of comments during the study period ranged from a high of 28 to a low of nil. Comments varied from:

- Simple positive and negative feedback to elaborated feedback:
 - "Good. I like your idea."
 - "Your information is too detailed."

- “This essay is very informative. It gives us a lot of information about. . . . This information is sorted into different categories, which is well-organized.”
- Simple suggestions of form and content to providing ideas:
 - “The second paragraph has some mistakes [grammar]!”
 - “You can write more information.”
 - “Sheepdogs are very clever. The people always use them . . .”
- Miscellaneous responses to the above feedback and suggestions or commenting on issues irrelevant to the writing topic:
 - “It is like playing MSN.”

The teacher reported some of the following problems and solutions in the questionnaire:

1. Uneven gender distribution of this class (13 boys and 27 girls) created conflict in mixed-gender grouping: “. . . students of this age group tend to be more aware of their gender . . . and become more sensitive to working with a different gender.” The teacher created a student preference table to facilitate even gender distribution and foster better understanding of gender differences within the groups, thus enhancing effective peer learning.
2. There were problems with job distribution among group members: “. . . every member in the group works on the project simultaneously; they have no ideas on whose writing they should edit/comment on.” Subsequently, “Group members had to nominate one student in their group to write and collate information. Others collected new information and commented on the writing.”
3. Technical problems, such as slow loading time when students were using PBworks simultaneously, were reported: “It took more than 30 minutes for some users to gain access . . . and the experience discouraged the use of the platform for exchange of ideas.” Subsequently, students saved their findings and comments in their personal USB as a backup, or e-mailed them to the members in charge of collating and organizing the ideas.
4. There were inadequate facilities at home: “Some students may not have the computer/internet access at home, or they are not allowed to use the systems.” Consequently, those having problems accessing computers at home were encouraged to use computers at school, in the public library, or at other members’ homes.
5. Students did not have adequate skills prior to the tasks: “. . . namely, scanning and skimming, note-taking skills; as well as translation techniques as they have to read a relatively large amount of information in English and Chinese.” The skills were taught after the problem had been identified, such as using an “online dictionary to help understand and translate the information they acquired.”

Focus-group discussion was conducted with eight students and their English teacher. Eight students were selected, as evenly as possible, to represent genders, and positive and negative respondents. Some students in the focus-group discussion mentioned the difficulties and challenges that they faced:

- “. . . it is frustrating to see how slow the computer is, and at those times I would rather write it on a paper instead.”
- “. . . it would be better if we could set the restrictions of who can edit my page and who cannot.”

However, generally, they were positive about their experience with the wiki:

- “. . . I can copy and paste the information on PBwiki easily without the need of any manual copying from paper to paper.”
- “I can put and edit anything I like in the content, and I can always organize the information and ideas without the feeling of wasting anything.”

This is in line with the findings from the student questionnaires. However, the students’ and teacher’s positive perceptions should be regarded with caution, since using wiki technology was a new experience for both the teacher and the students in this study. Thus, a “Hawthorn effect,” an effect of novelty, may have influenced their enthusiasm and overall outcomes.

Wiki’s key affordances

Qualitative data from open-ended questions in both student and teacher questionnaires and from transcribed interviews and student focus-group discussions were coded using Kirschner et al.’s (2004) three categories of affordances. To address sub-research question 2 on the key affordances that support student collaboration, elements of collaborative affordances were also included in social affordances.

Educational affordances

Various educational affordances were perceived by the students: the opportunity to write in English, posting peer comments to learn new words and grammar usage, the opportunity to use an online dictionary, extracting main ideas from the Internet, critically evaluating suitable information for the students' use, and generally learning to write better through sharing and examining examples from other groups. As one student said, "Maybe I wrote some words or sentences wrongly, and some other students would help me, and then I would correct it" (Student group discussion [SGD]).

Similarly, the teacher felt that the students had improved their writing skills: "Students read more and they learnt and used some new vocabulary and language forms" (Teacher questionnaire [TQ]). Other skill improvement that she observed was, "Improvement in reading, IT, collaboration skills and subject knowledge" (TQ). Wiki's tracking system afforded the teacher the opportunity to view the types of revision taking place and to provide the necessary support. It also provided the opportunity for the teacher to scaffold students when critically evaluating and extracting suitable information from the Internet, and to encourage students to paraphrase and summarize main ideas to avoid plagiarism. As the teacher said in her interview:

- ". . . I asked them to find, scan and skim for a few big topics. . . . It also helped to narrow down the amount they had to read."
- "Usually they wrote too little or just did the copy and paste. I would remind them to write in their own words. Sometimes they were also too long, and they had to cut some of the content."

Social and collaborative affordances

Regarding social affordances, many students cited the usefulness of peer-commenting through the wiki platform, as reported in the section on Student and Teacher Perceptions of this paper. The peer-commenting acted as scaffolds to improve students' writing and as a channel of communication, similar to MSN, encouraging interaction among other group members: "We can use the Wiki like an MSN to talk" (Student questionnaire [SQ]), and "They give me some messages and I feel so happy" (SQ). The open platform seemed to help communication between different genders, and the exchange of written comments online seemed to help those who were shy or had difficulty speaking in English:

- ". . . it is difficult for boys and girls to exchange information directly because some people might think there are secret dates going on if a boy talks to a girl, or vice versa. In wiki there are no such problems as we can type what we want to say easily without the embarrassment" (SGD).
- ". . . it is not easy to make them talk to each other in English. But when they type, it is easier for them to share what they think and share ideas. . . . Even the shy students will do a little bit more" (Teacher Interview [TI]).

Collaborative affordances had similar characteristics to social affordances in terms of affording social interactions, but the focus was more on whether the created interactions resulted in collaboration within a team. The transparency of sharing other groups' work and learning from them, collective feedback, and synergy in co-constructing the writing provided affordances for collaboration: "We can share our comments and teach others" (SQ), and "In PBwiki, I can read the work of other groups and learn from their examples" (SGD). Collaborative affordance provided an environment that encouraged students to engage in collaborative behavior, as illustrated below, where whatever challenges they encountered, they solved creatively in their own ways:

- "Someone would change our work, and we talked to the teacher to resolve this problem. Sometime the computer isn't working so we call each other" (SQ).
- "Our ideas may be different, but we voted to choose the title" (SQ).

Technological affordances

There were technological affordances that enhanced collaboration and task accomplishment. For example, the students cited the convenience of being able to amend their writing and post photos, and effective peer-communication prompting speedy idea sharing across group members: ". . . when we have found or written something, it is difficult to send the hard copy to other group mates. But with wiki, it can be done easily by copy and

paste for sharing” (SGD). Since technological affordance is concerned with the usability of technical devices (hardware), it is not the focus of this study.

Matching affordances

Affordances required for collaborative writing tasks were matched against wiki’s affordances based on Bower’s (2008) classification of e-learning technology affordances focusing on the educational and social functionality. Table 2 shows affordances in the area of applications, such as media, spatial, temporal, navigation, emphasis, synthesis, and access control. Affordances are further defined as abilities providing possibilities of actions they offer users. As the Table 2 shows, the affordances provided by PBworks aligned well with the affordances required by the learning tasks involved in collaborative writing. This was further supported by Table 3, which summarizes the participants’ perceived affordances and shows how they aligned with Bower’s categories of wiki’s affordances.

Table 2. Matching affordances of a wiki and of collaborative writing task

Wiki’s affordances (Bower, 2008)	Affordances	
	PBworks	Collaborative writing task
Media	Readability	✓
	View-ability	✓
	Write-ability	✓
	Draw-ability	✓
Spatial	Resize-ability	✓
	Move-ability	✓
Temporal	Playback-ability	✓
	Accessibility	✓
	Record-ability	✓
	Synchronous-ability	✓
Navigational	Browse-ability	✓
	Search-ability	✓
	Data-manipulation-ability	✓
	Link-ability	✓
Emphasis	Highlight-ability	✓ *spell-check-ability
Synthesis	Combine-ability	✓
	Integrate-ability	✓
Access control	Permission-ability	✓
	Share-ability	✓

*PBworks provides spell checks.

Table 3. Matching perceived affordances with Wiki’s affordances

Participants’ perceived affordances		Wiki’s affordances (Bower, 2008)
Educational	English writing	Media
	New words and grammar usages (using online dictionary)	Media, navigational, emphasis
	Extracting main ideas (paraphrasing and summarizing)	Media, spatial
	Critical thinking skills (critically evaluate information from the Internet and peer’s work for peer critiquing)	Media, navigational, access control
	Wiki’s tracking system helps teachers provide student supports:	Media, temporal, navigational, emphasis, access control
	<ul style="list-style-type: none"> • View students’ revision and give timely intervention • Scaffolding students to critically evaluate and extract information from the Internet. 	
Other skills: reading, IT, collaboration, subject knowledge	All	
Social &	Social interaction among group members, role of gender,	Media, temporal, access control

collaborative	benefits for shy or students with communication difficulties Channel of communication outside classrooms Creative problem-solving for authentic problems within collaborative group tasks Peer critiquing provides collective feedback and scaffolds students with their writing Transparency for sharing and examining others' group work Synergy in co-construction of writing	Media, temporal, access control Media, temporal, navigational, Synthesis, access control Media, temporal, emphasis, Access control Media, temporal, navigational, Access control Media, temporal, navigational, synthesis, access control
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Analysis of revisions

Wiki's tracking system provided information that was useful for gaining an in depth understanding of what kind of editing was taking place and how that would affect student collaboration and writing skills, addressing sub-research questions 2 and 3. Figure 1 shows types of editing seen in an excerpt from the wiki's tracking system. Figure 2 shows the number of activities recorded in the tracking system, varying from 1 to 27 for the number of edits posted and 0 to 28 for the comments posted during the first edits on Jan 22 to the last edits on March 14, 2009. Most groups from A to E were actively involved in either editing or commenting on their own group writing. Some groups posted more comments than editing to accomplish their group writing, while others frequently edited through the platform rather than commenting, as in the case of groups F and H, which had no comments recorded. Group G actively contributed to their group writing through comments, but constructed their group writing on Microsoft Word due to their familiarity with the program before pasting onto the wiki, thus showing a low frequency count on the editing record. Figure 2 and Table 4 indicate that the active groups spent more days working on their group work, as seen from the duration in days counted from the first edits to the last edits. Those groups that spent more days on their work tended to have higher scores for their written work based on a scoring method adapted from Lo and Hyland's (2008) study.



Figure 1. Excerpt from wiki tracking system

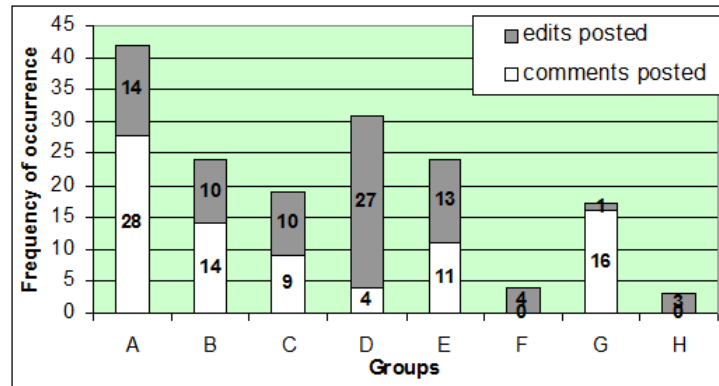


Figure 2. Activities on wiki platform

Table 4. Types of revision by groups

Group	A	B	C	D	E	F	G	H	Total by types
Content edits:									
Adding new ideas	12	10	17	21	13	6	–	–	79
Elaborating on existing ideas	2	–	1	6	–	–	–	–	9
Reorganizing existing ideas	–	2	1	3	2	4	–	–	12
Replacing existing ideas	5	–	3	5	3	6	–	6	28
Sub-total	19	12	22	35	18	16	0	6	128
Form edits:									
Grammar	1	–	1	4	–	1	–	–	7
Spelling	–	2	–	–1	–	–	–	–	3
Punctuation	–	1	–	2	–	1	–	–	4
Formatting	14	11	10	23	7	4	–	1	70
Sub-total	15	14	11	30	7	6	0	1	84
Total revision by Groups	34	26	33	65	25	22	0	7	212
Duration in days	28	17	35	34	23	4	8	14	
*Group writing scores	47	42	43	48	20	23	29	26	
**Word count	207	123	325	171	562	244	593	353	

*Group writing scores based on accumulative scores for content, organization, language, and graphics/pictures with a maximum of 65 points.

**Word count denotes the number of words in the writing.

A detailed analysis of the edits shows that most concerned content (adding, reorganizing, replacing, and elaborating on ideas) rather than form (syntax, spelling, punctuation, and formatting). Table 4 shows the types of revision done by eight different groups as recorded in the wiki's tracking system, categorized according to Mak and Coniam's (2008) adapted version of identifiers. Since the text type for this group writing was non-fiction, most of the first and second edits show new ideas being added, with the new ideas not being students' original ideas, but new information from the Internet. While exploring the use of the wiki platform, students frequently visited to change their spacing, fonts, and resizing of pictures as recorded under the formatting. Surprisingly, common edits concerned other content such as elaborating, reorganizing, and replacing ideas, which was also reported by Mak and Coniam in their study involving secondary-school students using a wiki. This is a good sign in encouraging writing skills from a whole-language perspective, especially in L2 writing, where many students tend to focus on form rather than content (Hyland, 2003). Although both content and form are important for quality writing, content and idea revision tend to involve sophisticated higher-order thinking skills that lead to better conceptual planning for a good writer (Bereiter & Scardamalia, 1987). Figure 2 and Table 4 show that those groups that edited frequently tended to revise more, as in the case of Group D, who recorded 27 visits and had 65 revisions in their work. On the other hand, frequent visits did not mean that quality revisions were taking place, as in the case of Group B, who had 10 visits, but recorded 12 content revisions. This is compared to Group F, who had only 4 visits, but had a greater number of content revisions, 16. Groups A, B, C, and D, with a higher number of revisions, tended to have better writing scores compared to the other groups, who had a lower number of revisions.

The fact that there were more edits on the content of ideas may be due to the spell checks that are built into PBworks and on access to the Internet. The spell checks helped students ease their cognitive load, thus allowing them to concentrate on the content. Similarly, a host of ideas and information was made available through the Internet, freeing the students to focus on analyzing and evaluating the content to extract the main points for their own writing. Other reasons might be that the students tended to feel at ease communicating through their familiar domain of technology, as was found in a study with peer tutoring for L2 writers using ICQ (Jones et al., 2006). The local study found that online interaction tended to produce more discussions concerning content and process, while face-to-face peer tutoring focused on forms such as syntax, vocabulary, and style. Although the study involved university students, it may be applicable to primary students who are familiar with MSN technology, as was observed from the data on social affordances. Another reason might be that students are more actively involved in the self-correction process when they have doubts or reservations about their peers' feedback, while teachers' feedback is believed to be correct and will not lead to further self-initiated correction, as was reported in a study of L2 writers' peer feedback with Chinese university students (Yang, Badger, & Yu, 2006). Teacher instruction encouraging students to focus on content also plays an important role and the reasons cannot be credited to technology alone.

All the groups were able to write 309.8 words on average, with the lowest word count being 123 and the highest count, 593. Length was not a problem, for with access to the Internet, students were able to produce much information: ". . . with the use of Internet resources, students tend to write more than they used to on paper" (TQ). They needed to exercise their critical-thinking skills to choose the appropriate information for their writing, as one student commented, "It was too difficult to group too much information when we were doing the work. We chose the main point in each information" (SQ). Another skill students needed was to paraphrase the information to avoid plagiarism, which the teacher realized as the project progressed. During the teacher interview, the teacher mentioned that she had noticed students cutting and pasting the information straight from the Internet. Subsequently, the teacher gave a mini-lesson on how to paraphrase information taken from other sources and to acknowledge the source.

Although a wiki platform seems to provide educational affordances for writers to focus on content, this does not happen automatically, as shown by differences in the quality of revision for Groups B and F. Quality content still needs to be encouraged and enforced through teacher instruction, and some groups may need more scaffolds in content revision than others. The tracking system provides teachers with windows of information on what is happening in each group's editing process and provides necessary support to scaffold writers during the writing process rather than when the writing is finished. The teacher in this study was beginning to realize the usefulness of the tracking system: "I could easily know and check who worked and edited their work as there were email notifications to remind me of every change my students made in their work in PBwiki" (TQ).

Conclusion and implications

The study found that a class of primary-five students in a Hong Kong Chinese primary school were positive in their perceptions of using a wiki. The students enjoyed using the wiki and commented how it helped them to work better as a team and write better, encouraged peer-to-peer interaction, and facilitated online group work. Both the students and their teacher perceived the exchange of comments through a wiki platform as beneficial to their collaboration and construction of their group writing. Among the eight groups observed in this primary-five class, those active groups that spent more time working on their project tended to produce higher writing scores.

The study observed three key affordances: educational, social (collaborative), and technological. It illuminated how these affordances were perceived as enhancement in collaborative writing and helped scaffold students to foster skills, including critical thinking and creative problem-solving. The study also found that the affordances for collaborative writing tasks seem to match the affordances provided by a wiki, which was further supported by a good alignment with participants' perception of affordances. The technological affordance missing in a wiki is providing users with information, such as charting the frequency of all members' visits and postings, which helps students to perceive an overall picture of interaction and encourage further collaboration. The data may also allow future research on how peer critiquing actually leads to creative-thinking skills and subsequently to revisions or new creative ideas.

A detailed analysis of the types of revisions in the wiki's tracking system indicated that the idea content was being revised more than the form. This may be due not only to PBworks' affordances in providing writers with spell

checks to lessen their cognitive loads, but also to the ease with which the Internet allows a host of ideas and information to be made available, freeing writers to focus on analyzing and evaluating the content to extract main points for their own writing. Other reasons may be that students feel at ease with communicating through technology, which tends to produce more content and process discussions (Jones et al., 2006), and that peer-feedback activates self-corrections (Yang, et al., 2006). Among this class of primary-five students, most groups revising ideas more than form seemed to produce higher writing scores. The teacher's instruction focusing on content also played an important role. This may need further investigation through comparative study to examine what other factors contribute to help produce content revision among the writers.

A wiki is an open-editing tool that is easily accessible online and simple enough for primary-five L2 writers to manage, as this study found. It may be easily integrated and adapted into other classrooms with appropriate scaffolds to guide students in posting constructive comments and timely teacher feedback. Although a wiki may provide affordances for writers to focus on content, it is not automatic, and a teacher's instructional role is still important in scaffolding students by teaching them the appropriate skills. Wiki's tracking system gives in-depth information about the types of edits the students are making and helps teachers assess their collaboration and the development of their group writing process, a task that may be difficult to monitor in traditional group work. This can help teachers decide on the kind of support to be given, and provide immediate feedback when necessary to scaffold the writers during the course of writing and not at the end when the product is finished.

In this study, wiki's key affordances helped facilitate students to engage collaboratively in creative problem solving and peer critiquing. This, in turn, may have helped scaffold students in applying their critical-thinking and creative-reasoning skills as they analyzed and evaluated their writing to construct comments and revise based on their peer-critique or formulated solutions to naturally occurring problems within their collaborative group tasks. Fostering these skills further may also help students nurture creative-thinking skills for generating more original and creative content ideas in their writing.

Acknowledgements

Thanks to Jan van Aalst and Seok Moi Ng for their valuable comments.

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Serious and Playful Inquiry: Epistemological Aspects of Collaborative Creativity

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ABSTRACT

This paper presents the results of a micro-genetic analysis of the development of a creative solution arrived at by students working collaboratively to solve a robotics problem in a sixth-grade science classroom. Results indicate that four aspects of the enacted curriculum proved important to developing the creative solution, including the following: an open-ended, goal-oriented task; teacher modeling of inquiry techniques; provision of tools and an environment that allowed students to move between dual modes of interaction (seriousness and play); and provision of tools and an environment that allowed students to jointly develop a shared understanding achieved through tool-mediated, communicative, and cognitive interaction. The findings suggest that play is an important mode of inquiry if creativity is the learning goal. Implications of this research for the design of learning spaces as well as directions for future collaborative creativity research are discussed.

Keywords

Creativity, Dialogism, Bricolage, Robotics, Collaborative problem-solving

The purpose of this paper is to further our understanding of collaborative creativity among middle-school students. National technology standards expressly discuss creativity as a desired learning outcome for K12 students (International Society of Technology in Education, 2007). This may be due to an envisioned need to address increasingly complex societal problems through innovation. Sonnenburg (2004) argues that collaborative teams will be an essential aspect of such creative work in the future. Collaborative creativity, then, is an important yet relatively new focus of research (Sawyer & DeZutter, 2009). As such, there is a limited amount of K12 educational research related to this topic. The research that does exist has shed light on two areas of collaborative creativity: group dynamics and local classroom practices.

Developing a shared understanding of a task through intersubjectivity is a key aspect of successful collaborative problem-solving (Roschelle & Teasley, 1995). However, it seems that for creative solutions, some level of disagreement or conflict regarding the task increases the groups' overall creativity (Chiu, 2008; Kurtzberg & Amabile, 2001), whereas personal or processual conflict will negatively affect the groups' creativity (Eteläpelto & Lahti, 2008). Vass, Littleton, Miell, and Jones (2008) found that for a collaborative creative-writing task, students' emotional reactions to the assignment also affect the quality of their creative work.

Researchers have identified local classroom practices that bear on collaborative creativity. These practices include language play, musing, singing, humor, acting out, and role-playing games (Fernández-Cárdenas, 2008; Vass, et al., 2008). These practices serve to open a space for all students to engage and offer ideas for consideration. Collaborative creativity also includes practices such as planning together, sharing opinions, building on and integrating one another's ideas, arguing for one's ideas, negotiation and coordination of viewpoints, and seeking agreement on points of discussion (Rojas-Drummond, Albarrán, & Littleton, 2008, p. 186).

This early research has begun to lay an empirical foundation for understanding phenomena involved in collaborative creativity. Yet, as Sonnenburg (2004) argues, we are still in need of a strong theoretical basis for understanding collaborative creativity, and as Sawyer and DeZutter (2009) point out, we know little about how creative ideas develop within a group. In this paper, I address both of these issues by examining the interactions of a small group of sixth graders solving a robotics problem. I analyze their interactions based on Bakhtin's (1981, 1986) theory of dialogism, providing a dialogic analysis of how a small group develops a creative solution to a technology problem.

Dialogism

Dialogism (Bakhtin, 1981) is a theory of communication that refers to the constant interplay of social forces on the meanings we make of the words we speak. In Bakhtin's formulation, the meanings of words are not fixed but are

dependent on the socio-ideological position of the speaker of the words and the situation in which the words are spoken. Bakhtin (1986) theorizes that all communication is historically situated and responsive to the anticipated understanding and response of the addressee. In this way, each utterance is multi-voiced and temporally dynamic, containing the voices of previous speakers and shaped by the anticipated voice of future speakers.

Bakhtin (1981) argues that people develop their frameworks for knowledge by appropriating the discourses of others. These appropriated discourses constitute the lens through which experience is filtered. Bakhtin has identified two types of discourse: authoritative discourse and internally persuasive discourse. Authoritative discourses emanate from hierarchical sources, demand to be accepted as they are, and are not open to the perspective of the other. Sources of authoritative discourse may be religious, political, familial, or educational. Internally persuasive discourses, on the other hand, may be altered, extended, or framed in new contexts. These discourses can be creatively developed to take on new meanings.

Internally persuasive discourses are expressed not only through speech and writing, but also through material culture. As D'Andrade (1986) noted, "Material culture — tables, chairs, buildings, and cities — is the reification of human ideas in solid medium" (p. 22). Indeed, it may be argued that the mediating power of a material object is derived in part from the accumulation of knowledge of prior generations inherent in the design of the artifact itself (Cole & Engestrom, 1993). Similarly, designed environments also reify the ideas of the creators of these environments (Pea, 1993) and in so doing reflect the voice of the designer.

From a Bakhtinian perspective, knowledge construction is a creative process of assimilating and transforming internally persuasive discourses that surround one in a given culture. Creativity, from this perspective, develops through the active engagement with, and transformation of, internally persuasive discourses and is an act of learning. One would expect, then, that in a classroom, creative ideas emerge and new meanings are made through engagement with the internally persuasive discourses among students.

Dialogism thus suggests an analytic approach for studying collaborative creativity in the classroom: focus on the interaction of internally persuasive discourses in students' activities. In other words, analysis should focus on *how* students are making meaning based on their engagement with the classroom's material objects, the structured environment, and other people in the classroom. Based on this theoretical stance, two research questions are pursued in this study of collaborative creativity: What are the dialogic influences present in the classroom? How do these dialogic influences interact to aid in the development of the creative solution?

Methods

Design, participants, and data collection

This case study follows a focal group of students in a sixth-grade science classroom at a middle school in Holyoke, Massachusetts, as they solved a light-sensor-enabled robotics problem. Seventy-four percent of students in Holyoke Public Schools are Latino. The focal group consisted of three 12-year old Latina/o students, two girls and a boy. The teacher, Mr. Smith, was a 25-year old white male with three years of teaching experience. The focal group was video- and audio-taped over a 12-day period as they engaged in the curriculum. The curriculum for this study utilized modified lessons developed by Cooper (2004) and Bratzel (2007). The curriculum focused on computer science, physics (light and heat energy), and science literacy concepts. All of the whole-class, teacher-group, and community-group interactions were also video- and audio-taped. Researcher notes were taken each day in the class. At the end of each class session, my research assistant and I discussed our observations and I wrote a set of general notes based on this discussion. Two interviews were conducted with the teacher, one at the end of the first week of the implementation and one at the end of the unit. Pseudonyms are used throughout.

Data analysis

A modified form of interaction analysis (Jordan & Henderson, 1995) was used to analyze the videotaped data. Rough content logs of the data were recorded at the actual time of videotaping, and a finer grained log was created in subsequent viewings of the videotapes. The content logs and the researcher notes were consulted to identify episodes

where a creative solution was found by the group. Of the six robotics challenges posed to the students, two of the challenges were solved by the students using a novel idea. I selected one of these episodes for further analysis based on the efficaciousness of the solution. The goal of this analysis is to understand how creative solutions are developed in groups. Therefore, it seems appropriate to select the strongest example of such a solution for analysis. Analysis related to the classroom environment was conducted using my notes and the interview I conducted with the teacher. The notes serve to develop a description of the classroom environment from which specific discourses can be discerned. Analysis proceeded from such description and was triangulated through the interview with the teacher.

In open-ended, collaborative approaches to robotics activity, students typically develop a troubleshooting cycle that consists of (1) writing and testing the program, (2) diagnosing problems with the program or structure of the device, (3) proposing and arguing for specific changes to the program/structure, (4) making changes to the program/structure, and (5) testing the device again. In order to systematically trace the development of the creative solution during the selected episode, I defined the troubleshooting cycle as the unit of analysis.

Analysis of the troubleshooting cycles proceeded in two steps. First, I applied the following procedure to each cycle: (1) identify the problem the students diagnosed, (2) determine the problem-solving ideas forwarded by each student, (3) identify the type of strategy the students were suggesting and/or the reasoning they were using to advance their respective ideas, (4) note the progression of the discourse as reflected by engagement with each other's ideas, and (5) note the appearance/re-appearance of specific ideas. Second, I determined the internally persuasive discourses students were engaging with during problem-solving. Strauss and Corbin (1990) note that one may create a set of analytical codes based on a theoretical rationale. I have done so in this analysis. Utilizing the theory of dialogism as discussed above, I identified the spoken and reified voices present in the classroom environment. I then used these codes to identify which voices were present during the problem-solving session. Then I determined the influence of these voices on student activity. I did this by focusing on how spoken ideas were taken up (or not) within the group (e.g., elaborating on ideas or ignoring suggestions). With regard to the voices reified in the artifacts or environment, I noted when and how focal-group students referred to the written instructions (e.g., for initial direction, for clarification, to support an argument they were making), when and why they moved about the classroom (e.g., to test their program, to interact with other students), and when and how they interacted with material objects and devices provided to them (e.g., observing the functioning of their robot, taking light readings, discussing light reflection and absorption properties of various materials).

This micro-genetic analysis allowed me to build a moment-by-moment picture of the development of the solution. I then used this analysis to develop a broader characterization of the cognitive aspects of student-collaborative problem-solving activity and important aspects of the enacted curriculum that emerged from the interaction of the internally persuasive discourses, both of which contributed to the development of the creative solution.

Findings

Summary

The challenge given to the students was to program the robotic vehicle to move forward until it sensed a darker surface, make a 90-degree turn, back up slowly for one foot, and repeat the program forever. The goal of the lesson was for students to develop their understanding of how the light sensor functions to trigger an event and how to program the light sensor to do so under certain conditions. The triggering sources of black paper provided by the teacher were set on the grey carpet in the front of the classroom. The focal group initially approached the problem by taking light readings of the black triggering surface only. They did not take a light reading of the grey carpet surrounding the sources of black. However, in some cases, the black triggering sources reflected more light than the grey carpet due to the texture of the paper (laminated or not). This was a confounding variable that complicated the problem for the students. They came to understand this problem over time through reasoning activities that included observation, experimentation, argumentation, elaboration, clarification, and play. Student reasoning was directly influenced by the spoken and reified voices present in the classroom. Once the students understood the variable nature of light readings and the role of the carpet in confounding their readings, they enacted a creative solution to the problem. This creative solution was to re-purpose the black cables provided in the robotics kit to serve as the source that would trigger the rest of the light-sensor program.

In this episode, in order to solve the light-sensor problem, the students needed to develop three interrelated key understandings. First, they needed to deepen their understanding of the light sensor from an initial view of it as a simple measuring device to a more complex view of it as a computational device. Second, they needed to develop the understanding that not all similarly hued entities reflect the same amount of light. And third, they needed to re-frame the given problem as one in which the light sensor is programmed to simply react to a black (or darker) surface to an understanding that any number of environmental variables may serve to confound the process (Sullivan, 2008), and, therefore, these variables need to be identified and taken into account.

On the following pages, I present the micro-analysis of the episode. The analysis demonstrates the influence of the various internally persuasive discourses as students engage with them. The episode consists of 17 troubleshooting cycles that took place over a 36-minute period. The troubleshooting cycles ranged in duration from 40 seconds to 4 minutes. Six of the 17 analyzed troubleshooting cycles suffice to illustrate the solution trajectory. The analysis for each troubleshooting cycle includes the following: (a) problem-solving ideas forwarded, (b) student strategy or reasoning, (c) the dialogic influence on the idea, and (d) the appearance and re-appearance of ideas over the problem-solving session. Only ideas and engagement with those ideas as they were voiced during the troubleshooting cycle are included in the table. Double parentheses denote the physical activity co-occurring with the utterance.

Micro-analysis

Students began to solve the problem by deciding on a programming approach. Table 1 presents this initial troubleshooting cycle.

Table 1. Troubleshooting Cycle 1

<i>Ideas forwarded</i>	<i>Type of strategy and/or reasoning</i>	<i>Dialogic influence</i>	<i>Appearance of ideas</i>
E: "Let's just test it out."	Guess and check strategy	Classroom environment, technology designer	
Y: "It needs to be triggered by a black line."	Reference to activity instructions	Curriculum designer	
J: "Okay, we gotta do that first" ((pointing to the solid black paper on the floor)).	Elaboration	Classroom environment	
E: "That's all black. Oh, well. Whatever."	Argumentation	Curriculum designer, Technology designer	First appearance of idea that two light readings are needed

Initially, Esteban suggests a guess-and-check strategy. This idea is influenced by the classroom condition of an open-ended, goal-oriented task. This condition arises as an interaction among the curriculum designers, the technology designers and the teacher's voice. The curriculum designers provided the robotics challenge, which is based on the constructionist nature of robotics technology (Resnick et al., 1996). But they provide no algorithm for solving the problem. The teacher provides the materials in the classroom environment for engaging with the problem, but he also gives them no specific solution instructions. Therefore, Esteban suggests a strategy that occurs to him and is allowed by the design of the technology.

Yolanda is influenced by the curriculum designers' voice as she suggests they follow the instructions that indicate that the light sensor should be triggered by a black line. Janice picks up on this and suggests that they take a reading of the black book cover provided on the floor by the teacher. Finally, Esteban raises the issue that the black book's cover is all black, inferring the need for a reading of the lighter-colored approach surface. His comment seems to be influenced by the curriculum designers, who call for a black line (not a solid block of black), and the technology designers, as the light-sensor function is to detect the difference between light readings from different sources. However, this idea is not taken up by the others, and Esteban does not insist that they take it up. As they take the first light reading, the students evidence understanding of the light sensor as a simple measurement device, useful for reading the amount of light reflected off a surface. They have not yet developed the key understanding that the light

sensor is a computational device, capable of comparing light readings to a programmed parameter in order to trigger a programmed event.

The group takes a light reading of the black book cover. They then write a program and send it to the robotic device. At this point, Janice remarks that they need a place to try the program. The students used a specific black source to get the initial light reading, but rather than return to that source to test their program they look for another place in the classroom to test it. This indicates that the students are operating under the idea that all black surfaces will reflect the same or similar amounts of light. They have not yet developed the understanding that not all similarly hued materials reflect the same amount of light. Table 2 presents this troubleshooting cycle.

Table 2. Troubleshooting Cycle 2

<i>Ideas forwarded</i>	<i>Type of strategy and/or reasoning</i>	<i>Dialogic influence</i>	<i>Appearance of ideas</i>
J: “Can we use that?” ((giggles and points at a piece of video equipment underneath the smartboard)). “I wonder if we can use that?”	Utilizing environmental affordances	Classroom environment	
E: “Are you going to use a wire?”	Clarification	Janice’s voice	First appearance of the idea of using a black wire as a triggering source
J: “No the thing, that, the string, the thing, I don’t know.”	Clarification	Classroom environment	
E: “You coulda used the wire.”	Utilizing environmental affordances	Classroom environment	Second appearance of the idea of using a black wire as a triggering source
J: “No, not the wire. This. ((bending down and pointing at the video equipment))	Clarification	Classroom environment	

It is during this cycle that the idea to use a black wire to trigger the light-sensor program is first advanced. The idea comes from the interaction between Janice and Esteban as they are influenced by the requirements of the curriculum to utilize a black source and the material culture of the classroom in the form of the black video equipment lying beneath the SMART Board. This exchange also evidences how the students are beginning to jointly develop their shared understanding through tool-mediated communicative and cognitive interaction. This suggestion by Esteban of using a black wire is picked up much later by Janice as an important aspect of solving the problem.

The students test their program and when this program does not work, Janice attempts to articulate why it is not functioning properly. Mr. Smith responds to Janice’s comment and lets the group know that he thinks that black material in the grey carpet may be interfering with the functioning of their program. This provides the students with important information that they are not able to initially use. This exchange is analyzed in Table 3.

Table 3. Troubleshooting Cycle 3

<i>Ideas forwarded</i>	<i>Type of strategy and/or reasoning</i>	<i>Dialogic influence</i>	<i>Appearance of ideas</i>
J: “I think it’s when it hits like the light— I don’t know.”	Observation	Technology designer, classroom environment	
E: “When it hits the light. It’s not hitting the light.”	Elaboration	Janice’s voice	
Mr. Smith: “It’s hitting the dark lines on the floor.”	Refinement	Technology designer, classroom environment	First appearance of the idea that the carpet is interfering with the light reading

In this segment, the dialogic influence on the discussion emanates from observations of the movement of the robotic device and/or from knowledge of how the sensor functions. In this way, the technology designer’s voice is the most salient. This is the first time during the problem-solving episode that the students engage with the key idea that other variables may interfere with the functioning of the light sensor.

After several attempts, the group writes a light-sensing program that seems to work. The students notice that the robot runs the algorithm every time it sees a black source. As the students observe the movement of the robot, Janice laughs and puts her black shoe in front of the robot, but it does not trigger the light sensor. Then, Mr. Smith, as he walks around the classroom, playfully triggers their light-sensor program with the tip of his black shoe. While Janice appears to be playing with these ideas, Mr. Smith concretizes the idea of using alternative sources of black through his effective use of his shoe to trigger the program. After this, Janice again puts her foot in front of the robot. Yolanda remarks on the movement of the robot. In this segment, Janice, Yolanda, and Mr. Smith jointly occupy a playful space. They have moved from a serious stance of problem-solving to a playful stance in which they are engaging with the light sensor as if it were a toy. This dual mode of interaction, seriousness and play, is afforded both by the toy-like nature of robotics and by Mr. Smith, who encourages play by taking part in it. This sequence is analyzed in Table 4.

Table 4. Troubleshooting Cycle 11

<i>Ideas forwarded</i>	<i>Type of strategy and/or reasoning</i>	<i>Dialogic influence</i>	<i>Appearance of ideas</i>
E: “Now it’s doing it. Now it’s doing it every time it finds a black line.” ((J puts her foot in front of the robot and laughs.))	Observation	Technology designer	
Mr. Smith: ((walking towards the robot on the floor)). “Hang on, hang on, hang on.”	Observation	Technology designer, Janice, Esteban	
J: “Mister, watch out for your shoe.” ((Mr. Smith puts his black shoe in front of the robot. The robot senses his shoe and begins to back up)).	Experimentation	Technology designer	First appearance of the idea that one’s black shoe might trigger the light sensor program.
J: “There ya go.”	Reflection	Mr. Smith	
Y: “It’s gonna follow you.”	Prediction	Mr. Smith	
J: “Hey look at my shoe.” ((Janice places her own shoe in front of the light sensor to trigger the program)).	Experimentation	Mr. Smith, technology designer	Second appearance of the idea of triggering the light sensor with one’s shoe.

At this point, the students still need to write a program that performs the entire algorithm specified in the challenge. So, they return to working on their program. Once they have written a new program, they decide to test it out using the teacher-provided black piece of construction paper as a triggering source. Based on the advice of Mr. Smith, they get a new light-sensor reading and program accordingly. When they run the program, they find that the robotic device, rather than moving forward, is immediately moving backward. They go over their program and note that all of the steps seem correct. What the students are lacking here is the understanding that the approach surface (the grey carpet) is reflecting a certain amount of light, and they need to know what that amount of reflected light is in order to correctly program the robotic device. They are assuming that the grey carpet reflects more light than the black piece of construction paper, but that is not the case. They have not yet developed the understanding that environmental variables may confound the process, and they are still thinking about the light sensor as a simple measurement tool, as opposed to a computational tool.

They again appeal to Mr. Smith. He looks at their written program and then he holds the robotic device in his hand and runs the program. He points out to the students that the robotic device is almost immediately going to step two of their program. At this point, Mr. Smith is modeling an inquiry technique to the students that entails close observation of the execution of the program in a neutral environment. He challenges the students to figure out why this is happening. The light reading for the construction paper is 42; they had set the sensor to trigger when it read “less than” 43. Esteban suggests that they try the program with the light sensor set to a lower trigger point of 28, which had worked previously.

They send the new program with a light sensor reading of 28 to the robot. Janice starts to move with the robot to the floor, but Esteban asks for the robot. She hands it to him and he holds the robot in his hands and runs the program. The three students watch the wheels. The students follow Mr. Smith’s modeled procedure of closely observing the execution of the program. Esteban and Janice note that the wheels are now moving in the forward direction. They then both put their hands over the light sensor to see if they can trigger the rest of the program. Here, Janice and Esteban are thinking together while jointly holding the robot and testing the light sensor. This mutual manipulation of the robotic device facilitates a non-vocal cognitive interaction between the two students related to deepening their understanding of the functioning of the light sensor through experimentation.

After this, Janice takes control of the robot and holds it over the carpet and runs the program. She orally references Mr. Smith’s earlier comment about the interference of the carpet and Esteban exclaims, “The floor is the black light!” A non-focal-group student who is working in the front of the room than asks “What is the floor?” and another student answers “The floor is 32.” This exchange is heard by the focal group students. In this sequence, the focal-group students solidify their understanding that the carpet is interfering with the functioning of their robot when it is programmed to read the black source provided by the construction paper. Table 5 presents the analysis of this exchange.

Table 5. Troubleshooting Cycle 15

<i>Ideas forwarded</i>	<i>Type of strategy and/or reasoning</i>	<i>Dialogic influence</i>	<i>Appearance of ideas</i>
E: “Okay, give me, watch, let’s see if 28, remember last time 28 (inaudible) ((J holds the robot while E sends the program. Then moves robot to the floor)).	Prior knowledge, guess and check	Technology designer, classroom environment	
E: ((reaching for the robot)) “No, no, wait. Wait, let me hold it up first.” ((J gives E the robot and he runs the program holding the robot in the air for all to see.))	Observation	Mr. Smith	
E: “See.” (((They watch as the robot wheels move in the forward direction)).	Observation	Mr. Smith, Technology designer	
J: “Now it does it.”	Observation	Mr. Smith, Esteban, Technology designer	
E: “It’s the last one.” ((J puts her hand over the light sensor and E does the same thing. J takes the robot from E.))	Observation	Mr. Smith, technology designer	
J: “Okay, see with the black light, remember? ((J runs the program while holding the robot in her hand, but close to the carpet.))	Prior knowledge	Mr. Smith, classroom Environment	Second appearance of the idea that the floor is affecting the light reading
E: “The floor is the black light.”	Elaboration	Mr. Smith, Janice, classroom environment	
Student 1: “What is the floor?”	Clarification	Esteban, technology designer, classroom environment	
Student 2: “The floor is 32.”	Measurement	Technology designer, classroom environment	
Mr. Smith: “The floor is 32.”	Reiteration	CM2	

E: "The floor is the black light."	Reiteration	Mr. Smith, Janice, classroom environment	
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The dialogic influence on student thinking in this segment derives primarily from the design of the technology. This is in large part due to the fact that they are developing the conceptual understanding that light is reflecting off all available surfaces, including the carpet, at varying rates. Observations of and experiments with the functioning of the light sensor are helping them develop this understanding. However, it is also clear to see in this segment that other voices have an influence. For example, Mr. Smith's influence is seen both in Esteban's use of the troubleshooting method modeled by him (hold the robot in your hands and observe the movement of the wheels) and in Janice's recollection of Mr. Smith's earlier comment about the interference of the carpet. We also see in this segment that the student community voices influence the student focal group.

The student's discovery that the grey carpet is interfering with their program causes them to think more deeply about the functioning of the light sensor. Both Esteban and Janice experiment with the robotic device by taking random light readings. At one point, Janice, begins to focus on other triggering black sources in the room. She suggests first that they use her shoe, and then she suggests that they use the black cables available in the Mindstorms kit. The students get a light reading for the cable and program the robot with that reading. This does not work because the students are using a "less than" command in programming the light sensor, which tells the robot to look for a reflection that is less than the reflection of the black cable. Janice seems to realize this when she suggests that they program the robot with the variable of 31. This is less than the reading of the amount of light reflected off the carpet, 32, but higher than the amount of light reflected off of the cable, 20. This suggestion allows them to successfully solve the light-sensing challenge a second time, and in so doing evidence the critical understanding that light is reflected off all surfaces in the room and that one always needs to take into account both the amount of light reflected off the approach surface and the triggering surface. Furthermore, they demonstrate an understanding of the light sensor as a computational device by selecting a modifying variable that falls somewhere between the two readings. Table 6 presents the analysis of this cycle.

Table 6. Troubleshooting Cycle 16

<i>Ideas forwarded</i>	<i>Type of strategy and/or reasoning</i>	<i>Dialogic influence</i>	<i>Appearance of ideas</i>
J: ((At the Mindstorms box, J looks towards E)) "Mira!" ((J holds up a cable from the Mindstorms kit and looks towards Y.)) "We could use this."	Observation	Esteban	Third appearance of the idea of using a wire/cable to trigger the light sensor.
E: "What?"	Clarification	Janice	
J: "Use that. Read it quick." ((J holds the cable horizontally so E can take a reading of it. E takes a light reading of the cable)).	Measurement	Technology designer	
E and Y: "Twenty."	Observation	Technology designer	
E: ((Revises program with new reading and sends to the robot. Students test the robot.)) "It's skipping the line. We have to measure it again."	Observation	Technology designer	
J: ((The students get another light reading.)) "Twenty. Hmmm. Dang, why can't it go on?"	Measurement	Technology designer	
Y: "What's the reading?"	Clarification	Technology designer	
J: ((To E)) "Put it thirty-one."	Hypothesis	Technology designer	Second appearance of the idea that one needs a light reading of both the approach surface and the triggering surface to correctly program the robot.

E: “Thirty-one. Okay now!” ((E sends the program to the robot. The students run the program. It works.))	Affirmation	Janice	
J: “Oh, there we go. There we go. It’s getting it.”	Observation, evaluation	Technology designer, classroom environment	

In this sequence, the students have solved the challenge through creative means and developed a deeper understanding of the functioning of the light sensor, which was the goal of the lesson.

Discussion

A key moment in this episode was the students’ discovery that the carpet was interfering with the functioning of their program. This discovery is what Koschmann and Zemel (2009) would call an occasioned production. It is a discovery that the students did not know they needed to make prior to the moment they made it. Once the students had discovered the confounding role of the carpet in their problem-solving, they developed all three of the key understandings needed to solve the problem. They realized that they needed a light reading of the approach surface as well as the target surface and that they could use the light sensor to discern between the two light readings (light sensor as computational device). They realized that not all similarly hued entities reflect the same amount of light. And finally, they understood that in order to solve the problem, they needed to take into account more than one variable.

Four sets of voices were important in the development of these understandings: (a) the teacher’s voice, (b) the curriculum designers’ voices, (c) the technology designers’ voices, and (d) the students’ voices. Furthermore, as shown in the analysis, the interaction of these voices contributed to the emergence of four critical aspects of the enacted curriculum that contributed to the development of the key understandings and the creative solution: (1) an open-ended, goal-oriented task, (2) teacher modeling of inquiry techniques, (3) provision of tools and an environment that allowed students to move between dual modes of interaction: seriousness and play, and (4) provision of tools and an environment that allow students to jointly develop a shared understanding achieved through tool-mediated communicative and cognitive interaction.

In this episode, students were working towards a goal in an open-ended, goal-oriented way. Their activity was constrained by the parameters of the challenge, and therefore structured, but they were given much freedom in pursuing their solution. Furthermore, the teacher’s modeling of modes of inquiry, which included investigation and reasoning (close examination of the functioning of the robot in a neutral setting) as well as playfulness and bricolage (demonstrated in this episode by Mr. Smith’s use of the tip of his shoe to trigger the program) aided in the development of the creative solution. Levi-Strauss (1966) defined bricolage as the re-purposing of items that are ready to hand in the environment. The creative idea of re-purposing the black cables was an act of bricolage that synthesized the idea of using found black materials — originally suggested by Janice (the video equipment), extended by Esteban (the power cord connected to the video equipment), and then playfully demonstrated by Mr. Smith (the tip of his black shoe).

While playfulness and bricolage are not generally considered modes of inquiry in science, they may well be important modes of inquiry with regard to the development of creative ideas. If this is so, it points to the importance of providing tools and an environment that allows students to move between dual modes of interaction: seriousness and play. In Mr. Smith’s class, the students had a serious purpose, which was to solve the light-sensor challenge, but they were allowed to move between modes of seriousness and modes of play as demonstrated through the teacher’s playing with triggering the robot with his shoe.

Tool-mediated activity was also an important part of the development of the key understandings and the creative solution. The primary mediating tool was the light-sensor-enabled robotic vehicle. The vehicle served both to focus students’ attention and as an object of inquiry. In Troubleshooting Cycle 11, Mr. Smith modeled the technique of holding the robot in one’s hands to test the program. Once he did this, the students (Janice and Esteban) followed suit. Their joint manipulation of the robot was demonstrated when they both put their hands over the light sensor to

see if they could trigger the program. They then jointly took light readings of various sources of light in the room and discussed those readings. These activities reflected their growing understanding of the light sensor as a more complicated device. Finally, the activity of experimentation with the light sensor, in concert with Janice's recollection of Mr. Smith's earlier comments, allowed them to construct the understanding that "the floor is the black light."

Implications

In considering the challenge of how to scaffold creative design in collaborative groups, this analysis demonstrates the importance of non-authoritative discourses. The classroom conditions created by internally persuasive discourses open a space for collaborative dialogic inquiry and the creation of new meanings. These conditions allow learners to engage in the reasoning processes (including play) that lead to creative solutions. Scaffolds for creative design then may include introducing an open-ended, goal-oriented task; modeling inquiry techniques that include play and bricolage; and providing the tools and an environment that allow students to move between the dual interaction modes of seriousness and play while jointly developing a shared understanding achieved through communicative and cognitive interaction.

While other researchers have noted student play as an aspect of collaborative creativity (Fernández-Cárdenas, 2008; Vass et al., 2008), this paper introduces the epistemological aspects of play and bricolage as important inquiry techniques in creative work. Play may be considered non-productive, especially in upper grade K12 educational situations. Yet, this analysis demonstrates the efficacy of play and bricolage in developing a creative solution. Therefore, if we are interested in helping students develop the ability to think creatively about problems, we may well wish to model play and bricolage and to create situations where students may fluidly move between serious inquiry and playful inquiry in a collaborative context.

Future research should focus on examining the relationship of play and bricolage to creativity in both the design of classroom environments, and in the design of digital learning environments. In terms of classroom environments, this study indicates the need for an ecological approach in studying collaborative creativity. For example, what are the myriad factors at various levels of institutional influence on the ability of teachers to introduce play and bricolage as inquiry techniques in a curriculum aimed at developing creativity in students? Such a study would help us to understand the impact of broader policy decisions on classroom practice and the development of creativity. This research is particularly important in an era of high-stakes standardized testing. Arguably, schools that focus on teaching to the test are actually engaged in teaching students to comply with authoritative discourses, rather than teaching them to act as bricoleurs or to engage and transform the internally persuasive discourses that animate consciousness.

In terms of studying play and bricolage in digital learning environments, it is likely that many digital environments are already re-purposed by students for various reasons. Understanding how, why, and when students act as bricoleurs with digital materials may aid in the development of scaffolds for further creative activity. Finally, when creativity is a learning goal of a curriculum, designers should carefully consider how to open a space for playful inquiry through the design of the digital learning environment itself.

Acknowledgements

The author wishes to thank Nick Wilson for his help on the study, and Janet Kolodner and the anonymous reviewers for their insightful comments on the manuscript. The study was supported by a grant from the Massachusetts Board of Higher Education (MA BHE ST#128221).

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Understanding Complex Natural Systems by Articulating Structure-Behavior-Function Models

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ABSTRACT

Artificial intelligence research on creative design has led to Structure-Behavior-Function (SBF) models that emphasize functions as abstractions for organizing understanding of physical systems. Empirical studies on understanding complex systems suggest that novice understanding is shallow, typically focusing on their visible structures and showing minimal understanding of their functions and invisible causal behaviors. In this paper, we describe an interactive learning environment called ACT (for Aquarium Construction Toolkit) in which middle-school students construct SBF models of complex systems as a vehicle for gaining a deeper understanding of how such systems work. We report on the use of ACT in middle-school science classrooms for stimulating, scaffolding, and supporting SBF thinking about aquarium systems as examples of complex systems. We present preliminary data indicating that SBF thinking, facilitated in part by the ACT tool, leads to enhanced understanding of the behaviors and functions of aquaria.

Keywords

Science education, Model-based inquiry, Complex systems, Interactive learning environments, Educational technology

Introduction

Our past research into artificial intelligence in automated, analogy-based creative design (e.g., Bhatta & Goel, 1997; Goel & Bhatta, 2004) led to the development of a class of normative models of complex systems called Structure-Behavior-Function models (Goel & Stroulia, 1996; Goel, Rugaber, & Vattam, 2009). The apparent success of Structure-Behavior-Function (SBF) models in automated creative design led to proposals about using them as external knowledge representations of complex systems in interactive learning environments (e.g., Goel et al., 1996). Empirical studies in the SBF framework showed that while experts and aquarium hobbyists typically understand aquaria in terms of their structure, behavior, and function, novices such as middle-school students and pre-service teachers focus on the visible structure, show minimal understanding of function and provide little evidence of understanding the invisible causal behaviors (Hmelo, Holton, & Kolodner 2000; Hmelo-Silver, Marathe, & Liu 2007). These empirical studies entailed the development of an SBF coding scheme for analyzing answers for questions about complex systems as well as metrics for measuring SBF understanding of complex systems.

Positive results from the empirical studies motivated development of a set of interactive tools called RepTools for promoting SBF thinking about complex systems (Liu & Hmelo-Silver, 2009). RepTools included SBF-inspired function-centered hypermedia as well as NetLogo-based expert simulations of aquaria. A subsequent study showed that use of RepTools leads to deeper SBF understanding of complex systems in middle-school science classrooms. Hmelo-Silver et al. (2008) summarize this work. However, although RepTools provided an information environment suitable for inquiry-driven learning, it did not provide a knowledge-construction tool that allowed students to articulate their understanding of complex systems.

In this paper, we describe a new interactive learning environment called ACT (for Aquarium Construction Toolkit) centered around a knowledge-construction tool called SBFAuthor. Unlike RepTools, the new SBFAuthor tool enables students to construct SBF models of classroom aquaria as complex systems. We describe the introduction of ACT in multiple middle-school science classrooms in the New Jersey area and present preliminary results on the use of ACT for stimulating, scaffolding, and supporting SBF thinking about classroom aquaria. We have developed three versions of the ACT interactive environment. In 2006, we developed ACT1, which we demonstrated to middle-

school teachers but did not introduce in any classroom. In 2007, we developed ACT2 based in part on feedback from middle-school teachers on ACT1. In early 2008, we introduced ACT2 into three middle-school classrooms in central New Jersey. Later in 2008, we developed ACT3 based in part on feedback from middle-school students and teachers on ACT2. In 2009, we introduced ACT3 in multiple middle-school classrooms in central New Jersey. We are still analyzing data from ACT3. In this paper we describe the design and development of ACT2 and the data collected from its use of middle-school science classes in 2008.

Educational background and context

The design of the ACT learning environment has been influenced by several areas of scholarship, which we briefly summarize below.

Complex systems

ACT was designed to help students understand complex systems such as aquaria. Narayanan (2007) characterizes complex systems as follows:

1. Complex systems exhibit hierarchical structures composed of subsystems and components.
2. Subsystems and components exhibit natural behaviors or engineered functions.
3. The subsystem/component behaviors causally influence other subsystems/components.
4. The propagation of these causal influences creates chains of events in the operation of the overall system and gives rise to its overall behavior and function.
5. These chains of events extend in temporal and spatial dimensions.

In complex systems, invisible causal processes occur at many levels of abstraction, with a causal process at one level emerging out of interactions among components at a lower level (Chi, 2005). Since complex systems are all around us, in nature as well as in society, the study of complex systems has been recognized as a key idea in science education in national science standards (National Research Council, 1996) as well as state and local standards (e.g., New Jersey Department of Education, 2006).

Aquaria as complex systems in ecological science

For the ACT project, we selected fish-aquarium systems as the context in which middle-school students would learn about complex systems. This context was motivated in part by a growing focus on earth systems education that necessitates an understanding of coupled earth and ecological systems (National Research Council, 1996). Given recent environmental stresses on the global community, ecosystem understanding is fast becoming a requisite for informed decision-making as citizens (Jordan, Singer, Vaughn, & Berkowitz, 2008). Further, the complex yet accessible nature of aquaria appeals to middle-school teachers seeking to incorporate model-based investigation with big ideas relating to ecosystems (e.g., Hmelo-Silver et al., 2008; Stansbury, 1999). The general familiarity with aquaria paired with the need to know often provides a motivating context for middle-school students to interact with this complex system. Finally, the themes highlighted by studying aquaria are aligned with the material and skills taught in many middle-school science classrooms. Because of this alignment in content and desired skill base, teachers can use aquarium systems to provide students with the opportunity to abstract and contextualize ideas at multiple levels of iterative complexity.

Design of aquaria as a context for learning about complex systems

ACT is intended to support design (i.e., the establishment and maintenance) of classroom aquaria. The notions of functions and causal behaviors that accomplish them are central to designing. Establishing and maintaining an aquarium system requires an understanding of biological, chemical, and physical properties and processes (Dawes, 2000; Stadelmann, Finley, & Vriends, 2003; Stansbury, 1999). Thus, the task of establishment and maintenance of a classroom aquarium should support deep understanding of causality and functionality at many levels of abstraction. However, without scaffolding, students may focus on completing the task rather than on understanding how the

system works. Puntambekar & Kolodner (2005) have shown that without support, children engaging in design activity may fail to focus on the underlying science.

Functional models of complex systems

The origin of our SBF models of complex systems lies in Chandrasekaran's (1994) Functional Representation (FR) scheme. Goel, Rugaber, & Vattam (2009) describe in detail how the SBF modeling language evolved from the FR scheme. Other researchers have developed similar formally specified functional models of complex systems for use in creative design. For example, Kitamura, Sano, Namba, & Mizoguchi (2002) describe the use of their ontology of functions for systematization of functional knowledge of complex systems. Erden et al. (2008) survey conceptual schemes for functional modeling of complex systems and their use in creative design. Although various schemes for functional modeling differ in many features, they all share some key characteristics, for example, the centrality of function in organizing knowledge of complex systems, a view of behavior as an intermediate abstraction between structure and function, and the importance of ontologies for representing functions and behaviors. This is in contrast to traditional general-purpose declarative models such as concepts maps (Novak & Gowin, 1984). While concept maps enable the construction of arbitrarily complex models (Krajcik, Czerniak, & Berger, 1999), the complexity and vagueness of concept maps makes critiquing hard (Marzano, Pickering, & Polluck, 2001). Functional modeling also contrasts with qualitative modeling and simulation tools such as Model-It (Metcalf, Krajcik, & Soloway, 2000) and SIMQUEST (van Joolingen & de Jong, 2003). These tools first convert parametric values and relationships entered by a user into a set of qualitative equations, then, given a set of initial conditions, they solve the qualitative equations to produce temporally evolving values of variables. SBF models are a specialized class of declarative models that have unique affordances for representing complex systems such as functional representation, causal explanation, and hierarchical organization.

Learning by constructing, critiquing, & revising models

Socio-cultural theories of learning suggest engaging learners in the knowledge-building practices of scientists (e.g., Edelson, 1997). Modeling, that is, model construction, critiquing, and revision, is central to scientific inquiry (Darden, 2006; Nersessian, 2008). Scientists build models of complex systems both to improve their understanding and to make predictions. Clement (2008) has argued that learning in science is fundamentally a process of model construction, critiquing and revision. Kreuzer (1986) believed that "the purpose of a model lies in the act of its construction and exploration and in the resultant, improved intuition about the system's behavior, essential aspects and sensitivities (p. 7)." Further, models can help students understand multiple levels of organization in complex systems (Buckley, 2000).

External representations of models

From a constructivist perspective, learning entails active construction of knowledge. Increasingly, there is an emphasis on learning through collaborative construction of external representations (Kozma, 2000; Lajoie, Lavigne, Guerrero, & Munsie, 2001; Papert, 1991; Suthers, 2006). Thus, ACT provides interactive tools for external articulation and representation of SBF models of complex systems. The social and cognitive roles of external representations in learning, particularly collaborative learning, have received significant attention as a research focus (e.g., Koedinger & Nathan, 2004; Smolensky, Fox, King, & Lewis, 1987; Suthers et al., 2001). Graesser, VanLehn, Rose, Jordan, & Harter (2001) and Bredeweg & Forbus (2003) describe interactive tools for constructing external representations of causal models. Betty's Brain (Biswas, Leelawong, Schwartz, & Vye, 2005) is an interesting example of articulation of causal models because it enables students to act as teachers.

Visual SBF language

In order to adapt the SBF modeling language to serve as an effective scheme for learners, we augmented it with a visual syntax to obtain vSBF, a visual SBF modeling language. Developing an SBF model of a complex system in vSBF now becomes an exercise in drawing an annotated diagram of the system using the modeling primitives

provided by the language. The diagrammatic representation of the modeled system is an external representation that serves as stimulus, coordinator, and guide for various learning interactions.

Our goal in developing the vSBF syntax was to empower learners with the unique affordances of the SBF language in order to help them understand not only the specifics of particular systems they model but also the meta-level concepts related to complex systems. For example, SBFAuthor supports functional representation and causal explanation of behaviors as described below. (Note, however, that although SBF models in general are organized in a $F \rightarrow B \rightarrow F \rightarrow B \dots F(S)$ system-subsystem hierarchy, and though a user may use SBFAuthor to model any system or subsystem, SBFAuthor at present does not directly support hierarchical organization of system-subsystem models.) vSBF was developed under the assumption that a visual representation language (augmented with suitable scaffolding) can help students learn these concepts of complex systems provided that (a) the language is capable of capturing all of the said concepts and (b) students express their understanding in the language. Guided by these two assumptions, vSBF contains a palette of visual primitives corresponding to the elements of SBF ontology. Figure 1 captures a sample of the correspondence between the elements of the SBF scheme and their visual counterparts.

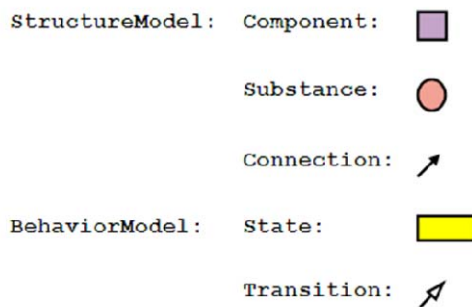


Figure 1. Elements of vSBF language

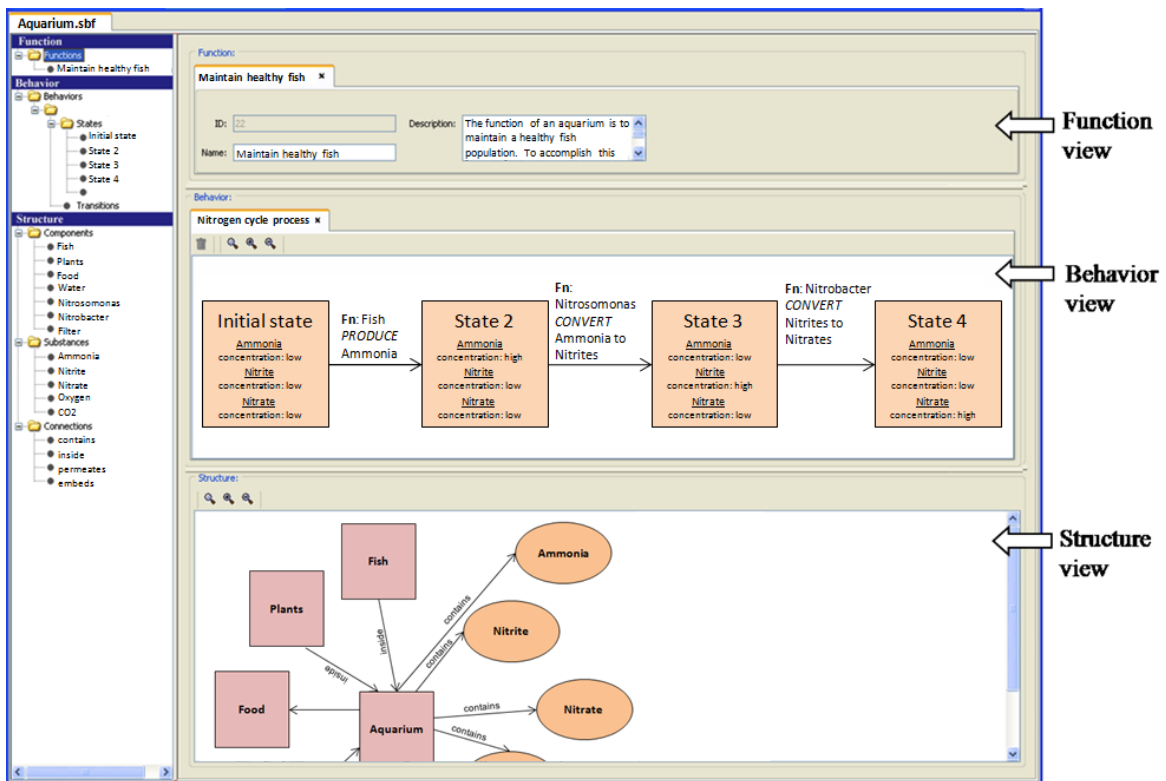


Figure 2. A snapshot of SBFAuthor's main interface

Interactive construction of SBF models

SBFAuthor is an editor for building partial SBF models using vSBF. SBFAuthor partitions an SBF model into three views: structure view, behavior view, and function view, as shown in Figure 2. This figure depicts part of the SBF model of an aquarium. One of the primary functions of a fish tank is to maintain a healthy fish population. Fish release nitrogenous waste products that break down into ammonia. Ammonia, which is highly toxic to most fish, can be removed from a fish tank through nitrification process. Nitrification is the biological process that converts ammonia into other relatively harmless nitrogen compounds. Several species of bacteria are involved in performing this conversion. Some species (such as Nitrosomonas) convert ammonia into nitrite, while others (such as Nitrobacter) convert nitrite into nitrate, which is less toxic than ammonia.

Structure view

The structure view enables users to create the structure portion of an SBF model in terms of its components, substances, and their associated connections. The structure model is presented as a graph. For each component or substance in the structure, a corresponding node is created. The connections are represented as labeled links between nodes. Figure 3(a) shows the structure view of the aquarium. It consists of component nodes such as “fish,” “plants,” “food,” and “water,” and bacteria such as “Nitrosomonas” and “Nitrobacter.” It also contains substance nodes such as “ammonia,” “nitrite,” “nitrate,” etc. Links between these nodes indicate specific kinds of connections such as “contains,” “inside,” “permeates,” etc. As shown in Figure 3(b), components and substances can be described using dialog boxes in terms of their properties (e.g., “concentration” and “toxicity” are properties associated with “ammonia”). According to the SBF specification, a component can itself comprise a subsystem with its own SBF model. In such situations users can create a separate SBF model for that component and include a reference to the function of the child model in the parent model.

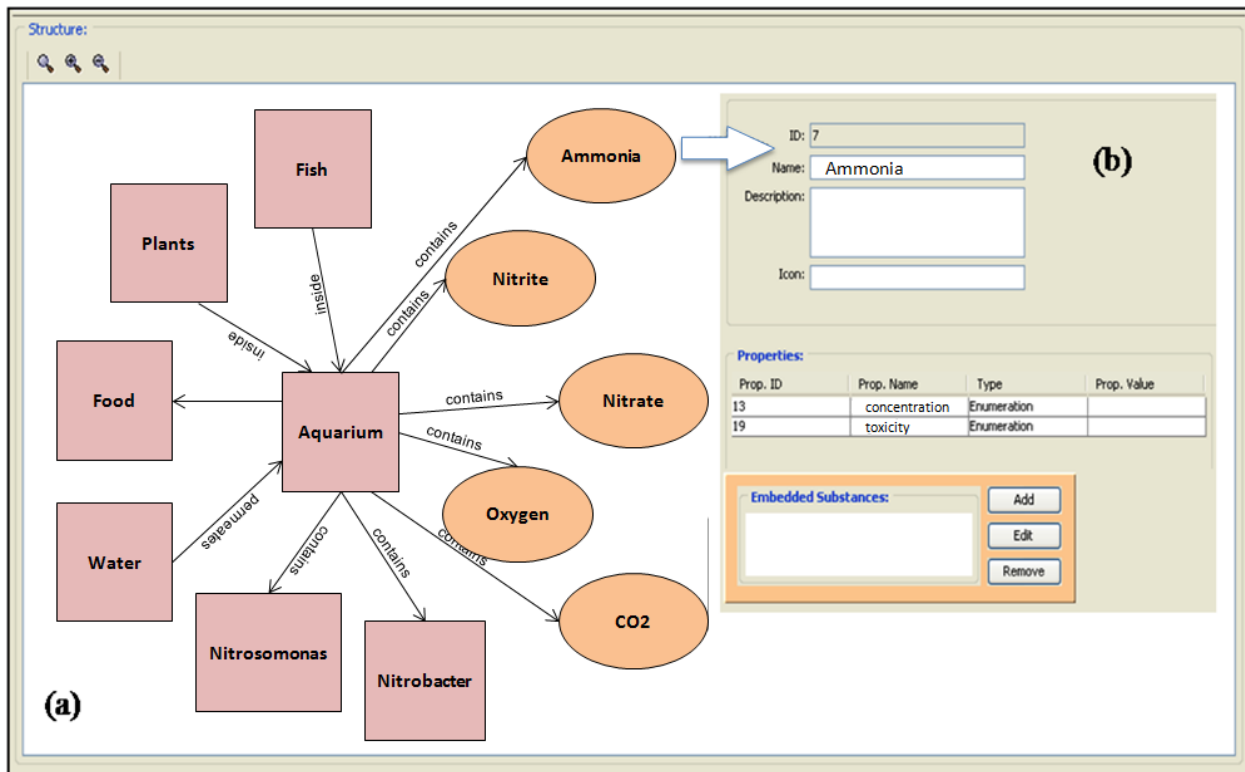


Figure 3. Structure view: (a) a structure model of an aquarium, (b) a substance dialog box

Behavior view

The behavior view enables users to create the behavior model portion of an SBF model by allowing them to create one or more behaviors, which appear as different tabs in the behavior view. Each behavior is represented as a state-transition graph like the one shown in Figure 4(a). For each such behavior, users can create states and transitions.

A state is like a snapshot of the complex system in time. A state describes the properties, values, and connections of the structural elements of a system at a given moment. Every state is associated with a dialog box that allows the user to model state variables and their values by choosing them from a list of properties derived from the structure model. For example, Figure 4(a) depicts several states comprising a behavior: “State 1,” where the concentrations of various substances are zero, (Figure 4(b) partially shows this state expanded); “State 2,” where the concentration of ammonia is high; “State 3,” where the concentration of nitrites is high and the concentration of nitrates is low; and “State 4,” where concentration of nitrates is high but that of nitrites is low.

A transition is a unidirectional arrow that links two states that are causally connected. For each state change there must be some reason for that change, an explanation for why and how the system changed from one state to another. Annotations on transitions capture the reasons for, or causal explanations for, changes, between states. For instance, in Figure 4(c) the transition between “State 1” and “State 2” contains a reference to the function “Fish PRODUCE Ammonia,” which explains why the concentration of ammonia rose from zero to high as a result of fish activity. Similarly, the transition between “State 2” and “State 3” contains reference to the function “Nitrosomonas CONVERT Ammonia to Nitrites” as an explanation for the increase in the nitrite concentration and decrease in ammonia concentration. Finally, a reference to the function “Nitrobacter CONVERT Nitrites to Nitrates” in the transition between “State 3” and “State 4” explains the increase in nitrates and decrease in nitrites.

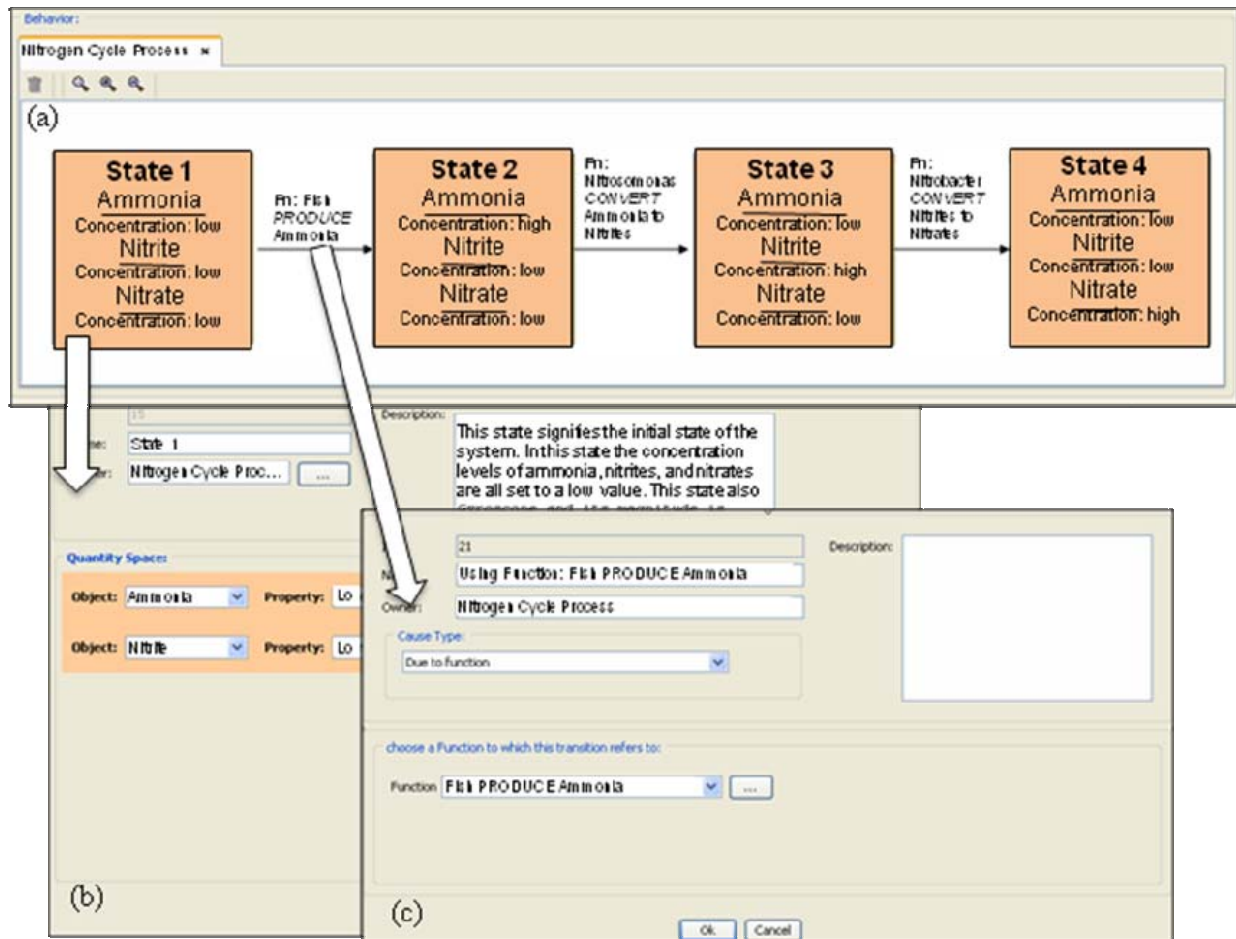


Figure 4. Behavior view: (a) a specific behavior, (b) state dialog box, (c) transition dialog box

Function view

The function view enables users to create the function model portion of an SBF model of a system. A function model has one or more functions that appear on different tabs in the function view. For each function, users can state its type (primitive or non-primitive). If the function being modeled is a primitive function, the user can choose from an existing set of primitive functions that are provided by the system. If it is a non-primitive function, the user has to define the new function and include a reference to a behavior that accomplishes it. In Figure 5, for example, the function “maintain healthy fish” is accomplished by the behavior “nitrogen cycle process.” In addition to a reference to the behavior, a user has to specify a pre-state (shown as “initial state” in Figure 5) and a post-state (shown as “desired state” in Figure 5) associated with that function, which represent the necessary states of the system before and after the function is accomplished. In the function view, users can also include a reference to an external stimulus that initiates that function.

Figure 5. The function view

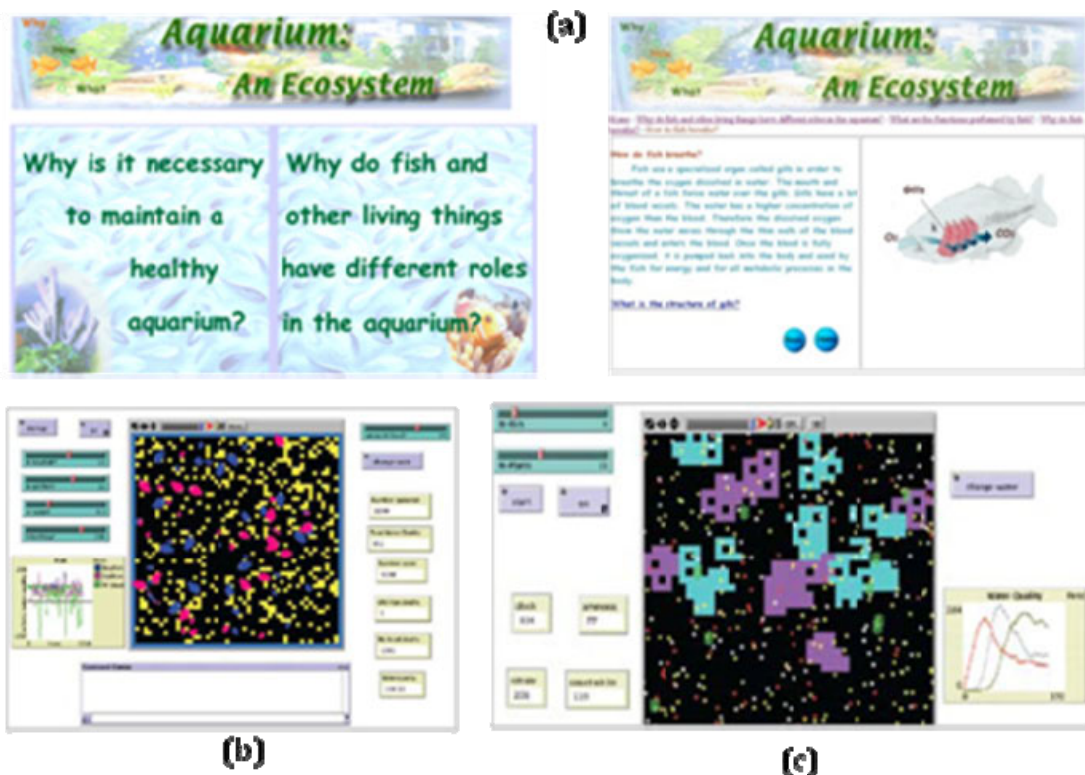


Figure 6. RepTools contains (a) a function-centered hypermedia, expert simulations of (b) fish spawning, (c) nitrification process

Other tools in the ACT learning environment

In addition to SBFAuthor, the ACT environment consists of two other major functional units: (1) RepTools are a set of domain-specific (aquaria, in this case) digital tools developed earlier (Hmelo-Silver, Liu, Gray, Finkelstein, & Schwartz, 2007, Liu & Hmelo-Silver, 2009). (2) SBF-NetLogo Simulator allows learners to simulate their SBF models on the NetLogo simulation platform (Wilensky & Resnick 1999).

RepTools

The ACT environment embeds RepTools within it. RepTools was designed to accompany a physical aquarium installed in each classroom. The kit provides digital tools that feature a function-centered hypermedia from which students can read about the structures, behaviors, and functions occurring within an aquarium system. It also includes micro- and macro-level NetLogo-based simulation developed by experts. The macro-level simulation enables students to test ideas about fish spawning and water quality, and the micro-level simulates the nitrification process that occurs within an aquarium as part of its biological filtration. In combination, these digital tools allow students to gain insight into the explanations behind the processes and outcomes that occur at multiple levels within the aquarium. Figure 6 provides snapshots of this suite of tools.

SBFAuthor-NetLogo Simulator

The benefits of coupling modeling and simulation are well known (e.g., Feurzeig & Roberts 1999): Students can (1) visualize the behavior of the system they modeled, (2) get feedback about their models by comparing the behavior of the system they modeled with either an expert's simulation or a real-life version of the system, and (3) get feedback at intermediate stages of their model development. For these reasons, we integrated SBFAuthor with the NetLogo platform (Wilensky 1999; Wilensky & Resnick 1999). Figure 7 illustrates the coupling of an SBF model of an aquarium, given as a declarative conceptual representation (Figure 7a), with NetLogo to produce an agent-based simulation of the model in the form of a graphical animation (Figure 7b). Although SBF models are declarative conceptual representations and NetLogo simulations are agent-based and stochastic, we chose to couple SBFAuthor with NetLogo because of the latter's use in the extant RepTools. We thought this integration would allow students to compare simulations of the SBF models they construct with the expert simulations in RepTools. However, in the empirical study reported here the students did not make use of this coupling. Instead, in this study, the students used only the NetLogo simulations available as part of RepTools. Thus, in this paper we do not describe integration of SBFAuthor and the NetLogo simulation platform in detail; see Vattam et al., 2009 for more details.

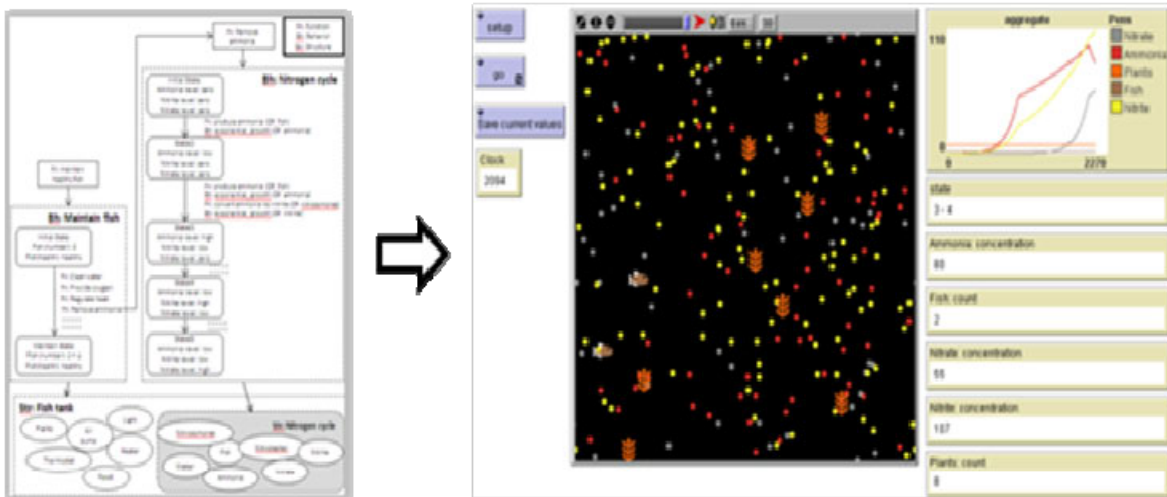


Figure 7: (a) Sample SBF model, (b) corresponding simulation in NetLogo

ACT in the classroom

We now describe the use of the ACT learning environment in a curricular unit on ecological systems in three public middle schools in New Jersey. We focus on pre- and post-test results of 157 middle-school students in the course of this unit. The students were either seventh-grade life-science students or eighth-grade physical-science students. The study was conducted as part of the students' science instruction. Prior to the intervention, none of the classrooms had aquaria, and SBF had not been taught. In all classroom settings, the teachers used the SBF Author and RepTools in the ACT environment to help students learn about the aquarium ecosystem. Prior to the study, all classrooms had a physical aquarium placed in the classroom. Students used the interactive tools on laptops while working in small groups, which varied from two to six students per computer, to generate fifty models. All teachers attended an evening workshop where they were introduced to these interactive tools prior to deployment in the classroom. Teacher A's class had 32 students, Teacher B's class had 70 students, and Teacher C's class had 55 students.

Although members of our research team were in each classroom for the duration of the project for data collection and to provide technical support, teachers were not directed in any manner beyond instruction in the SBF modeling scheme, key science concepts and how to use the tools. This freedom allowed teachers to incorporate the tools in manners they saw as appropriate and presumably in ways that complemented their pedagogical styles.

Teacher A: Teacher A began with a discussion of SBF modeling and how it can help in reasoning about complex systems. She then introduced the classroom aquarium as a complex system. Students then had the opportunity to read through the function-centered hypermedia. Next students worked first with the macro-level fish spawn simulation and then with the micro-level nitrification process simulation. Following this, students were instructed to generate a model of the nitrification process based on the simulations they had run and through consultation with the hypermedia.

Teacher B: Teacher B began with a discussion of SBF modeling and then had students use the SBF scheme as a means to model the aquarium installed in the classroom. Students were encouraged to read the hypermedia then generate an initial model. Following this, students were able to explore the expert-developed simulations. Once completed, students refined their models and incorporated new knowledge as they collected it through self-guided inquiry.

Teacher C: Teacher C began with a discussion of the aquarium and used it as a context to introduce SBF modeling. Students were immediately able to read through the hypermedia and answered a series of guiding questions provided on a worksheet. Students also had worksheets on which questions about the macro-level and then the micro-level simulations were provided. Students completed these tasks immediately after working through the hypermedia. From there, students were asked to model the entire aquarium system.

Table 1. Variation in implementation of the curriculum by Teachers A, B, & C

Activity	Teacher A	Teacher B	Teacher C
Introduction	Introduced the concept of SBF modeling and then used the ACT tool to model the aquarium in the classroom.	Introduced the concept of SBF modeling and then used the ACT tool to model the aquarium in the classroom.	Used the class aquarium as the context for introducing the SBF modeling scheme.
Purpose of students' models	Used the models to represent ideas in summative fashion.	Encouraged students to formulate and refine their thinking by having them continually revise their models.	Used the models to represent ideas in summative fashion.
Content of students' models	Had students create models on a specific part of the aquarium curriculum.	Had students create models on the entire aquarium unit.	Had students create models on the entire aquarium unit.

Table 1 summarizes the different approaches the three teachers took to introducing the aquarium system, the SBF modeling scheme and the ACT learning environment (Jordan, Hmelo-Silver, Gray, Goel, & Rugaber, 2009). Thus,

the modeling task and the learning tool were compatible with different classroom cultures. Teachers A and B first introduced SBF modeling and then encouraged the modeling of the aquarium, whereas Teacher C chose to introduce ideas in the reverse order. Teachers A and C used the model as a means to represent ideas in summative fashion, whereas Teacher B chose to use the modeling task throughout implementation as a means to continually formulate and refine ideas. Additionally, Teachers B and C chose to have students model the entire system, while Teacher A had students generate a model based on a portion of the system that corresponded quite closely to one of the simulations. Finally, although all teachers explicitly introduced SBF modeling to the students as a way to organize their learning about the complex system, the emphasis and duration of the exposure to the SBF modeling schemes varied significantly by teacher. These differences in teaching practices, and focus resulted in distinct models produced by the students in each classroom (Figures 8, 9, and 10).

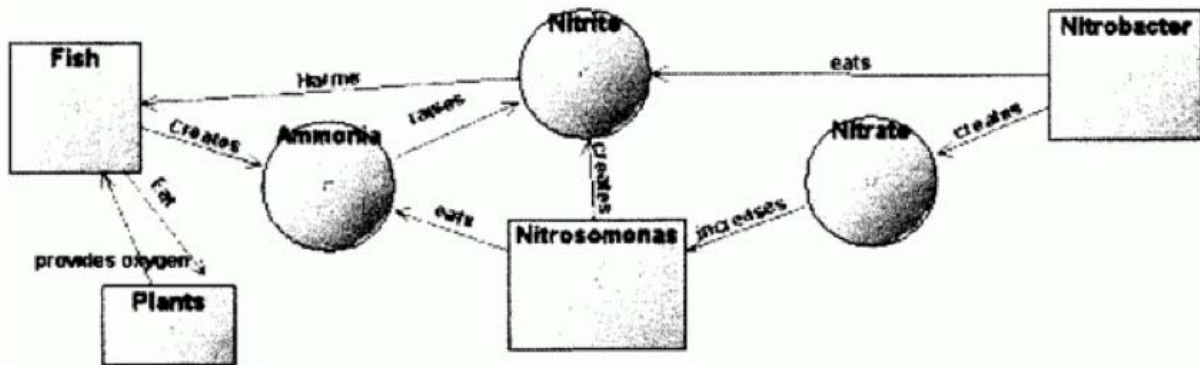


Figure 8. An example of models from Teacher A (students were asked to model only the nitrification process as a subsystem of the aquarium)

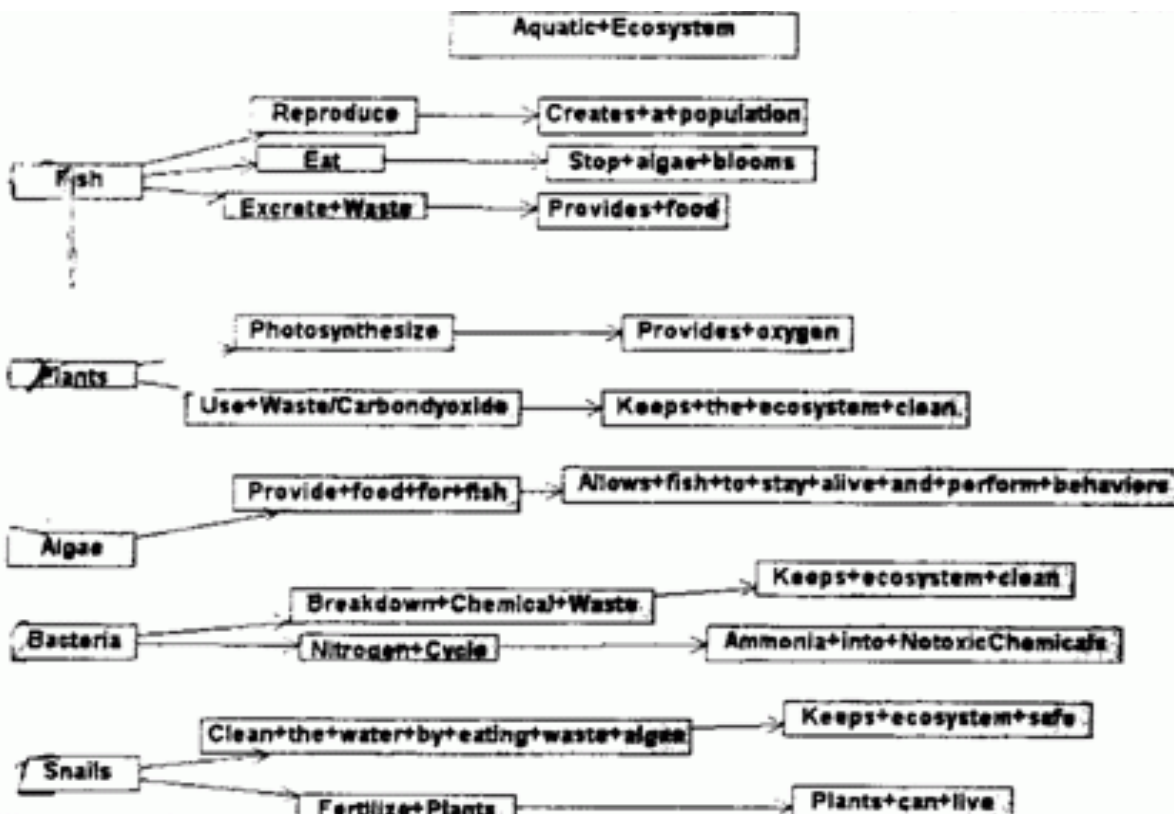


Figure 9. An example of models from Teacher B (students were asked to model the system according to the Structure-Behavior-Function theory in terms of how the functions of different structures related to the whole system)

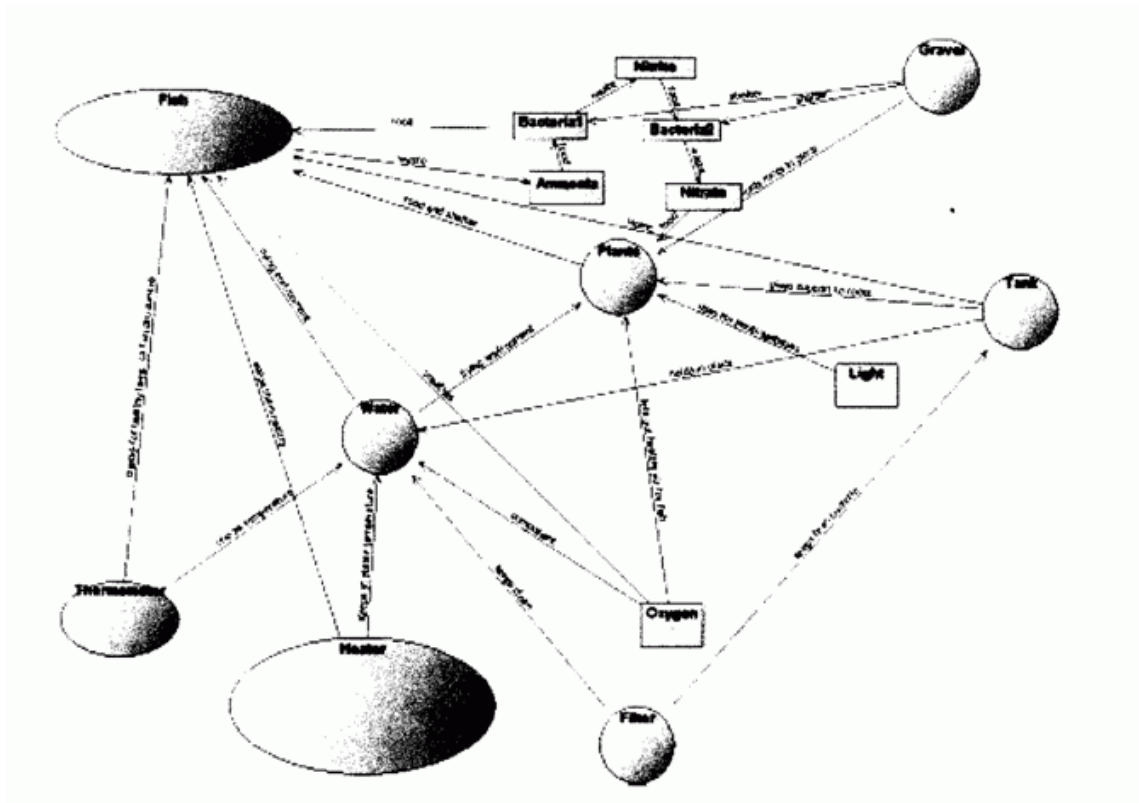


Figure 10. An example of models from Teacher C (students were first introduced to the aquarium system and then asked to model the elements and their relationships)

SBF coding scheme

To compare learning gains across classroom and teacher context, we investigated the extent to which students in each of the three classrooms showed increases in their understanding of aquaria as a complex system. To do this, we focused our analysis on two questions that were part of a pre-test administered prior to the educational intervention and post-test administered after the completion of the unit. The first question was designed to elicit student ideas of structures in the system. The second question was designed to uncover student identifications of behaviors and functions of specific structural elements. The questions analyzed pre and post were:

Draw all of the parts of an aquarium. Please label your drawing.

Explain how the following elements are related to the aquarium system. Be sure to tell everything that you know about each of them and why they are important for the aquarium.

- a. fish
- b. plat
- c. bacteria
- d. algae
- e. oxygen
- f. carbon dioxide
- g. nitrogen
- h. ammonia
- i. light
- j. heater
- k. air pump
- l. substrate
- m. food

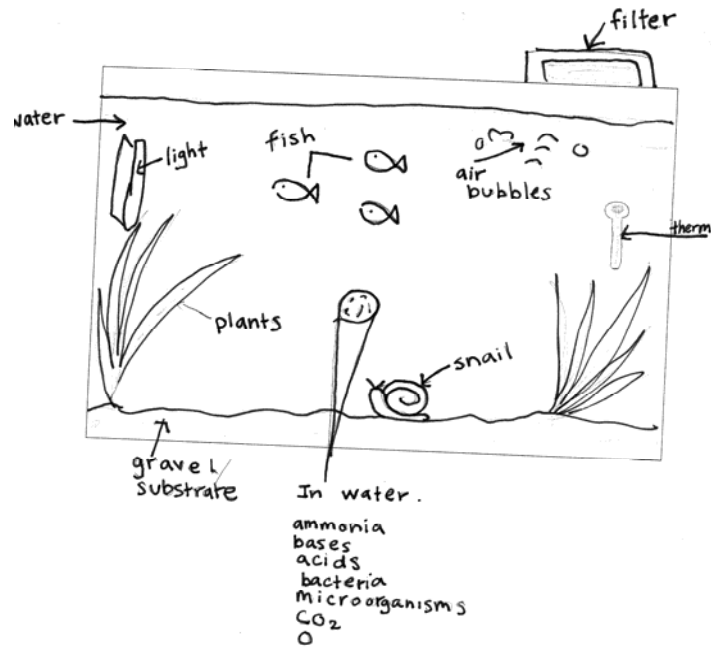


Figure 11. An example of a student's answer to Question 1 on the post-test

Student responses to these two questions were then analyzed with respect to SBF using an SBF coding scheme developed earlier (Hmelo-Silver et al., 2007). To understand student representation of structures, components, and labels represented in student drawings (Question 1 above) were counted. Figure 11 illustrates a drawing made by one of the students. Structural components in a drawing included representation and labels such as fish, plants, and filter. To understand student representations of behaviors and functions, answers to Question 2 were analyzed. Figure 12 illustrates one student's answer to the question. Descriptions of mechanisms or processes within the system were coded as including behavior. For example, a behavior of the plants could be to absorb some of the carbon dioxide in the fish tank and produce oxygen through photosynthesis. Descriptions of outcomes of processes of the mechanism were coded as function. For example, a function of the filter could be to clean and circulate water. All tests were coded blind to condition by one rater.

c) Bacteria

Everyone thinks bacteria is bad. Well, it is if there is too much. In this case, bacteria helps. Ammonia, Nitrite, and Nitrate are harmful at certain levels. The bacteria help keep it at the normal level. It works like this:

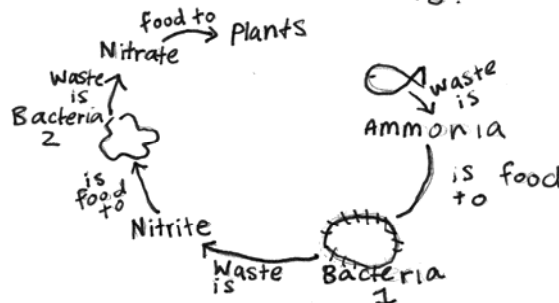


Figure 12. An example of a student's answer to Question 2 on the post-test (For each element, student responses were coded as including or not including behaviors and functions. The example below includes functions, since written responses identify outcomes (why) for processes but not for behaviors since no mechanisms (how) are identified)

Preliminary results

Table 2 shows initial results from the pre- and post-tests. Results indicate that in spite of differences in how teachers defined the modeling task, there were gains in structure, behavior, and function understanding in all classrooms. Not surprisingly, structural understanding was initially highest for all groups. Gains in structural understanding were modest but that might be attributable to the already high level of understanding. Post-test of functional understanding yielded significant gains. However, we saw the largest effect size for increase in behavioral understanding for all groups. We need to conduct further analysis of the classroom intervention to conjecture about the causes for the differences between different classrooms. We believe that what is most important to take away from these results is that teachers used ACT in three different ways, and in all three classrooms, learners showed significant gains in their understanding of structures, behaviors, and functions. The increase in behavior and function dimensions is especially important as they are indicative of deeper understanding of complex systems (Liu & Hmelo-Silver, 2009).

Table 2: Descriptive statistics by teacher and SBF

	Structure	Teacher A Behavior	Function
Pre-test mean, <i>SD</i>	8.63 (1.79)	4.44 (2.14)	4.50 (2.71)
Post-test mean, <i>SD</i>	9.06 (1.29)	5.69 (2.07)	6.56 (2.73)
Sample size (<i>N</i>)	32	32	32
<i>T</i>	1.30	3.22	3.23
Effect size	0.28	0.76	0.58
	Structure	Teacher B Behavior	Function
Pre-test mean, <i>SD</i>	9.56 (1.22)	7.62 (2.36)	5.50 (1.78)
Post-test mean, <i>SD</i>	10.33 (.90)	9.90 (2.87)	7.69 (2.51)
Sample size (<i>N</i>)	70	70	70
<i>T</i>	4.37	7.13	7.72
Effect size	0.72	1.00	0.86
	Structure	Teacher C Behavior	Function
Pre-test mean, <i>SD</i>	9.09 (1.67)	4.20 (2.01)	5.45 (2.85)
Post-test mean, <i>SD</i>	10.13 (1.67)	6.80 (2.26)	8.04 (3.19)
Sample size (<i>N</i>)	55	55	55
<i>T</i>	4.96	5.83	6.81
Effect size	0.62	1.21	0.86

Conclusions

Understanding complex systems is the basis for much inquiry in science and engineering. As such, the study of complex systems has been recognized as a key idea in science education. However, we also know that learning about complex systems is hard because there are many systems concepts that we never directly experience or that violate our intuitions, and learning about these systems challenges our cognitive and metacognitive resources, restricting our ability to think beyond linear flow, single causality, and visible structure. Motivated by the problem of helping middle-school students gain a deeper understanding of complex systems, we have developed an interactive learning environment called ACT that enables construction of SBF models of complex systems in the domain of aquaria. SBF models are known to be useful for supporting creative design.

From initial data on the introduction of ACT 2.0 into multiple middle-school classrooms in 2008, we may draw two preliminary conclusions. Firstly, different teachers use ACT to stimulate, scaffold, and structure SBF thinking in different ways, which of course has a major influence on the SBF models constructed by the students using ACT. In the section above, we described the way three different teachers structured their classes and illustrated some of the SBF models constructed by their students, respectively. Secondly, and perhaps most importantly, preliminary results pertain to statistically significant improvement in understanding of the structure, behavior, and function of aquaria in our sample of 157 middle-school students. Since students tend to have better prior understanding of structure of

aquaria, the improvement is more marked in functional and behavioral understanding of aquaria. This result needs to be qualified with the observation that we conducted the pre- and post-tests at the beginning and the end of the curriculum units, and not at the beginning and end of the students' use of ACT. Thus, the results pertain to cumulative learning that occurred in the curriculum unit of which ACT was one, but not the only, part. These preliminary results seem promising enough to build on the work reported here.

In our current work, we are extending the work reported here in several directions. Firstly, it appears that several student teams had significant difficulty in using the ACT tool for constructing and simulating behaviors of aquaria. Most student teams were able to use ACT to articulate their knowledge of the structure of aquaria relatively easily, and many teams also managed to use ACT to express their understanding of the functions of aquaria. However, some student teams had difficulty using the ACT tool's interface in articulating their understanding of the behaviors of aquaria. Thus, we are developing new user interactions in ACT that use external representations of structure and functions of aquaria to scaffold the articulation of its behaviors.

Secondly, it seems that one-week curriculum units of ecological science in middle school are not long enough to exercise the full set of capabilities available in ACT. In particular, in the three classrooms in which we introduced ACT, the students did not get to exercise ACT's facility for run-time simulation and visualization of the SBF models they had constructed. Now that the middle-school teachers on our team have some confidence in using ACT, in the next set of classroom studies we expect that they will use ACT in three- to four-week curriculum units in the earth and ecological sciences, when, we hope, students will get to use the full spectrum of ACT capabilities.

Thirdly, we are examining whether middle-school students are able to transfer the conceptual structure of SBF models to other complex systems. In particular, we want to determine if students can transfer the notion of function and the use of function to organize understanding of causal processes to other ecosystems.

Fourthly, we are examining whether the affordances provided by the SBF models enable middle-school children to better design, establish and maintain classroom aquaria. In particular, we plan to instrument classroom aquaria so that physical sensors can read the values of important variables (e.g., temperature, pH value, level of oxygen, etc.) and ACT can display these values over time. The students may then engage in the establishment and maintenance of aquaria, using ACT as and when needed to model and simulate the aquarium and to not only revise the model depending on the results, but to also redesign the aquarium itself.

Acknowledgements

This research has been supported by NSF ALT Grant (# 0632519), "Learning about Complex Systems in Middle School by Constructing Structure-Behavior-Function Models." We thank Vivek Menon for his contributions to the development of ACT and David Joyner for discussions about this work.

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A Web-based Decision Support Tool for Academic Advising

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ABSTRACT

Student advising is an important and time-consuming effort in academic life. This paper attempts to solve a technology-based “last mile” problem by developing and evaluating a web-based decision support tool (the Online Advisor) that helps advisors and students make better use of an already present university student information system. Two questionnaires were administered to 20 undergraduate students and five faculty members: one to gain insight about their perception of the current advising process, and the other to assess the usability of the proposed Online Advisor. 79% of users stated that they were satisfied with the Online Advisor. 90% rated the Online Advisor as effective and efficient. More than 75% rated the Online Advisor as useful and helpful.

Keywords

Decision Support, Web-based Tool, Academic Advising, Web Usability, Online Advisor

Introduction

Student advising is an essential component of a successful academic experience. It involves tasks where faculty members help students complete the requirements necessary to graduate. It also requires considerable planning on the part of both students and advisors. Academic advisors are exposed to a variety of opportunities, enhancements, problems, and choices as technology becomes more prevalent on university campuses (Steele 2000). Various universities and institutions around the world use automated advising systems. They are helpful and beneficial for both advisors and advisees in that they contribute to assisting in making better-informed decisions and improved services (Murray 1995). Introducing technology to the advising process aims at leveraging repetitive tasks on software and dedicating time to helping a student plan his/her education road map.

The current American University of Beirut (AUB) student information system (AUBsis) is a rigorous one that provides administrators with information about each student’s academic standing, future planning, and graduation requirements. The system enables users, with proper authorization, to view a student’s transcript and enter grades for student assignments and exams. It provides information about all courses taken by a student and the courses that still need to be met for that student to finish his/her degree. However, AUBsis and in its current implementation runs short from delivering a solution to the “last mile” problem. Some of the system’s output is difficult to read, not web enabled, and is rarely used by its stakeholders due to its user unfriendliness. This is especially true for advising purposes. AUBsis has all the academic rules built-in as well as a comprehensive student, faculty, and course data, but does not deliver this information in a way to be quickly, easily, and efficiently used by both the student and the advisor.

The purpose of this study is to evaluate the current advising process at the Olayan School of Business, introduce and evaluate the effectiveness of an easy-to-read web-based decision support tool that elevates the student (advisee) and professor (advisor) relationship from a prescriptive one to a more engaging one, and to assess the web usability of such a tool. We refer to the visual web-based decision support tool as the ‘Online Advisor’. The Online Advisor’s role is to relieve clerical burdens and enable advisors to be student centered, allow academic advisors to aid students beyond the routine, and provide time for advisors to focus on student development (Kramer & McCauley, 1995).

Academic Advising

Research literature on student retention suggests that contact with a significant person within an institution of higher education is a crucial factor in a student’s decision to remain in college. Higher education professionals who understand student challenges are primary candidates for advisor/mentor roles. While faculty, administrators, and student affairs professionals all serve as student advocates and play an integral part in student retention, advisors are

typically in the best positions to assist students in making quality academic decisions (Heisserer 2002). Most universities are using technology in academic advising to allow advisors more time to focus on student development rather than spend time on the paper-based administrative part of advising.

Effective advising depends on knowledge of the plans and goals of the student requiring the advice. Advice must be adapted to each particular student to provide explicit steps for accomplishing the incomplete parts of the task (McKendree 1988). Numerous skills are critical for successful academic advising, among which is the regular faculty-student contact or the one-to-one relationship between the advisee and advisor, which provides an opportunity for the student to build a personal link with the institution (Heisserer 2002). In addition, an advisor should be knowledgeable about academic programs and curricula requirements within the institution. He/She is expected to give accurate and correct academic guidance (Creamer 2000).

Models of Advising

From the literature, we select four models for academic advising: Prescriptive advising model, developmental advising model, integrated advising model, and the engagement model. The Prescriptive Advising model is characterized by an authoritarian relationship in which students follow the prescriptive regimen of their advisors concerning course selection, degree requirements, and registration, without assuming responsibility for decision-making (Crookston 1972). The Developmental Advising models rely on a shared responsibility between the student and the advisor in which the advisor directs the student to proper resources; thus, facilitating the development of greater independence, decision-making, and problem solving (Chando 1997). The Integrated Advising model combines elements of both prescriptive and developmental advising models (Heisserer 2002). The Engagement model involves building a relationship between the student-advisee and the professor-advisor to enhance student self-efficacy for completing the degree requirements. This approach would require an even more concentrated effort on the part of the academic advisor in a time when current technological practices might limit the face-to-face student-advisor interactions. Technology should be used to increase and facilitate access to student information and not to replace the face-to-face student-advisor interactions (Yarbrough 2002).

Technology in Academic Advising

The use of technology in academic advising may introduce greater accountability and may provide better services to students. The benefits of the use of technology in academic advising enable administrators to be student centered (Kramer & McCauley 1995). Technology is helpful to advisors and advisees in that it contributes to assisting in making better-informed decisions and improved services. However, technology does not replace one-on-one interactions. Advisors should recognize technology as a tool to enhance the advising experience, not to replace it (Steele 2000). Universities need a comprehensive plan that addresses advising, adequate faculty and advisor training, web support for targeted students, development of comprehensive databases for managing student data, and ongoing research to evaluate intervention effectiveness (Heisserer 2002). Advising can be a very time consuming process leading to the need for automating some of its functions. Ideally, an automated advisor gives answers to a student's routine questions. The student can then meet with the advisor for further consultation. This combination of human and machine can save time for the human advisor (Rao 1987).

Technology-Based Advisory Systems

An automated system for academic advising or a technology-based advisory system helps a student plan the proper courses to take, by checking and listing courses for which he/she has satisfied the prerequisites, allowing students to do the work themselves, without referring to their advisors. This reduces long-term planning errors and puts the responsibility on the student. In addition, a technology-based advisory system can suggest the order in which the courses should be taken to minimize the amount of time required to complete a degree. Such a system is as good as the integrity and freshness of the information it stores. Therefore, it is only necessary to encode accurately the data from the published university catalogue listing the requirements for each major as well as to enter prerequisite rules that guide a student eligible for graduation (Dinkel 1989). Efforts have been made to develop and use technology-based systems to emulate the process used by academics for advising. Expert systems usually reply on the

knowledge and rules held by an expert in a discipline (Grupe, 2002). Expert systems applied to academic advising can be customized to specific student and institution needs.

In the 1980s, computerized degree audit programs, either homegrown or commercially available productions like Miami University's DARS or Georgia State University's PACE systems started to appear (von Munkwitz-Smith, 2005). Diffenbach (1988) tested a system for selecting candidates for admission to a university. Valorta et al. (1984), Golumbic et al. (1986), and Schwartz (1986) developed systems for advising mathematics and computer science majors. Whers (1992) developed an advisement system for education majors. Leonard (1996) reported on an effort to develop better tools for both advisers and advisees based on the university experience. In 1998, the computer science department of California State University developed a rule-based online academic advising system. The advising system helps students enroll in courses that meet degree requirements and students' interests and then creates feedback output on the student's computer and sends a corresponding e-mail to the department (Distance Education Report, 2004). Patankar (1998) describes and discusses the development of an expert system solution, which has automated academic advising at the Faculty of Aviation at San Jose State University. Presbury and Marchal (2000) implemented an expert system that allows advisers to try to develop their own expert systems. The Pennsylvania State University has an artificial intelligence component of their advising system that evaluates the impact of a student dropping a course. In this context, Grupe (2002) developed a web-based expert system that, after assessing a student's capabilities, informs him/her about the best majors to consider.

Technology-based advisory systems have come a long way from being data repositories to incorporating more intelligence in their processes. As the field develops issues will still have to be addressed for a better experience for the advisor and the student alike. As the systems become more complicated information security will have to be approached as financial and medical data are. The same applies to student privacy. Therefore, the legal aspect will have to be developed. As systems grow in complexity, their reliability and availability will have to have less tolerance to error. When social networking is integrated in future advisor systems a whole new set of interesting concerns will have to be addressed such as peer-to-peer advising and the even newer role of the advisor.

Web Usability

We address the literature on web usability to set the grounds for the proposed solution. In order to give maximum benefits, web sites should be user-friendly. However, about 90% of current web sites have low usability. These websites will lead to unsatisfied users and consequently, will not grow into long-term successes (Teo 2003). Attitude is the predisposition to respond in a particular way towards a specified class of objects. It comprises affective and cognitive components (Schaik 2004). User attitude is important because it contributes to users' intention to use a system, which is the best predictor of actual system use according to the Technology Acceptance Model (Teo 2003). Recently, both web users and web designers are demanding from web pages not only usability but also appropriate feelings. However, despite this, users do not always experience the same kinds of impressions that designers intended to convey through their web pages (Park 2004). Users' attitude towards web sites calls for improvements (Nielsen, 2001). Prior research suggests increased interactivity to improve web usability. Potential benefits of interactivity include sense of fun and satisfaction, engagement and performance quality, and time saving. To create value for an individual and therefore positive attitude towards the online experience, satisfaction, effectiveness, and efficiency have to be addresses (Teo et al. 2003).

Research indicates that usability of a web site is associated with numerous positive outcomes, including reduction in the number of errors, enhanced accuracy, more positive attitude towards the target system, and increased usage (Nielsen 2001). The International Organization for Standardization (ISO) defines usability as 'the extent in which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use'. ISO defines satisfaction as the user's comfort with and positive attitude towards the use of a system. Satisfied users may spend a longer time on a web site, revisit it and may recommend it to others. ISO's effectiveness is the accuracy and completeness with which users achieve certain goals. Effectiveness is one major factor that can maximize users' perceived value of a web site. The extent to which a web site is informative and the relevance, completeness and timeliness of substantive information are all critical to web site visitors. ISO defines efficiency as the relation between the accuracy and completeness with which users achieve certain goals, and the resources expended to achieving them (Teo 2003). Major complaints from web sites with poor usability include the enormous amount of time and effort expended in getting information. Higher efficiency experienced in using a Web

site maybe positively related to a more favorable assessment of the web site. Product design should satisfy both usability and content requirements of target users (Schaik 2003). Design is traditionally subdivided into three macro-categories, based on meaningful characteristics both of the whole site and of its single pages: Information representation and appearance, access-navigation-orientation, and information architecture (Marsico 2004).

The “last mile” Problem

The AUB Student Information System

The current AUB system (AUBsis) provides students with a very basic interface that contains no intelligence: it is an online transcript, showing the semester in which the student is registered with a listing of the courses took with their respective grades. It does not courses that a student may have failed, nor does it inform a student if he/she is meeting his/her degree requirements. This interface is common to all students from all faculties, and thus falls short from providing the customized information that is needed by individual student and faculty/advisor users (Figure 1 shows the record of an MBA student with an Engineering Bachelor Degree).

Spring 2002 - 2003

College: Engineering & Architecture
Major: Computer & Communications Eng.
Student Type: Continuing

Academic Standing:

Subject	Course	Level	Title	Grade	Credit Hours	Quality Points	Start and End Dates	R
ASST	110	UG	Technology & Society	79	3.000	237.00		
ASST	632	UG	Intr.to Geo.Inform.Systems	82	3.000	246.00		
EECE	114C	UG	Communications Laboratory II	90	1.000	90.00		
EECE	117	UG	Final Year Project	88	3.000	264.00		
EECE	503	UG	Sp.Tp:Cellular Network	73	3.000	219.00		
OPIM	330	UG	Intelligent Support Systems	78	3.000	234.00		
PSPA	234	UG	Globaliz:Evolu.&Impact on Stat	92	3.000	276.00		

Term Totals (Undergraduate)

	Attempt Hours	Passed Hours	Earned Hours	GPA Hours	Quality Points	GPA
Current Term:	19.000	19.000	19.000	19.000	1566.00	82.42
Cumulative:	164.000	164.000	164.000	164.000	13359.00	81.45

Unofficial Transcript

Fall 2005 - 2006

College: Suliman S.Olayan S.of Business
Major: Business Administration
Student Type: Continuing/New

Academic Standing:

Subject	Course	Level	Title	Grade	Credit Hours	Quality Points	Start and End Dates	R
FOLC	301A	GR	Survey of Financial Accounting	90	2.000	180.00		
FOLC	301B	GR	Survey of Managerial Account.	86	2.000	172.00		
FOLC	302A	GR	Survey of Financial Mangement	89	2.000	178.00		
FOLC	304A	GR	Survey of Microeconomics	95	2.000	190.00		
FOLC	304B	GR	Survey of Macroeconomics	92	1.000	92.00		

Figure 1. Record of an MBA student with an Engineering Bachelor Degree

The Current Advising Process

Currently, undergraduate academic advisors request from the student advisee to fill out a form prior to sitting with him/her for advising. The form (academic degree plan) is close to a real snapshot of the current student's position in his/her academic career at the university, but can be inaccurate and not updated. Supported with this student-filled form and the student's current transcript available online, the advisor proceeds in discussing with the student his/her next steps. The advisor uses as support tools the print version of the university catalog to read about the published rules. In addition, he/she may use, when in doubt, the phone to contact the student services office at the Olayan School of Business for validation of the most updated rules regarding any specific issue. As an option, faculty members may request a several-page computer output document detailing all academic activities (with rule-based validation) in which a particular student has been engaged, as well as on-demand degree requirement output document. Finally, the advisee brings to the discussion what his/her peers suggest to him/her; and the advisor is equipped with his/her advising experience (or lack of). Figure 2 describes the situation.

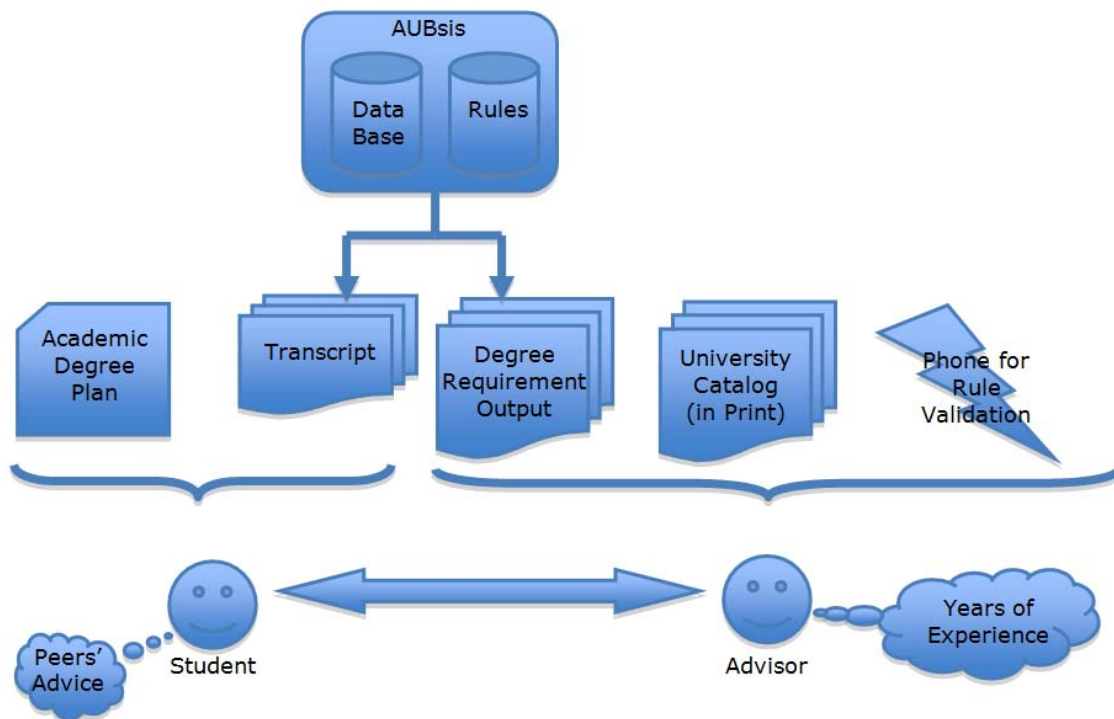


Figure 2. Record of an MBA student with an Engineering Bachelor Degree

The Online Advisor

Goal and Role in the Advising Process

The goal of the Online Advisor is to consolidate all information in one interface. By decreasing the chance of error, and displaying information instantly, an advisor will have more time to spend with his/her student on short and longer-term planning.

The Online Advisor gives the advisor and the student one interface with three separate views on the current academic situation of the student in real time. The Online advisor encapsulates the real data available in the AUBsis, the most updated rules for pre-requisites, core-requisites, number of credits attained, and graduation requirements, among others, in a color-coded one-page on-screen and printable display. From an advisor or student's point of view, guessing grades and rules are no more an option. With the Online Advisor, advising has the chance to move from a prescriptive model (Crookston 1972) to a more involved and engaging model (Yarbrough 2002). Figure 3 shows the proposed change due to the introduction of the Online Advisor to the advising process.

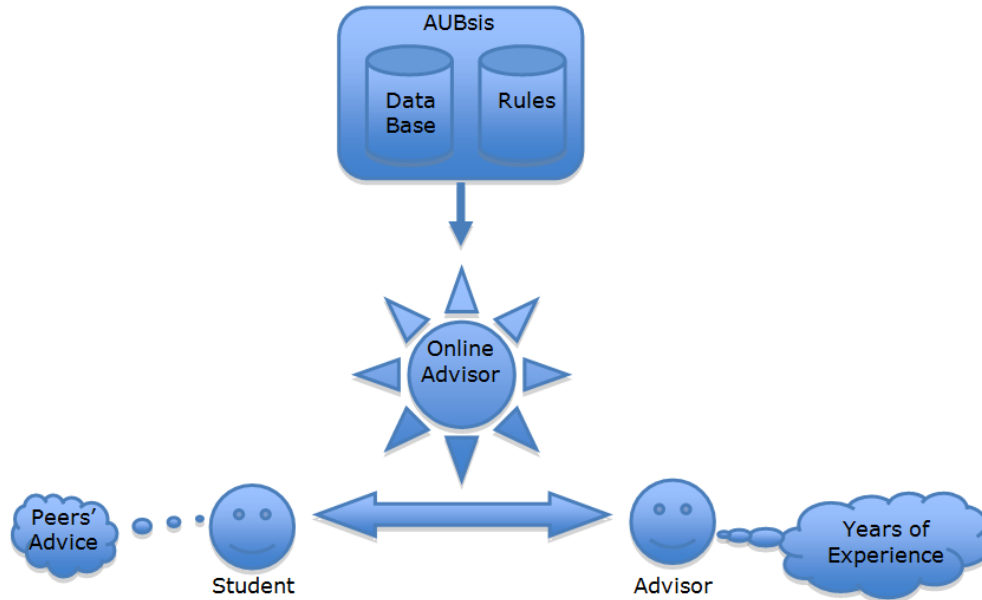


Figure 3. Record of an MBA student with an Engineering Bachelor Degree

BBA Summary - Microsoft Internet Explorer

Address: http://sb.aub.edu.lb/advising/BBAsummary.aspx

BBA Summary | [Records By Term](#) | [Degree Checklist](#) | [Degree Plan](#) | [Change Password](#) | [Print](#) | [Logoff](#)

Arabic Placement English Test TOEFL / CBT 250
 Degree Admitted to OSB BBA Fall 2003-2004 English Placement ENGL 203
 As Freshman Concentration1
 Class Junior Concentration2

Course Legend

passed registered failed withdrawn incomplete repeated

† if exempted from arabic, one elective from outside the OSB is required.
 †† if exempted from ENGL203, students must take ENGL204 and one elective from outside the OSB.
 ††† if exempted from MATH203, one elective from outside the OSB is required.

Sophomore Term 1		Grade	Sophomore Term 2		Grade
CMPS 209	(3 cr)	73	ACCT 210	(3 cr)	65
ECON 211	(3 cr)	65	ECON 212	(3 cr)	72
ENGL 203 ²	(3 cr)	77	ENGL 204	(3 cr)	78
MATH 203 ³	(3 cr)		MKTG 210	(3 cr)	84
MNGT 215	(3 cr)	82	MATH 204	(3 cr)	84
Junior Term 1		Grade	Junior Term 2		Grade
ACCT 215	(3 cr)	75	BUSS 200	(3 cr)	73
CVSP 201, 202, 205, 207 ⁴	(3 cr)	88	BUSS 211	(2 cr)	69
DCSN 200	(3 cr)	66	BUSS 239	(0 cr)	
FINA 210	(3 cr)	67	Bus. Elective ⁵	(3 cr)	79
INFO 200	(3 cr)	86	Humanity ⁶	(3 cr)	85
			ENGL 208	(3 cr)	78
Summer 2 Internship Practicum: BUSS 245			Grade:		
Senior Term 1		Grade	Senior Term 2		Grade
Bus. Elective ⁷	(3 cr)	87	BUSS 248	(0 cr)	
Bus. Elective ⁷	(3 cr)		BUSS 249	(3 cr)	
BUSS 230	(3 cr)	81	Bus. Elective ⁷	(3 cr)	

Local intranet

Figure 4. Summary Page

Description

The Online Advisor creates academic schedules semester-to-semester and year-to-year by organizing information from many sources. The Online Advisor provides information needed for course planning in an understandable and visually appealing way. In particular, the system displays the major and overall average, indicates which major, university and distribution requirements have been satisfied and which need to be completed. It displays the number of credits completed and the number still needed for graduation. The information is displayed on one screen, enabling the advisor and student to construct a recommended schedule for a following semester until graduation. A database management system through a web application acts as an interface between AUB's current running applications and the Online Advisor. The online advisor is not 'intelligent' on its own. It only uses the rules that are stored in the AUBsis and displays them with the user in mind.

Three pages define the interface between the system and the student or advisor: the summary, the degree checklist and the degree plan pages. The summary is the one page that is mostly used by advisors and students that gives a quick snapshot of the most current situation of a student's file. It shows, with color-coding, courses passed, registered, withdrawn, failed, and repeated (Figure 4).

The Degree Checklist page displays the courses required from each student in order to fulfill his degree requirements. Courses are grouped by area (major requirements, concentration, requirements from outside the faculty, and university general requirements). Each area contains the courses already taken, the courses registered, and the courses that need to be met. At the end of each area, the credits required, the credits earned, and the area averages are shown (Figure 5).

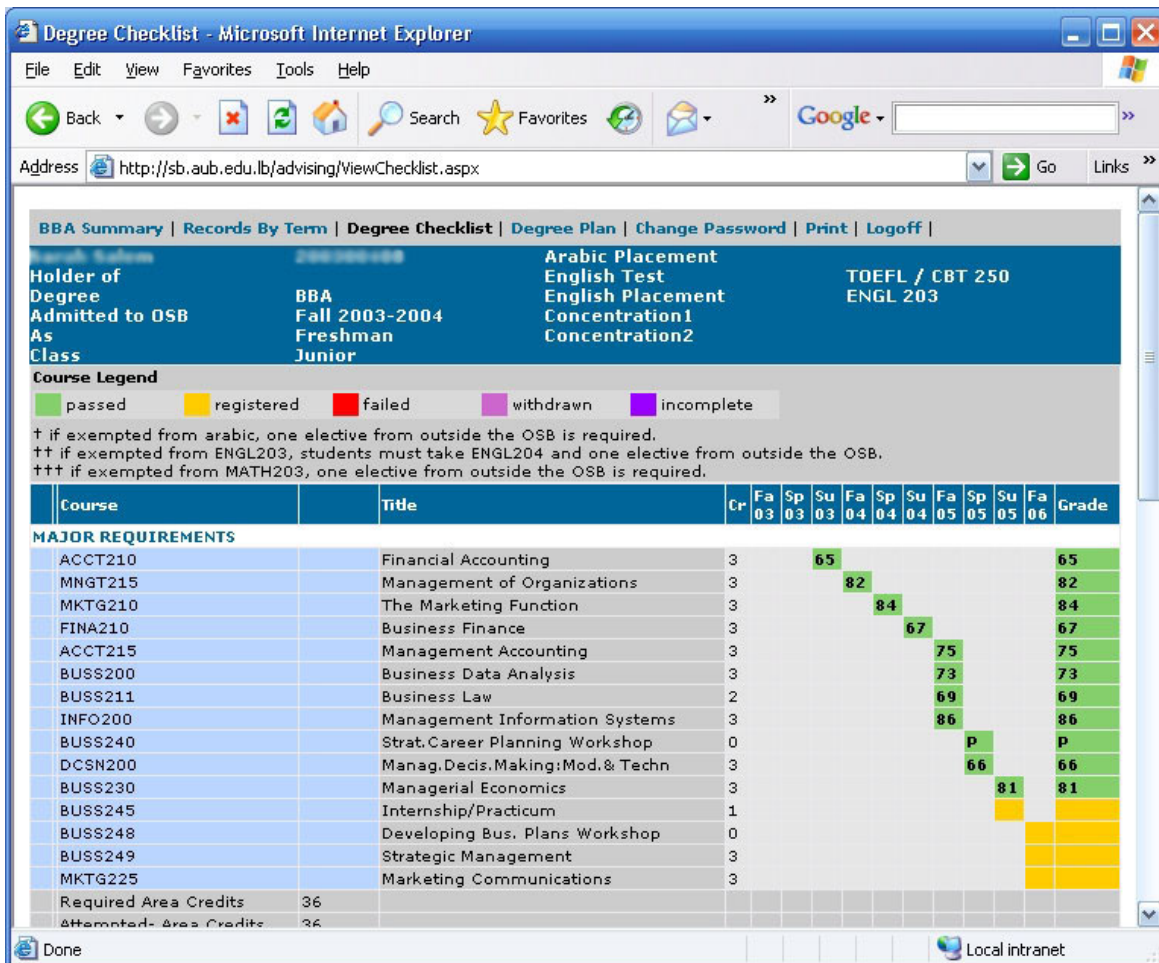


Figure 5. Degree Checklist Page

The “degree plan” page allows the student or the advisor to select the courses that he/she thinks must be taken in a specific semester. The student must select first the semester for which he/she wants to construct a plan and then the courses recommended from the courses that are still not met. At the end, students would click the ‘Update Degree Plan’ button at the bottom of the page in order to update the database with the new information (Figure 6). If there are still courses not met, students can build a plan for a new semester or click on ‘New Degree Plan’ to erase any previous plans created.

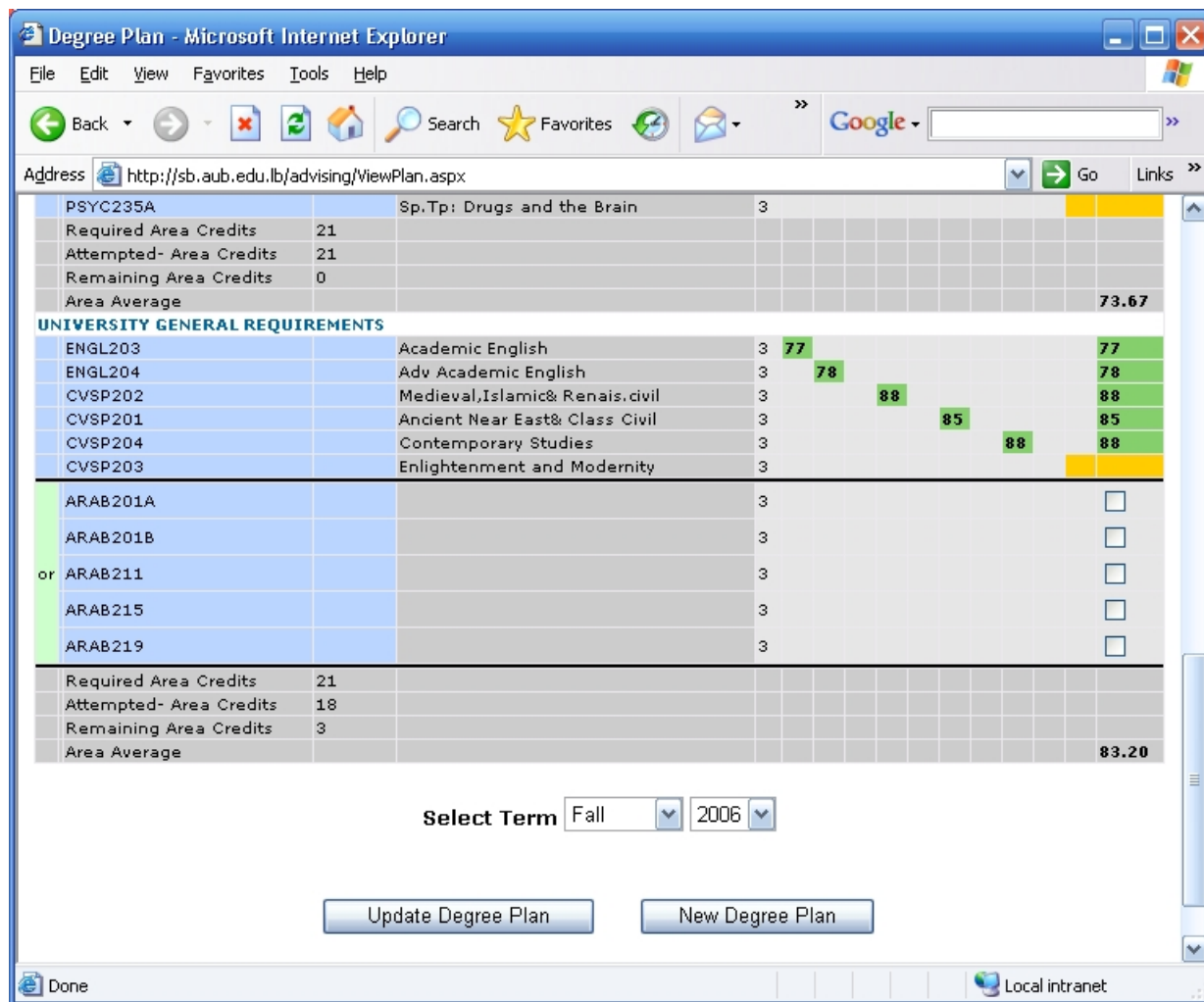


Figure 6. Degree Plan Page

Methodology

The Online Advisor was developed after several meetings with advisors, faculty members, administration, and students in order to decide on the information that needed to be displayed. The feedback of ten students and two professors were used to fine-tune the initial interface and functionalities of the system. After the implementation of the Online Advisor, the files of 30 randomly selected undergraduate business major students were used in order to correct any errors that may exist in the system.

In order to evaluate users' level of satisfaction with the Online Advisor, two questionnaires were administered. The first 7-point Likert scale questionnaire was addressed to students, and aimed to gain insight about students' perceptions and their satisfaction level of the current advising process without the Online Advisor, and to identify existing problems, and recommend changes.

The second 7-point Likert scale questionnaire was adopted from Teo (2003) with slight modifications to reflect changes in the advising process. It was administered to students and advisors in order to assess the web usability of the Online Advisor, measure users' satisfaction and attitude towards it, and measure the Online Advisor's effectiveness, efficiency and value.

The sample consisted of two groups. The first group was composed of five advisors selected randomly from the Olayan School of Business at AUB who filled only the web usability questionnaire. The second group was composed of 20 undergraduate business students selected randomly who filled both questionnaires. Users were informed about the advising process before they were asked to use the AUB Online Advisor.

Results

Students' Perceptions of the Current Advising Process

The first academic advising questionnaire contained measures of student satisfaction with the overall current advising system. Twenty students responded to the questionnaire (10% freshman, 30% sophomore, 25% junior and 30% senior). 95% of students reported that an advisor was assigned to them on time; and half reported that they met with their advisor during their current semester. 25% indicated that they have seen their advisor the previous semester; and 25% met with their advisor the previous year or before. It is observed that not all students meet with their advisors each semester. As for the reason why students did not meet with their advisor, the questionnaire allowed respondents to check as many choices as were relevant to their situation. Students felt that they could do the task at hand by themselves (54%). They also indicated that lack of time or the advisor's availability or the student's schedules (23%) were other reasons.

In addition, the questionnaire measured six other factors that are pertinent to academic advising. The factors included availability of advisor, helpfulness of advisor, knowledge of advisor about requirements and prerequisites, knowledge of advisor about changes in academic requirements, familiarity of advisor with the student academic background, as well as knowledge of advisor about required courses outside the business School. The mean for the evaluation of the current advising process ranged between 3.75 and 4.9 (1 being very dissatisfied and 7 being very satisfied). The factors that were most satisfying to students (>50%) were helpfulness of advisor ($x=4.9$, 60%) and advisor information about requirements and prerequisites ($x=4.65$, 50%). The least satisfying were advisor knowledge about requirements outside their major area of study ($x=3.75$, 30%), followed by advisor familiarity with student academic background ($x=3.9$, 30%) and availability of advisor ($x=3.95$, 35%). Finally, 20% of students felt satisfied with the current academic advising system, 60% were neutral, and 20% were mostly dissatisfied. It is to be noted that the mean for the above satisfaction questions as rated by the students were all below 5. Over 30% of the responses to these items were "neutral" ($x=4$).

Evaluation of the Online Advisor

To assess the usability of the Online Advisor, a 7-point Likert scale questionnaire was used to measure student and advisor satisfaction, and attitude towards the Online Advisor. The questionnaire was designed to measure the system's effectiveness, efficiency, and value. All participants' ratings in a single category were averaged. Furthermore, participants' ratings in all five categories were again averaged to determine their overall rating of the AUB Online Advisor.

Satisfaction

The average mean for the satisfaction indicators was 5.37, which is higher than the mean depicted in the first questionnaire ($x=4.1$ for the question "How well does the current academic advising system meet your needs?"). In other words, students were, on average, more satisfied with the sole use of the Online Advisor than with the current system. Only 4% were somewhat dissatisfied compared to 20% in the first questionnaire. 79% of the users who filled the questionnaire stated that they were satisfied with the Online Advisor. Table 1 provides details.

Table 1. Satisfaction Measurement of the Online Advisor

Satisfaction Indicator	N	Mean	Dissatisfied (%)	Somewhat Dissatisfied (%)	Neutral (%)	Satisfied (%)	Highly Dissatisfied (%)
I feel satisfied with the Online Advisor	25	5.28	0	8	16	64	12
Important	25	5.36	0	0	24	68	8
Helpful	25	5.48	0	4	12	72	12
Average		5.37	0	4	17	68	11

Effectiveness

More than 90% of respondents rated the Online Advisor as effective. The average mean for the effectiveness indicators ($x=5.71$) was higher than the means depicted in the first questionnaire. Results were as follows: knowledge of advisor about requirements and prerequisites ($x=4.65$), knowledge of advisor about changes in academic requirements ($x=4.35$), familiarity of advisor with the student academic background ($x=3.9$), and knowledge of advisor about required courses outside the Business School ($x=3.75$). With the Online Advisor, advisors can have all the information needed about the courses taken by each student, the courses left and the changes in the academic requirements since this will be automatically traduced by the system. Table 2 lists more details on the effectiveness of the Online Advisor.

Table 2. Effectiveness of the Online Advisor

Effectiveness Indicator	Dissatisfied	Neutral	Satisfied
The Online Advisor increased my awareness of the curriculum	0%	4%	96%
The Online Advisor provided me with relevant information to facilitate my decision	4%	8%	88%
The Online Advisor helped me to meet my decision-making need	0%	12%	88%
Average	1%	8%	91%

Efficiency

More than 90% of the participants rated the Online Advisor as efficient ($x=5.99$). The Online Advisor has a simple menu where information is displayed in a familiar fashion for both students and advisors (see table 3).

Table 3. Efficiency of the Online Advisor

Efficiency Indicator	N	Mean	Dissatisfied (%)	Somewhat Dissatisfied (%)	Neutral (%)	Satisfied (%)	Highly Dissatisfied (%)
	25	6.28	0	0	0	56	44
	25	6.12	0	0	0	64	36
		5.88	0	0	12	64	24
	25	5.68	0	0	12	76	12
Average		5.99	0	0	6	65	29

Value and Attitude

Both students and advisors had a favorable impression about the AUB Online Advisor ($x=5.35$). More than 75% of the participants rated the Online Advisor as useful and helpful. The average mean for the attitude indicators was 5.12 with more than 80% of respondents rated the system as interesting. Tables 4 and 5 indicate the results for value and attitude measurements, respectively.

Table 4. Value Measurement

Value Indicator	N	Mean	Dissatisfied (%)	Somewhat Dissatisfied (%)	Neutral (%)	Satisfied (%)	Highly Dissatisfied (%)
Useful	25	5.8	0	4	8	56	32
Important	25	5.24	4	0	24	56	16
Helpful	25	5.24	0	4	20	68	8
Valuable	25	5.12	0	0	36	56	8
Average		5.35	1	2	22	59	16

Table 5. Attitude Measurement

Attitude Indicator	N	Mean	Dissatisfied (%)	Somewhat Dissatisfied (%)	Neutral (%)	Satisfied (%)	Highly Dissatisfied (%)
Interesting	25	5.16	0	4	12	80	4
Enjoyable	25	5.08	0	4	16	76	4
Like	25	5.12	0	0	32	60	8
Average		5.12	0	3	20	72	5

Comparison between the Online Advisor and the Current Advising System

In general, participants rated the Online Advisor favorably, and their satisfaction level remained relatively stable across the different categories of the questionnaire (satisfaction, effectiveness, efficiency, value, and attitude). The mean for the overall rating of the Online Advisor ranged between 5.12 and 5.99 compared with a range of 3.75 and 4.9 for the current advising system. The categories that were most satisfying to users were efficiency (x=5.99, 94%) and effectiveness (x=5.71, 91%). The least satisfying was attitude towards the Online Advisor (x=5.12, 3%). The overall rating for the Online Advisor was 5.51. Table 6 gives details.

Table 6. Comparison of user responses to both questionnaires

	Current Academic Advising Process				AUB Online Advisor			
	Mean	Dissatisfied (%)	Neutral (%)	Satisfied (%)	Mean	Dissatisfied (%)	Neutral (%)	Satisfied (%)
Helpfulness	4.9	5	35	60	5.24	4	20	76
Information about curriculum	4.16	18	55	27	5.92	0	4	96
Satisfaction	4.1	20	60	20	5.37	4	17	79

For each item factor, the average rating across all the participants is displayed for each questionnaire. The profiles of the two questionnaires revealed that users were more satisfied with the Online Advisor (x=5.37) versus the current advising system (x=4.1). Comparison showed that participants were more satisfied with the help of the Online Advisor (x=5.24) than that of the current advising system (x=4.9). Furthermore, the curriculum seems to be clearer with the Online Advisor (x=5.92) since it provide exact information about requirements, courses taken, academic background and courses required outside the business school. Using a one Tail t-Test, the mean rating of the Online Advisor for the specific questions of helpfulness, information about the curriculum, and satisfaction is greater than the mean rating of the current advising system at a significance level of 0.05.

Discussion and Recommendations

This research wanted to introduce a web-based tool to alleviate the prescriptive nature of the advising process and give more time for an academic advisor to move into a developmental advising model, an integrated advising model, or a full engagement model.

Using technology in the advising process offers certain advantages over the traditional advising process. In fact, with this particular Online Advisor, advisors can have all the information needed about the courses taken by each student, about the courses still to be taken, about the changes in the academic requirements as they are decided by the

appropriate committee(s) on campus, and explore future options for a student. This is done instantly and accurately due to the Online Advisor's direct connection with the university's student information system. The Online Advisor has a simple menu; information is displayed in a way that is familiar for both advisors and students.

While this research compared a student's evaluation of his/her current advising process to a web-based tool, it is not the intention of the authors' to suggest that the Online Advisor should replace an academic advisor. This work showed that the Online Advisor brings a lot of value to the advising process for students and advisors individually as figure 7 shows. We are suggesting that this will be positively compounded when an advisor meets his/her advisee as previously shown in figure 3 with the direct communication arrow between them.

Since the advisor will still need to provide counseling to the student, the Online Advisor offers an effective means of collecting information about the student before meeting with his/her advisor. This will reduce the time needed to acquire complete information from the student, thus allowing advisors to see more students or to counsel them in greater depth.

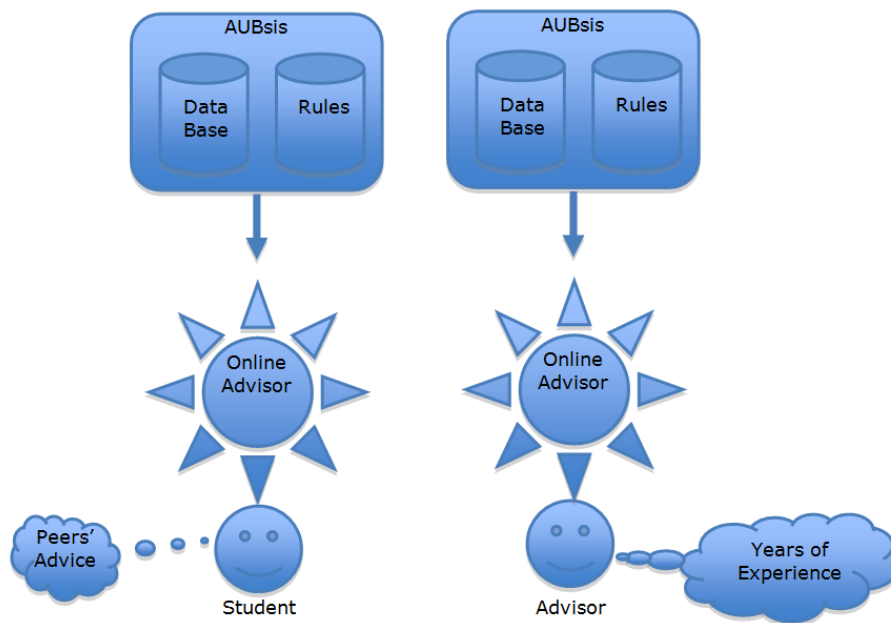


Figure 7. The Research as Conducted

The Online Advisor has several parts that can be improved further in functionality and application. This can only be through extensive use by students and academic advisors. The real measure of success is the extent to which it will be adopted on campus. Measures have to be taken to secure that the Online Advisor delivers what it is designed to do. It has to support the face-to-face meeting between advisor and student and not replace it except for optional prescriptive functions. It has to provide advisors more time to focus on student development and contribute in making better planning and scheduling. Finally, the Online Advisor is as good as the "freshness" of its information. Therefore, it is critical that all information is updated promptly to secure higher adoption on campus.

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Cooperative Weblog Learning in Higher Education: Its Facilitating Effects on Social Interaction, Time Lag, and Cognitive Load

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ABSTRACT

This paper examines the effects of using weblog technologies to support cooperative learning in higher education. The study focused on the effects of features embedded in weblogs on social interactions, time lags, and cognitive loads. A quasi-experimental control-group research design was adopted. The participants were 115 undergraduates who were randomly divided into two groups. Students in the comparison group engaged in Jigsaw learning activities in the classroom, while the experimental group used a weblogging system during parts of the cooperative processes. Two findings were found. (1) Weblogs with Jigsaw cooperative learning activities, promoted better social interactions than those found in the comparison group. (2) RSS feeds and keyword searches made important contributions to cooperative learning, more than had been previously identified in the literature. These two components were found to alleviate cognitive overload and the consequences of time lag. Consequently, this study provides new insights into the role of weblogging in higher education.

Keywords

Cooperative learning, weblog, social interaction, blended learning

Introduction

The Internet is now being broadly applied in e-Learning settings and in recent years new web-based learning systems have been developed. These systems constitute a trend in technology-enhanced education (Khalifa & Lam, 2002; Chen et al., 2005) and many studies have focused on web-based features for computer supported cooperative learning (CSCL) environments (Neo, 2005; Piccinini & Scollo, 2006).

Despite previous studies in the benefits of using web-based technology in educational settings, some questions remain unanswered. (1) Web-based learning scenarios may lead to time lags, the contextual structure of exchanged messages might be impaired by asynchronous communications. This raises questions about the consistency of message quality and the effectiveness of communications in asynchronous scenarios. (2) Web-based learning creates social situations outside the parameters of face-to-face interactions. This suggests that social interactions should be supported by suitable didactical arrangements and instructional measures (Swan et al., 2000). (3) Cognitive overload in web-based learning seems likely. When learners have to use complex technology, process large quantities of information (e.g. multimedia form via various channels), and simultaneously communicate with others (Van Bruggen et al., 2002), their attention is often divided. The question is the extent to which this impairs learning.

Weblogs in educational settings

A weblog (i.e. blog) is a web-based technology that has been around for many years; the number of bloggers making informed contributions to a multitude of specific topics continues to grow rapidly. To compare with other social software applications (e.g. online forums, wikis), blogs have a broader application and allow simple web pages, links and resource collections (Fessakis et al., 2008). The automatic chronological archiving function of blog entries is regarded as a support to find needed information efficiently (Beldarrain, 2006). RSS delivery, sense of ownership, and entries and comments archives are attributes a blog contributes to overcome the limitations of current computer-mediated communication (CMC) systems (Kim, 2008). Kim mentioned that a blog communicates differently to traditional CMC tools (e.g. message board or listserv) because it utilizes a permalink, blog users leave comments simpler and more effectively when compared to the traditional CMC applications. Since blogs are so easy to use,

they are increasingly being viewed as viable educational resources and applications (Chen & Bonk, 2008; Wang et al., 2008; Huang et al., 2009).

However, if blogs are to be effective in educational settings, mechanisms are necessary to overcome information overflow and time lag which were rarely mentioned in the past blog-related studies. One such mechanism is the use of RSS (Really Simple Syndication or Rich Site Summary) feeds; RSS is a family of web feed formats that are used to publish frequently updated content. In an e-learning environment, RSS feeds might be used to update the content of auxiliary materials created from blog-based entries (Huang et al., 2008). Studies have mentioned the potential of RSS feeds to filter and track the ever-growing number of online resources (Karrer, 2007); however, no studies have investigated the effects of RSS feeds on learning materials in real classroom settings. Therefore, this study applies RSS feeds to blog entries and seeks to determine how and to what extent they can help students remain aware of the ever-expanding supplementary materials.

In addition to above two issues in communications, there is also the potential for social interaction problems in blog-based learning settings. Makri & Kynigos (2007) indicated that the forms of social interaction in blog-based learning settings are very different with ones in a classroom. They concluded that the blog-based learning needs to be supported by appropriate pedagogical strategies. Hence, to facilitate social interactions in blog-based learning settings, suitable didactic arrangements should be created. Cooperative learning is frequently used to facilitate interactions in real classroom settings; nevertheless, face-to-face interactions can be undermined by such social factors as atmosphere, shyness, peer pressure, and time constraints. This study seeks to investigate whether these limitations can be mitigated by using a blog-assisted cooperative learning environment. Additionally, it is the fact that the formal curriculums in Taiwan educational settings are very difficult to be completely taught on the Internet due to lots of causes that should be considered (e.g. equipment, class size, lack of online synchronous teaching system etc.). Hence, the goal of the current study is to investigate whether blended learning with Web 2.0 technology can deal with some problems met in the classroom learning. Specifically, the Jigsaw cooperative learning strategy is combined with weblogging in an attempt to create a suitable and interactive learning setting.

The Jigsaw cooperative learning strategy

The Jigsaw model is a cooperative learning technique initially proposed by Aronson & Patnoe (1997). Its benefits include enhanced student attitudes, performance, and attendance, reduced test-taking anxiety, and more active participation in learning (Lai & Wu, 2006). However, little research has been done on applications of Jigsaw cooperative methods outside of classroom settings (Huang, Huang, & Hsieh, 2008), and consequently, little is known about the possible benefits of incorporating the Jigsaw model into a blog-assisted learning context. Since Jigsaw cooperative learning emphasizes the ability to work independently in a group, every piece students made need to be presented by each student independently. With this concern, blog technology provides a suitable environment for demonstrating their works. Meanwhile, every learning track (e.g. entries, comments, and trackbacks) would be kept in blog sites for further evaluations. To investigate this issue, we implemented the Jigsaw model using blog technology and examined teacher and student attitudes toward the blended approach. For the concerns, we sought to determine how comfortable members of the same group felt about comments posted on the blogs by their peers. Traditionally, the Jigsaw cooperative learning is usually solely conducted in primary and secondary education for developing cooperative learning in classroom. However, in higher education environment, we have more expectation of creating a blended learning setting to not only educate learners face to face communication skills but also teach them how to use technology to reduce the learning burden efficiently.

The cognitive load issue in web-based learning settings

One issue that has attracted much attention in web-based learning settings is the danger of cognitive overload due to exposure to a surfeit of online resources over a short time. There is a well-known consequence of high cognitive loads: the redundancy effect (Chandler & Sweller, 1991). The effect occurs when separate parts of the material repeat the same piece of information, thereby making it more difficult to learn. To alleviate this effect, material should be presented in an integrated and unitary manner.

In this study, we argue that the tagging function, collocating the keyword search function, could alleviate cognitive overloads that may be associated with a huge number of educational blog entries. A tag can be regarded as a label “stuck” to the blog article. By using tags, authors can conveniently attach semantic keywords to each blog article, and this, in turn, may shape the way readers search through related articles and help them filter out redundant information.

Three main research questions

We developed a weblogging system with the above-mentioned features and expected to answer the following three questions.

1. To what extent can RSS feeds help mitigate the effects of time lags in delivery (information lag) when the RSS feeds are applied to supplementary materials?
2. To what extent can a cooperatively structured blog using the Jigsaw method foster better social interactions than a classroom environment that uses the same cooperative model? In particular, do the levels of perceived peer and time pressure differ between these two situations?
3. To what extent can the keyword search function, combined with the blog tag feature, alleviate cognitive overloads as perceived by participants?

Methods

Setting

The study was carried out in the fall semester of 2006 in the Department of Engineering Science at one large university in Taiwan. Two classes of sophomores (N=115) enrolled in a course titled ‘Data Structure’ participated in the study. The course was a three-hour weekly course.

Research design

A quasi-experimental comparison-group research design was adopted for the study. Two classes were randomly assigned as either an experimental or a comparison group. The experimental group consisted of 57 students who learned using the blog-assisted Jigsaw method; of these, 79% (N=45) were male and 21% (N=12) were female. The comparison group consisted of 58 students who learned using the Jigsaw method in a classroom; of these, 81% (N=47) were male and 19% (N=11) were female. To evaluate the impact of the blog-assisted Jigsaw method, qualitative and quantitative data analyses were carried out via questionnaires.

Jigsaw learning activities

This section introduces the six Jigsaw learning activities given to both groups. As shown in Fig. 1, step 1 and step 4 are face to face instruction and discussion conducted in the classrooms. Both groups go through these two steps. The only difference being the venue or medium in which Jigsaw group meetings and work feedback were provided (Figure 1, step 5 and step 6). In the experimental group knowledge was shared by blog-based supplementary materials delivery and discussion spaces were offered via the weblogging system. The latter allowed students to review or discuss each other’s work online. In contrast, the comparison group performed these activities in the classroom setting.

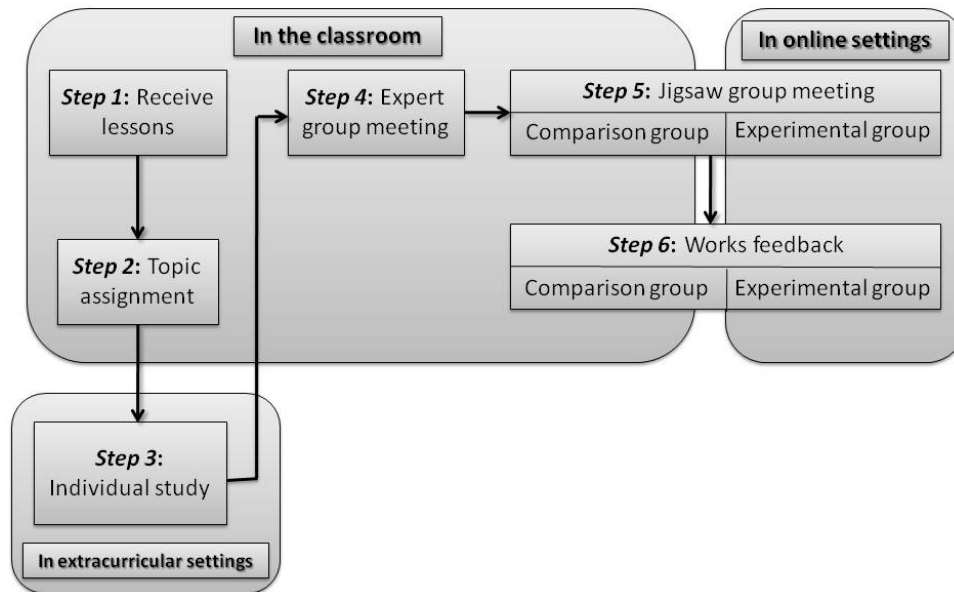


Figure 1. The flowchart of Jigsaw learning activities

Step 1: Receive lessons

The component, although not usually mentioned in Jigsaw activities, was intentionally included to ensure that students have a sound foundation in the basic concepts of a topic by receiving lessons from instructors at the beginning of the course.

Step 2: Topic assignment

The instructor divided each lesson into several topics or exercises. These were randomly assigned to the students in the Jigsaw groups. For example, if the lesson unit is ‘Trees’, the topics might encompass “Representation of Trees”, “Binary Tree Representations”, “Binary Tree Traversal and Tree Searches”, and the exercises might be “Write a function that reads in a tree represented as a list and creates its internal representation using nodes with three fields: tag, data, and link”, or “What is the maximum number of nodes in a k -ary tree of height h ? Prove your answer.”

Step 3: Individual study

After the large-class instructional session was given by the instructor, students studied individually using such resources as the course textbook, notes, reference books, and online resources. During this period, they were advised to take notes to record their own learning or the steps they used to solve problem exercises. Students were asked to familiarize themselves with all the tasks needed to complete the assigned exercises.

Step 4: Expert group meeting

Expert groups were formed in this phase by having one student from each Jigsaw group cooperate with students from other groups assigned to the same topics or exercises. In order to construct ‘expert knowledge’, all expert students shared their notes and knowledge acquired during the previous phase, and then they refined their work on the basis of input received during this cooperation phase. This phase lasted for approximately fifty minutes and was conducted in the classroom for both the comparison and experimental groups.

Step 5: Jigsaw group meeting

When the expert students returned to their Jigsaw groups, the process of knowledge sharing proceeded. The purposes of this phase are to train expert students to present their work and to give students opportunities to extend their knowledge by replying to and clarifying questions from group members. Also, this phase gives group members an opportunity to query or comment on the expert student's work. In this phase, the experimental group utilized a weblogging system to present and comment on work, while the comparison group presented work in the classroom using traditional pen and paper methods. To complete this phase, the comparison groups spent one fifty-minute section in the classroom, while the experimental group was required to carry out this phase on the blogging system for a suggested total time of fifty minutes.

Step 6: Feedback of work

For each Jigsaw group, both the TA and the instructor used blogs to identify some of the strengths and weakness of each piece by providing feedback and suggesting improvements to student work. However, the TA and instructor provided comments on paper to the classroom group; these were delivered in class about one week later.

Asynchronous Jigsaw group meetings on the blogging system

Meetings on the weblogging system are asynchronous discussions, which can free participants from the time and space constraints placed upon a traditional Jigsaw method held in a classroom. Blogging encourages participation from those not used to speaking up and criticizing in public. Group members can in turn review, comment, and raise questions for further clarification whenever they want. The weblogging system developed to facilitate the cooperative activities of the experimental group contained several functions, including the following.

Keyword search and tag functions to assist learning

The degree to which the materials are organized directly influences the amount of information that students can take in, store, and recall (Tan et al., 2003). From this perspective the benefits of a search function are obvious. Students can use the keyword search function to find relevant blog entries. The search results should display information similar to the searched concept, thereby organizing the available materials efficiently and directing attention to the desired topics. Additionally, the search engine is able to grab topic-related blog entries using tags added by expert students when they post their work. The tag feature with the keyword search function is responsible for helping to alleviate cognitive overload caused by looking for related information that shifts through all blog entries.

Cooperative blog-based supplementary materials using the RSS mechanism

At the end of the whole Jigsaw activity the TA reformatted and edited high-quality posts to serve as supplementary materials. The reformatting process including figure redrawing, typesetting, and error correction, enabled students to study effectively with peer-generated supplementary materials. By using the RSS subscription, students can easily and instantly access latest information on their topic of study, rather than being informed of changes by the material designer (the TA in this study). Therefore, we expect the time-lag problem of information acquisition to be solved by the RSS mechanism. Figure 2 shows an example of using blog-based supplementary materials in a web-based setting. In this study, participants used a free RSS reader (e.g. Google reader) to recognize these subscription feeds and manage them easily and efficiently.

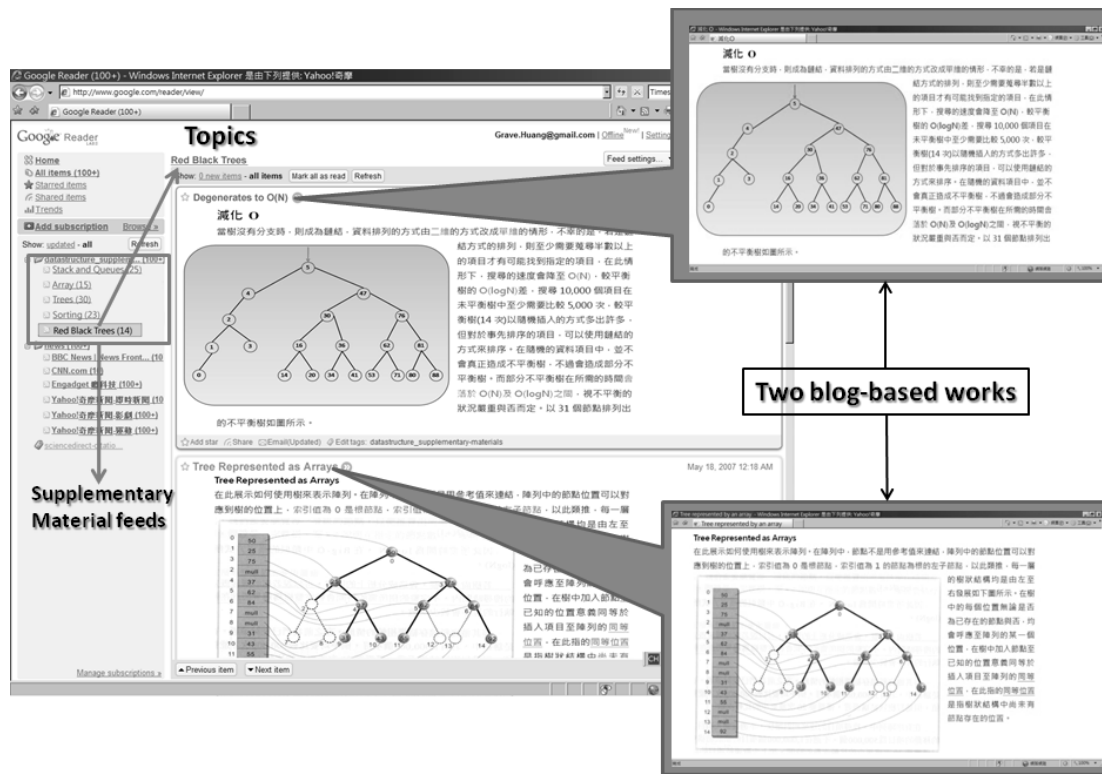


Figure 2. An example of using supplementary materials

Measures

Two questionnaires were used in the study.

- Questionnaire 1 was used to examine any differential perceptions toward social interactions during the Jigsaw learning activities between two groups (Table 1). Students were requested to provide explanation for their answers. The results of items 5 to 8 are expected to answer the second research question.
- Questionnaire 2 was distributed only to the blog-assisted group. It examined perceptions of the RSS mechanism (the first item) that is used to investigate the first research question, blog-based supplementary materials (items 2-4), the keyword search function (items 5 and 6), and the blog tag feature (the last item). It also asked students if and how these functions helped them obtain related materials and alleviate cognitive overloading, which is expected to answer the third research question (items 5-7). The data were collected via half open-ended questions after each of the seven statements (Table 2).

Responses to both questionnaires were scored using a Likert-type scale: strongly agree (5 points), agree (4 points), neutral (3 points), disagree (2 points), strongly disagree (1 point).

Quantitative responses to questionnaire 1 were analyzed using an independent *t*-test, while quantitative responses to questionnaire 2 were analyzed using a one group *t*-test on each statement. The constant comparative method suggested by Lincoln & Guba (1985) was employed as the data analysis method for coding responses to the open-ended questions in the questionnaires.

Table 1. Questionnaire 1: Students' responses to the Jigsaw learning activities and social interaction

Question	Group	SA & A	Neutral	D&SD	Mean	<i>t</i>
1. Cooperative learning helps me learn more.	Blog-assisted	42% (24)	38% (22)	20% (11)	3.18	2.622**
	Classroom	31% (18)	40% (23)	29% (17)	3.02	
2. The expert group meeting helps me to fill knowledge gaps left by	Blog-assisted	73% (42)	24% (14)	3% (1)	3.70	0.704
	Classroom	66% (38)	34% (20)	0% (0)	3.67	

independent study.						
3. The Jigsaw group meeting made me show my work to group members effectively.	Blog-assisted	61% (35)	35% (20)	4% (2)	3.58	2.832**
	Classroom	57% (33)	24% (14)	19% (11)	3.41	
4. I did not feel peer pressure and was comfortable while sharing my work with my group-mates.	Blog-assisted	47%(27)	41%(23)	12%(7)	3.39	5.062**
	Classroom	22%(13)	19%(11)	59%(34)	2.36	
5. I was not under time pressure and felt at ease while sharing my work with my group-mate.	Blog-assisted	79%(45)	16%(9)	5%(3)	3.91	4.945**
	Classroom	35%(20)	50%(29)	15%(9)	3.16	
6. I did not feel peer pressure while I commented or criticised others' work.	Blog-assisted	14%(8)	60%(34)	26%(15)	2.84	2.578*
	Classroom	19%(11)	11%(6)	70%(41)	2.41	
7. I was not under time pressure while I commented or criticised others' work.	Blog-assisted	81%(46)	19%(11)	0%(0)	4.37	0.658
	Classroom	75%(44)	18%(10)	7%(4)	4.26	

* $p < 0.05$, ** $p < 0.01$

Table 2. Questionnaire 2: The blog-assisted group's perceptions of the blog-based supplementary materials and functionalities of the proposed system

Question	SA & A (%)	Neutral (%)	D&SD (%)	Mean	t(vs. Neutral)
1. With the help of the RSS mechanism, supplementary materials were obtained quickly and used easily.	92(52)	8(5)	0	4.47	16.921**
2. The supplementary materials truly helped me study the course.	83(47)	10(6)	7(4)	4.05	8.881**
3. The supplementary materials can help me organise the new knowledge.	85(48)	12(7)	3(2)	4.16	11.289**
4. I like to exploit supplementary materials in my studies.	75(42)	12(7)	13(8)	3.88	5.835**
5. The keyword search function provided in the blog system helped me quickly locate needed information.	85(48)	10(6)	5(3)	4.00	9.416**
6. The keyword search function provided in the blog system helped me effectively locate needed information.	78(44)	12(7)	10(6)	3.84	6.625**
7. With tag feature, the keyword search helped me sift through information without feeling overwhelmed by the large quantity of blog entries.	23(13)	60(34)	17(10)	3.04	0.322

* $p < 0.05$, ** $p < 0.01$

Results

Attitudes towards social interaction during Jigsaw learning activities

Responses from the experimental group to questions concerning their impressions of the Jigsaw learning activities were all more positive than those from the comparison group (Table 1). *T*-tests on each item found only two items to not be significant. Item 1 assessed overall attitudes toward the cooperative learning activities. It was found to be statistically significant at .01 level (Question 1, $t(1,113) = 2.622$, $p < 0.01$). In the half open-ended response area, students in the classroom said that they "felt anxious, nervous, and under a great deal of pressure" to express their opinions to group members in face-to-face situations. In contrast, the majority of experimental group students thought that asynchronous cooperative learning gave them more time to think and organise the information they had received, and it gave them a greater sense of ownership over their newly expanded knowledge base.

The results of *t*-tests on item 3 found that the effectiveness of the Jigsaw group meeting for presenting work was statistically significant (Question 3, $t(1,113) = 2.832, p < 0.01$). Only some students in the blog-assisted group expressed negative views about presenting their work during the Jigsaw group meeting, while nearly 20% of students in the classroom group disagreed with this point (4% vs. 19%).

Perceptions of social interaction in the weblogging cooperative learning environment

Analyses on items 4 to 7 were performed to investigate differences between the groups regarding social interaction, including peer and time pressure, when presenting and commenting on work. The results showed a significant difference in the reactions of the two groups (Question 4, $t(1,113) = 5.602, p < 0.01$). Of the students in the experimental group, 47% agreed and strongly agreed that they did not feel pressure from their peers when sharing their work. However, 59% of comparison group students felt pressure from their peers. Analysis of the data from the open-ended question points to two themes regarding this effect: First, the online learning environment creates a virtual space, which enables students to concentrate on posting their work. Students in the online learning environment were less likely to be “*disturbed or distracted*” by instant responses from peers. Second, the online learning environment reduced the number of situations where students needed to respond on the spot; this also alleviated anxiety.

Results from the *t*-test indicated a significant difference between the experimental group and the comparison group with regards to time pressure when presenting their work (Question 5, $t(1,113) = 4.945, p < 0.01$). Up to 45 students (79%) in the experimental group did not feel time pressure when presenting work. The main reason identified by descriptive responses was that the online learning environment allowed students to set their own pace. Twenty-two students mentioned that they “*didn't have to implement it at any particular time*”, so they can “*work in separate order*” to set their own pace and schedule. Moreover, one student indicated that she could “*take her time examining and revising the work*”. In contrast, four comparison group students mentioned in their written responses that “*due to the limitation of class time*”, they may “*take up time allocated for other group members*”, which resulted in time pressure when presenting their work. With regard to item 6 (commenting on my groupmates' work does not generate peer pressure), the difference between the groups was found to be significant ($t(1,113) = 2.578, p < 0.05$). Experimental group students indicated significantly less peer pressure than the comparison group when evaluating their groupmates' work. The main reason was that the online learning environment did not require students to face the group members; therefore, when evaluating group members' work, the influence exerted by the presence or judgement of others was lowered. For example, “*comment is a very sensitive issue. Not seeing the person I am commenting on makes me less likely to be influenced by others' presence or judgment*”; “*because I do not need to worry about others' presence or judgement, I can express my thoughts without reservation*”. In the comparison group, 70% of students did not agree with this statement. Two main reasons were deduced from student explanations. One was that, when evaluating others' work in the classroom, some were afraid of “*awkward*” feelings resulting from “*on the spot commenting behaviour*”. For example, some students indicated that

- *When commenting in front of everyone, I will worry about other people's feeling and only dare to express positive points.*

Meanwhile, there were students who worried about showing lack of ability when commenting. Concerns may include showing lack of professional knowledge or lack of questioning and commenting abilities. Some responses include these:

- *When confronting public speaking or situation where you need to speak spontaneously, I do not know what to say.*

Finally, no statistical significance was found regarding item 7 (time pressure while presenting work, $t(1,113) = 0.658, p = 0.638$). Most students in both groups did not feel time pressure while commenting about work ($M_{exp} = 4.37; M_{comparison} = 4.26$). Twenty-eight students in the two groups remarked that “*the content of each comment is not long*”, so they “*didn't feel time pressure while commenting*”. On the other hand, the fact that students in the experimental group did not perceive any time pressure is consistent with their responses to item 5. Eighteen students mentioned that they were able to “*view member's work in greater details before commenting*” and “*didn't have to comment immediately but separately at different times*”, so they “*sensed no time pressure while commenting*”.

Although the quantitative data did not reveal a difference between the two groups, some variation can be seen in the written responses. No students in the experimental group indicated that they perceived time pressure while commenting, but all students who chose to strongly disagree in the comparison group indicated that "*immediate commenting*" results in a great deal of time pressure. In other words, an asynchronous learning environment enables individuals to prepare for commenting. For experimental students, they experienced not only online group meeting process in level 5 but also the classroom meeting process in level 4. Although we didn't require students to express their perceptions for both learning situations, the unofficial interview shows that students did agree the online instruction and discussion process brought less time and peer pressure to them.

Responses to the blog-based supplementary materials with RSS delivery

The purpose of the second questionnaire was to examine the blog-assisted group's perceptions of the blog-based supplementary materials, keyword search, and tag function of the developed system. A *t*-test was conducted to compare the difference between responses (agree or disagree or neutral) to each of the nine variables in Table 2.

Four items were used to assess attitudes toward the RSS feed and supplementary materials. More than 90% of the students gave a positive response to use of the RSS feed as an aid in obtaining supplementary materials in a fast manner (Question 1, $t(1,56) = 16.921, p < 0.01$). Most students (83%) agreed that the supplementary materials helped them study Data Structure (Question 2, $t(1,56) = 8.881, p < 0.01$) and 85% of them thought that supplementary materials helped them organize new knowledge (Question 3, $t(1,56) = 11.289, p < 0.01$). A small proportion (13%) of the group did not like using the supplementary materials in their learning (Question 4).

Perceptions of the keyword search and tag functions

Most students responded that the keyword search function helped them quickly and efficiently get the information that they required (Question 5, 85%, $t(56) = 9.416, p < 0.01$) (Question 6, 78%, $t(56) = 6.625, p < 0.01$). Students indicated that the keyword search function helped them find relevant information in a large database in an effective and efficient way. One student responded, "*Without reading every single article, necessary information can be found within short period of time.*" Some students said they used the keyword search function to "*find learning resources for their studies,*" and that by helping them to find the work of their peers in their own and other groups, it helped them in "*extending, reviewing and organizing learning content*".

It is noteworthy that, although most students acknowledged the keyword's usefulness, some individuals disagreed with it. As clearly stated in the responses, an individual's ability to search using keywords can affect the search results. One student indicated, "*I am not good at using keywords. I often need to try many times, and sometimes there are no matching results.*"

Regarding the tag function, only 23% of students agreed that it helped to sort large amounts of information (Question 7, $t(1,56) = 0.322, p > 0.05$). Reasons that students shared included

- *I have a habit of using tags, and maybe because I am familiar with picking keywords this decreases the time I spend on searching.*

It is surprising that up to 60% students chose neutral. From responses like "*not understanding the tag feature*" and "*not being in the habit of using the tag feature*", we can extrapolate that these are the main reasons.

Discussion

The aim of this study was to examine the effects of incorporating a weblogging system into a higher education course so as to allow students to cooperate with their peers in an asynchronous cooperative learning environment. We first examined the RSS mechanism as applied to supplemental materials to alleviate the time lag issue. The results (the first item of questionnaire 2) suggest that an RSS feed not only helps supplementary materials be quickly delivered to students, but it also helps make those materials easy to access. Hence, we conclude that the RSS mechanism can reduce the time lag when delivering supplementary materials. This ensures consistency in the

delivered information and should lead to learning efficiency in an asynchronous learning environment. Put differently, without the RSS subscription, students may access less of the available supplementary materials and access supplementary materials less efficiently, which could cause learning gaps. Therefore, according to this research, the RSS subscription mechanism can help ensure the integrity of supplementary materials.

The results of items 2-4 in questionnaire 2 indicated that students were willing to exploit the supplementary materials when studying and that the content of those materials indeed assisted their learning. The topics and exercises assigned to students were required readings. Supplementary materials elaborated on these readings and exercises and presented them in a structured way.

Although the RSS mechanism was used to syndicate supplementary materials, the benefits of the RSS mechanism are not limited to speed of delivery. Subscription to RSS feeds enables students to choose the materials they want to see. RSS technology is a pull technology rather than push technology; that is, content is not forced on students. Students can quickly scan titles and read materials of interest via the RSS mechanism. Hence, active selection may trigger intrinsic interest, which could allow them to learn more (Tobias, 1994). This kind of application clearly needs further exploration.

As for the second research question, items 5-8 in questionnaire 1 were designed to investigate whether the effects of social factors, like peer pressure and time constraints, could be alleviated by using a blog-assisted cooperative learning environment. The results indicated that students used blogs to express their opinions and suggestions more freely when commenting on others' work; in comparison, students in the classroom group tended to take into consideration group atmosphere, time limitations, and the perspectives of others. As revealed, not needing to be physically present to face their group-mates direct reactions, it helped experimental group students alleviate uneasy feelings, emotional burdens or tensions that may occur as a result of the evaluative comments they made about their classmates' performance on the work during works feedback session. This data substantiated the findings of media effects that mediated communication differed significantly from face-to-face interaction (Jessup & Tansik, 1991; Williams, 1977). Specifically, nonverbal cues, such as gestures and facial expressions, which may have many indicative functions to point to the dynamic psychological state of the individual, are easily emitted in face-to-face situations to the effect of regulating individual psychological states and behaviors (Williams, 1977).

These results may be explained by considering the influence of collectivism, which is prevalent in Oriental societies. Collectivism stresses human interdependence and the importance of a collective. Students in Oriental countries are usually influenced by collectivism, so they may feel a great deal of peer pressure when they are asked to criticize their peers' work or when they are to be criticized openly (Brown et al., 2007; Shea & Yeh, 2008). Peer pressure, as shown in the study, seemed to be partially eliminated. According to the above statements, we can conclude that, when participating in the same cooperative learning model, students with the support of an asynchronous learning environment perceived better social interactions than those in the classroom group.

The third research question was designed to investigate whether the keyword search and tag functions in the blogging system helped alleviate cognitive overload. Items 5-7 in questionnaire 2 were devised to answer this question. The results indicated that the keyword search function was regarded as a filtering technique, used to filter out repetitive information, which consequently minimized the redundancy effect. Since the materials found by a search were limited to those relevant to the search terms, students were able to filter out any redundant parts of the search result so that they could avoid studying similar content. These findings are consistent with findings reported in previous studies (Cao et al., 2004, Sutherland & Schneider, 2008). Our results, however, should be treated cautiously because the results seem not to support the effects of the tag feature. According to student responses, most students lack the ability to use tags and are unfamiliar with many of the potential associated with tag (e.g. multiple tags can be defined, users can define their own tags by themselves), hence, this obviously becomes a null curriculum (what is missing from the curriculum) (Eisner, 1985) in this study. The potential utility of tags in weblog learning settings clearly needs further exploration.

Limitations of the study

We need to admit that much remains to be done, then, but we anticipate that the work will generate important findings in the fields of blended learning environments. We have not shown the academic performance of the subject

matter between both groups because we argued that a grade on an examination paper cannot answer any one of three research questions. In this sense, the difference of actual performance between two groups is not our main concern.

In addition, the time student took on online posting is very difficult to control. Firstly, the time they spent on learning depends on their learning motivation. Secondly, for an educator, we hope that learners can make as much effort in school work as possible. Therefore, both groups were requested for the least time limitation (fifty minutes) they should spend to access to the weblog or report in public. The experiment design may not be ideal due to the partial time control. The different session arrangement may lead to different results in terms of the time pressure. Since the official class time frame was regulated as three successive sessions per week, this experiment design and time frame was limited to the higher education regulations about the class arrangement. Therefore, the results, particularly on the time pressure issue, may be limited to generalize to other type of class session arrangement.

Conclusions

This paper described a study undertaken in a Taiwan university that explored student perceptions of a weblogging learning system developed to support Jigsaw cooperative learning. Blog posts were further processed as supplementary materials to assist students in learning the course 'Data Structure'.

Results indicated that students in the Jigsaw cooperative learning group that used the weblogging system exploited the benefits offered by the blog. The use of blogs encouraged students to strengthen their own skills with regards to easily sharing course key points and to fully express their thoughts in such an environment with less peer and time pressures. In addition, the other components built into the weblogging system, such as the keyword search function, decreased cognitive overload. Therefore, the main conclusions of this study are two: (1) Weblogs can be combined with Jigsaw cooperative learning activities to form a better social interaction model than the classroom cooperative learning model. This may be particularly true for students in Oriental countries. (2) The components built into the weblogging system, specifically the RSS mechanism and keyword search function, have a much wider role to play in cooperative learning than has been previously articulated in the literature. In particular, this study has indicated that these functions can alleviate cognitive overload and the time lag of information delivery.

This study shows that cooperative learning among students need not be restricted to the classroom, as might be implied by traditional applications of the method. In fact, limitations imposed by the physical space can be overcome through the use of an online social system, such as a weblogging system. Additionally, since the Jigsaw learning method was conducted in a typical manner, the implementation of this process should be practical in other course domains and for students at other levels.

To achieve effective learning in this kind of online cooperative setting, some basic skills need to be taught and developed. First, students need the ability to construct a precise keyword search query. Further, the system should provide some mechanisms to help learners to refine search results. Second, although the tag feature was expected to enhance student abilities to extract keywords informally and personally, and then improve the precision of their keyword search, the results of this study did not support this expectation. This is most likely due to inability to use this function. Therefore, students should be taught in how to apply the tagging function to organize materials and revisit self-made work. In view of the above-mentioned null curriculums, we suggest that educators ought to take them into consideration when developing online learning systems and teaching strategies.

In addition, the results suggest that use of the RSS mechanism in blog-assisted learning may be a productive topic for future research. We are hopeful that more applications and more detailed results may differentiate these views from one another in the near future. Finally, research and development in this area will be continued with the goal of refining the practicality and appropriateness of the weblogging learning environment so that it meets all expectations for supporting and enhancing student learning using a cooperative learning model.

Acknowledgement

The authors would like to thank the National Science Council of the Republic of China for financially supporting this research under Contract No. NSC 99-2511-S-157 -001 -MY2.

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Aberrant Learning Achievement Detection Based on Person-fit Statistics in Personalized e-Learning Systems

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ABSTRACT

A personalized e-learning service provides learning content to fit learners' individual differences. Learning achievements are influenced by cognitive as well as non-cognitive factors such as mood, motivation, interest, and personal styles. This paper proposes the Learning Caution Indexes (LCI) to detect aberrant learning patterns. The philosophy behind the LCI is that if any non-cognitive factor influences a learner, the effect will eventually be reflected in his/her learning achievement. Therefore, it's our explicit attempt to build a prototype system aimed at assessing aspects of learning other than cognitive factors. This study proposes a personalized e-learning system based on Item Response Theory which considers both course difficulty and learner's ability to provide adaptive learning paths. The LCI, which originates from the person-fit statistics in psychometric theory, statistically judges whether the observed learning achievement is significantly different from the achievement predicted by the Item Response Theory (IRT) models. If such an aberrant learning pattern is detected, a computer tutoring agent appears to notify and encourage that learner. Furthermore, human tutors may get involved periodically to offer further guidance to support learners with aberrant patterns. Experimental results show that such diagnostics could enhance the learning efficiency and smooth the learning experience.

Keywords

Intelligent tutoring systems, Personalized learning, Person-fit statistics, Item Response Theory, Learning caution indexes

Introduction

Individual differences are recognized in almost every area of performance (Waite, Wheeler, & Bromfield, 2007; Sohn, Doane, & Garrison, 2006). Educational psychologists have always emphasized the cognitive as well as the individual affective and conative differences. Human diversity is ubiquitous in education, as stated by previous researchers. Teachers and educational designers need to understand the variations in students' attitude, motivation, and style as well as ability. Some previous studies provide personalized learning service by considering only the cognitive aspects of students. Recent studies have pointed out the important role of motivation and affectivity in cognitive activities, such as learning (Damasio, 1994; Izard, 1984).

In this study, Learning Caution Indexes (LCI) and the Item Response Theory (IRT) model together are regarded as a complete framework for personalized e-learning system. IRT models are used to estimate learner's ability level from the learning response data, and the LCI is used to detect aberrant learning patterns by examining the fit of learning response vector to the IRT models. Note that we use dichotomous learning response in this study. A learner's positive learning response to a course unit means that the learner can completely understand that course unit; a learner's negative learning response means that the learner cannot completely understand that course unit. Instead of identifying all possible sources that influence learning achievements, the proposed LCI, originates from person-fit statistics, works in a different way. The philosophy behind LCI is that if any non-cognitive factors influence a learner, that effect will eventually be reflected in his/her learning achievement. We focus on the analysis of learning response. The duration, type, and frequency of various non-cognitive factors that affect learning are not the main concerns in this study.

In this paper IRT is chosen as the modeling technique because it is theoretically sound and has been widely used in many famous exams such as Graduate Record Examination (GRE) and Test Of English as a Foreign Language (TOEFL). This study applies IRT in the personalized e-learning domain, which has the following main advantages:

- **Tracking learner's ability level:** Learner's ability level is tracked and re-estimated after each completion of course unit.
- **Recommending course units according to learner's ability level:** The information function inherently provided by IRT is used to recommend course units with appropriate difficulty that match learner's ability level.

- **Detecting aberrant learning achievements:** The Learning Caution Indexes, based on person-fit statistics, can effectively detect aberrant learning patterns in a statistically way. Detecting aberrant learning patterns is helpful to 1) encourage learners to concentrate on the learning activity, and 2) remind human tutors to pay attention to learners that may have learning difficulties.

In summary, some researchers focus on cognitive aspects when doing research in personalized e-learning domain. However, learning achievements actually result from an interaction between cognitive, affective, and conative aspects. Therefore, we attempt to build a prototype system aimed at assessing aspects of learning other than cognitive. Our research question in this study is “How to build a model to detect aberrant learning patterns?”. By using the Learning Caution Indexes, aberrant learning patterns, e.g. a learner who had performed well in difficult course units but failed in some easy course units, can be detected effectively. Note that the difficulty parameters of all course units must be determined first, as described in the third section titled “Learning Diagnosis Model”. If an aberrant learning pattern is detected, the computer tutoring agent raises a warning to notify that learner and encourage him/her to concentrate. Furthermore, human tutors are involved to offer further learning guidance to support learners with aberrant learning patterns.

The remainder of this paper is organized as follows. The second section reviews the theoretical foundations related to personalized e-learning system and person-fit statistics. The third section describes the proposed learning diagnosis model. The fourth section describes the learning environment. The fifth section provides some experimental results and the sixth section draws our conclusions.

Theoretical Foundations

A Literature Review on Personalized e-Learning and Intelligent Tutoring Systems

The research background and related works are reviewed in this section. Personalized e-learning systems and intelligent tutoring systems considering cognitive, affective or conative aspects are reviewed.

Personalized e-learning systems tailor learning content for learners to fit individual differences (Graesser, Chipman, Haynes, & Olney, 2005; Hatzilygeroudis, & Prentzas, 2004; Kavcic, 2004; Litman, & Forbes-Riley, 2006). Adapting content to individual students significantly increases the speed of learning (Davidovic, Warren, & Trichina, 2003). Modeling the student’s knowledge structure is the key to support adaptive learning. Various mechanisms have been developed and evaluated by educational researchers. For example, Atolagbe, Hlupic, and Taylor (2001) discussed the role of pedagogical strategies to facilitate the acquisition of simulation modeling knowledge. Hwang (2003) proposed an adaptive learning system which provides learning suggestions by analyzing the subject materials and test results based on a concept map. Wang (2004) proposed an adaptive item selection to make students progress up the cognitive ladder based on non-symbolic neural network technology. His proposed model memorized learning paths of well-performing students, and accordingly provided personalized learning sequences for students with a similar trait level.

Chen, Lee, and Chen (2005) proposed a personalized e-learning system based on the Item Response Theory. The adaptive testing theory in computer adaptive testing (CAT) inspired them to transfer IRT into the personalized e-learning domain. This approach applies the one-parameter logistic model proposed by Georg Rasch in 1966 (Hambleton, 1985; Horward, 1990; Rasch 1966) to model the difficulty levels of course units. Furthermore, learner’s ability level could be dynamically estimated based on the maximum likelihood estimation (MLE). Their system could recommend appropriate course units to fit each learner’s ability level, but could not deal with aberrant learning patterns. The BUGGY system, which is partially similar to our proposed system, detects aberrant learning patterns in a different way (Brown & Burton, 1978). The BUGGY system uses its student model to simulate a student with “buggy” thinking. The knowledge representation model for their study is the procedural network, which breaks down a larger task into a number of related subtasks. The developers of BUGGY system attempted to enumerate the different possible procedural bugs that students might acquire while trying to solve math problems. Using a catalog of possible bugs, the BUGGY system could generate general diagnostic tests to identify learner’s mistakes. Compared with BUGGY system, our proposed system could detect aberrant learning behaviors through the IRT model without knowing anything about the learning content. Consequently, our system has fewer limitations and therefore could be applied in various domains including mathematics. Anderson and colleagues built intelligent

computer-based tutors around the Adaptive Control of Thought (ACT) theory (Anderson, Conrad, & Corbett, 1989). The basic idea was to build into the computer a model of how ACT would solve a cognitive task such as generating mathematical proofs. The tutor used the ACT theory to get the student to emulate the model. The Math tutor derived from the ACT theory and its successive versions has had a significant impact on mathematics achievements in many schools. Anderson and colleagues' work is often cited as the most successful intelligent tutoring effort. The concept of building a cognitive model is similar to our work. However, if IRT model is used, person-fit statistics could be further integrated to detect aberrant learning behaviors.

Some educational researchers have devoted their attention to revealing how affectivity and conation influence learning. Psychologists and educators point out how the emotions affect learning (Goleman, 1995; Vygotsky, 1994). Motivated by connections between learning and student's emotional state (Izard, 1984; Masters, Barden, & Ford, 1979; Nasby, & Yando, 1982), affective reasoning has been incorporated into computer tutoring systems to narrow the performance gap with human tutors (Conati, Chabbal, & Maclaren, 2003; Kort, Reilly, & Picard, 2001; Bhatt, Evens, & Argamon, 2004). Techniques from artificial intelligence have been studied to increase the customizability of student's affective states in educational systems. The affective states have been modeled to recognize users' emotions by voice, facial expressions, or even physiological signs (Kopecek, 2000; Ekman, 1999; Picard, 1997; Picard, Vyzas, & Healey, 2002).

Observable behaviors also provide implicit clues to approach student's emotional state. Jaques and Viccari (2005) suggested that emotions can be inferred by student's observable behavior, i.e., student's actions in the interface of the learning environment, such as success or failure in tasks, request or refusal of help. Jaques and Viccari adopted the belief-desire-intention (BDI) model to implement the process of affective diagnosis. They used the psychological OCC model (Ortony, Clore, & Collins, 1988) that infers learners' emotions from their actions in the system interface.

Motivation deals with the student's desire to participate in the learning process (Ames, 1990). Motivation has been viewed as the primary determinant of student's learning and success in school (Pintrich and Schunk, 2002). In earlier studies, motivation was seen as a personal trait, a part that depended on the genetic nature and the childhood experiences of the student (Meece & McColskey, 2001). However, more and more researchers believe that motivation is sensitive to context and can be fostered in the classroom. Based on this belief, a lot of studies have been carried out on fostering student's motivation to learn in an educational system (Bercht & Viccari, 2000; de Vicente & Pain, 2002; del Soldato & du Boulay, 1995).

Person-fit statistics

The statistical technique is borrowed from the person-fit statistics in modern test theories to diagnose learner's behavior. Person-fit statistics are developed by educational researchers to identify examinees with an aberrant test response pattern. Similarly, aberrant learning patterns of learners with learning difficulties could be identified by person-fit statistics.

Patterns with a significant number of wrong answers to "easy" questions but right answers to "hard" questions are regarded as "aberrant". Actually, person-fit statistics are statistical methods for identifying students with aberrant patterns. Researchers have been interested in analyzing response patterns to model learners instead of using only the total score of a test (Tatsuoka, 1984). Harnisch, & Linn (1981) observed that the same number of right answers on a test could mean very different things without reference to individual characteristics. For instance, on a 20-item test, a score with 10 right answers can be obtained in 184,756 different ways.

The detection of aberrant examinees using person-fit statistics inspired us to transfer person-fit statistics into the personalized e-learning domain for learning diagnosis. Learners are diagnosed according to their observable behaviors in this study, as suggested by Jaques and Viccari (2005). There are several robust person-fit statistics, such as the Person-fit U3 statistic (Van der Flier, 1977, 1982) and the Caution Index (Sato, 1975, 1982). Wright and his students proposed two person-fit statistics (Wright, 1977; Wright & Stone, 1979) INFIT and OUTFIT, whose distributional properties have been exhaustively investigated and reported by Smith (1986). Most person-fit statistics can be employed to diagnose the learning response data after necessary modifications. However, INFIT has been shown to be near optimal in identifying spurious scores at the ability distribution tails (Rudner, 1977). Thus INFIT

and OUTFIT are chosen as a sample implementation to demonstrate that person-fit statistics could be applied to recognize aberrant learning patterns.

Learning Diagnosis Model

Determine the difficulty parameters of course units

In the learning diagnosis model, the one-parameter item characteristic function is used. The difficulty parameters of course units must be determined first. Although the difficulty parameters can be assigned manually by course experts, we employ the following procedure to estimate them systematically. Course experts identified learning concepts and then design a corresponding test item for each learning concept. These test items are then taken by a number of examinees, and the testing results are analyzed by BILOG-MG (Mislevy & Bock, 1990) to obtain the appropriate difficulty parameter of every test item. BILOG-MG is a software program for IRT analysis of dichotomous (correct/incorrect) data, including fit and differential item functioning. Course units are then designed to cover all learning concepts. Since the test items and the course units are both derived from the learning concepts, each course unit has the same difficulty parameter value as its corresponding test item. This approach can obtain more dependable difficulty parameters than manual calibration, because parameters are estimated based on real experimental data (Chen, Lee, & Chen, 2005; Chen, Liu, & Chang, 2006).

Estimate learner's ability level

Maximum likelihood estimation (MLE) (Horward, 1990) is a popular statistical method to fit a model to data and to provide estimation of parameters in that model. In this study, MLE is applied to estimate learner's ability level. We first assume that a randomly chosen learner responds to a set of n course units with response pattern $(U_1, U_2, \dots, U_{n-1}, U_n)$, where U_j ($j=1, 2, \dots, n$) is either 1 or 0 for the j th course unit. $U_j = 1$ means that learners can completely understand the recommended course unit, and $U_j = 0$ means that learners cannot completely understand the course unit. Based on the assumption of local independence (Baker & Frank, 1992; Wang, 1995), the formula which estimates learner's ability level based on the difficulty parameters of course units is:

$$L(U_1, U_2, \dots, U_n | \theta) = \prod_{j=1}^n P_j(\theta)^{U_j} Q_j(\theta)^{1-U_j} \quad (1)$$

where $P_j(\theta) = \frac{e^{(\theta-b_j)}}{1+e^{(\theta-b_j)}}$ and $Q_j(\theta) = 1 - P_j(\theta)$. Note that $P_j(\theta)$ denotes the probability that a learner with ability level θ

can completely understand the j th course unit, b_j is the difficulty parameter of the j th course unit. Since $P_j(\theta)$ and $Q_j(\theta)$ are the functions of learner's ability level θ and the difficulty parameters of course units, the likelihood function $L(U_1, U_2, \dots, U_n | \theta)$ is also a function of these parameters. Learner's ability level θ can be estimated by computing the maximum value of the likelihood function (Hambleton, Swaminathan, & Rogers, 1991). The method of the maximum likelihood estimation requires two input parameters to evaluate learner's ability level: the difficulty parameters of the course units and the yes/no responses from learners to course units.

Ability levels are limited between -3 and 3 . Learners' ability levels are estimated based on their feedback. If a learner can completely understand the content of the recommended course units, his/her ability level will be increased; otherwise, his/her ability level will be decreased. The estimated ability levels are further used by the information function in the course recommendation procedure to rank course units.

Recommend a course unit

In this study, course recommendation considers both course difficulty and learner's ability, which affect both learners' interest and learning results. Two common approaches, the maximum information strategy and the Bayesian strategy (Baker, & Frank, 1992; Hambleton, 1985; Hulin, Drasgow, & Parsons, 1983), are available to choose appropriate items for examinees in modern test theories. Since the Bayesian strategy is more complicated than the maximum information strategy, the latter is employed to recommend appropriate course units. The

maximum information strategy chooses a course unit with the difficulty parameter that exhibits the maximum information value for a learner with ability level θ . The information function is defined as:

$$I_j(\theta) = \frac{(D)^2}{[e^{D(\theta-b_j)}][1+e^{-D(\theta-b_j)}]^2} \quad (2)$$

where $I_j(\theta)$ is the information value of the j th course unit for a learner with ability level θ , and b_j is the difficulty parameter of the j th course unit. D is a scaling constant often set to $D = 1.702$ when the logistic function in formula (2) needs to approximate a cumulative normal probability function. When “normal ogive” scaling is used (i.e., $D = 1.702$), and assuming that θ is normally distributed, we can treat θ as a z-score. Normal ogive scaling therefore facilitates basic interpretations of θ for practitioners familiar with z-scores and the normal curve.

After calculating the information value of every course unit, the course-recommendation module gives the recommendation list of course units, which are sorted by the ranking order of the information function value. Learners then choose a course unit to study from the recommendation list. Our system records each learner’s learning history and feedback responses into the user profile database. The learning history recorded in the user profile database is then use to detection aberrant learning patterns as described in the next subsection.

Detect aberrant learning achievements

The proposed Learning Caution Indexes: Learning_INFIT and Learning_OUTFIT are delivered from the INFIT and OUTFIT statistics respectively. IRT-based person-fit statistics are designed to evaluate the misfit of an observed response vector to IRT model by calculating the probabilities associated with student’s ability parameter and item parameters. According to the IRT model, if the probability of a correct response from a student is high, the hypothesis is posited that the student should answer that item correctly, and vice versa. INFIT is an information-weighted sum and OUTFIT is based on the conventional mean of squared standardized residuals (Bond & Fox, 2007). Learning_INFIT is defined as:

$$Learning_INFIT = \frac{\sum_{j=1}^n [U_j - P_j(\theta)]^2}{\sum_{j=1}^n P_j(\theta)Q_j(\theta)}, \quad (3)$$

and Learning_OUTFIT is defined as:

$$Learning_OUTFIT = \frac{\sum_{j=1}^n [U_j - P_j(\theta)]^2}{n}, \quad (4)$$

where $[U_j - P_j(\theta)]$ is the residual (U_j is regarded as an observed response and $P_j(\theta)$ is regarded as the expected response value), $P_j(\theta)Q_j(\theta)$ is the statistical information (model variance) according to Fisher information theory (Pratt, 1976), and $\frac{[U_j - P_j(\theta)]^2}{P_j(\theta)Q_j(\theta)}$ is the squared standardized residual.

The behavior of Learning_INFIT and Learning_OUTFIT is demonstrated by some response patterns in Table 1. Four typical response patterns, which are modeled, carelessness, lucky-guessing, and special-knowledge, are listed (Linacre & Wright, 1994). The learning pattern represents learner’s learning outcome of sixteen course units which are sorted by their difficulty. ‘1’ response means that the learner can completely understand the course unit and ‘0’ response means that the learner cannot completely understand the course unit. The modeled pattern may be regarded as a normal pattern. However, the carelessness pattern may be interpreted as a possible aberrant learning pattern that a learner succeeded in difficult course units but failed an easy course unit. Similarly, the lucky-guessing pattern may be interpreted as another possible aberrant learning pattern that a learner surprisingly succeeded in a difficult course unit that is far beyond his/her ability level. The special-knowledge pattern may be interpreted as a possible aberrant learning pattern that a learner succeeded in some difficult course units but failed some easy course units that s/he could master. This pattern may have a slightly different interpretation in personalized e-learning domain. In a test, examinees answer test items according to their own knowledge. Wrong responses may be made to test items with unknown concepts, even though these concepts are very easy. On the contrary, learners have the chance to learn

these easy concepts from the course units, but they still failed. In our experiences, this pattern might suggest that either learners have individual interests in some specific concepts, or there are some flaws in the course unit so that learners can not understand these learning concepts. Learning_OUTFIT is sensitive to carelessness and lucky-guessing pattern, and Learning_INFIT is sensitive to special-knowledge pattern.

Table 1. The behaviors of Learning_INFIT and Learning_OUTFIT

Learning Pattern (Sorted by difficulty) Easy Median Hard	Diagnosis	Learning_INFIT	Learning_OUTFIT
111 0110110100 000	Modeled	1.1	1.0
011 1111110000 000	Carelessness	1.0	3.8*
111 1111000000 001	Lucky-guessing	1.0	3.8*
111 1000011110 000	Special-knowledge	1.3*	0.9

(* marks high Learning_INFIT/Learning_OUTFIT values which indicate aberrant learning responses)

Each time when a learner finishes a recommended course and posts a learning response, his/her learning response pattern is diagnosed by the Learning Caution Indexes (Learning_INFIT and Learning_OUTFIT). The thresholds are both 1.20 which rejects response strings manifesting more than 20% unmodeled noise. A high value (greater than the threshold) of Learning_INFIT or Learning_OUTFIT is interpreted as that the learner is possibly learning in a perfunctory or careless manner. Once such an aberrant learning pattern is detected, a computer tutoring agent appears to notify and encourage that learner.

The Learning Environment

Sample courseware

A sample courseware “Library Tutorial” was designed in this study. Several experienced librarians were invited as course experts to analyze the learning concepts. “Library Tutorial” is aimed at helping students who are not familiar with the library system. The prototype of the personalized e-learning system with learning diagnosis was implemented to evaluate the performance of the Learning Caution Indexes. A total of 375 freshmen in National Chung-Cheng University, Chia-Yi, Taiwan took the exam with 40 test items that cover all learning concepts. The difficulty parameters of course units were estimated according to the analysis of the testing result using BILOG-MG.

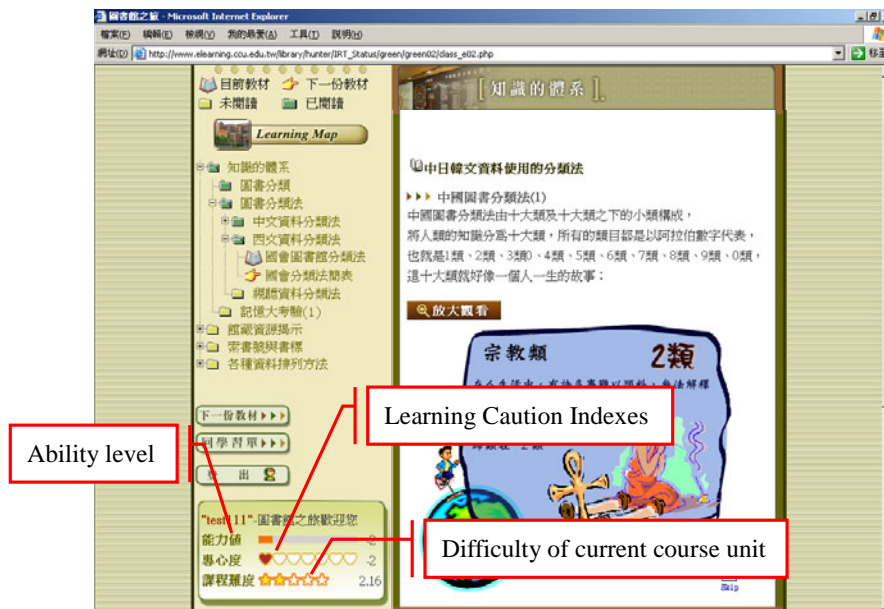


Figure 1. User interface of the proposed learning system with course unit recommendation

Personalized e-learning system

Learner's current ability level, the difficulty of current course unit, and the values of Learning Caution Indexes are all displayed in the user interface of the personalized learning environment as shown in Figure 1.

Each time when completing a course unit, the learner was asked to answer the following question in the learning questionnaire: "Do you completely understand this course unit?" as shown in Figure 2. In this study, we always use the ability level estimated from the result of the self-rating learning questionnaire. The sample course "Library Tutorial" was not a regular course, and the learners did not have the pressure to pass this course. Moreover, learners were reminded and recommended to give honest answers to the learning questionnaire. Therefore, we might reasonably assume that learners provide reliable answers on whether they understood the unit or not. However, alternative mechanisms such as "a test item after finishing each course unit" could be used instead to prevent the problem that if a learner thinks that s/he understands completely a course unit ("yes" answer) when, in fact, s/he does not.

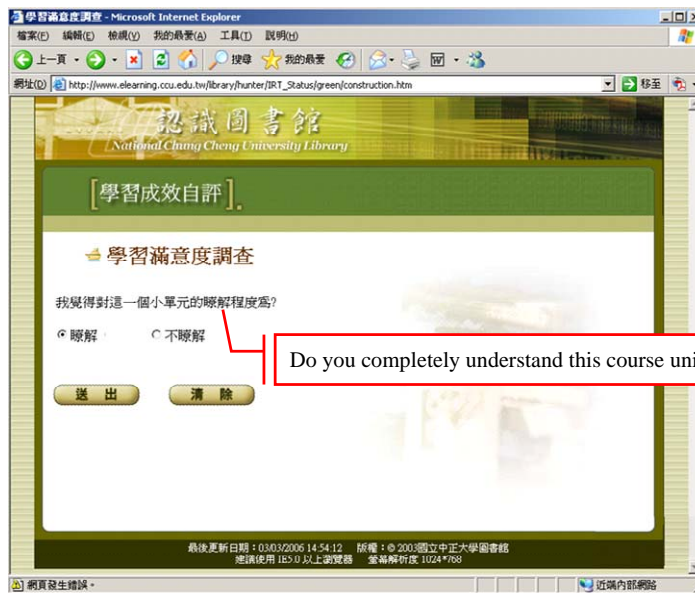


Figure 2. Learning questionnaire page which collect learning response for a course unit



Figure 3. An agent appears to notify and encourage a learner with an aberrant learning pattern

After answering the question “Do you completely understand the course unit?”, learner’s ability level is re-estimated and Learning Caution Indexes are applied to detect aberrant learning patterns. A computer tutoring agent appears to notify and encourage that learner to concentrate on learning if an aberrant learning pattern is detected as shown in Figure 3.

The system architecture of the personalized e-learning system with learning diagnosis is illustrated in Figure 4.

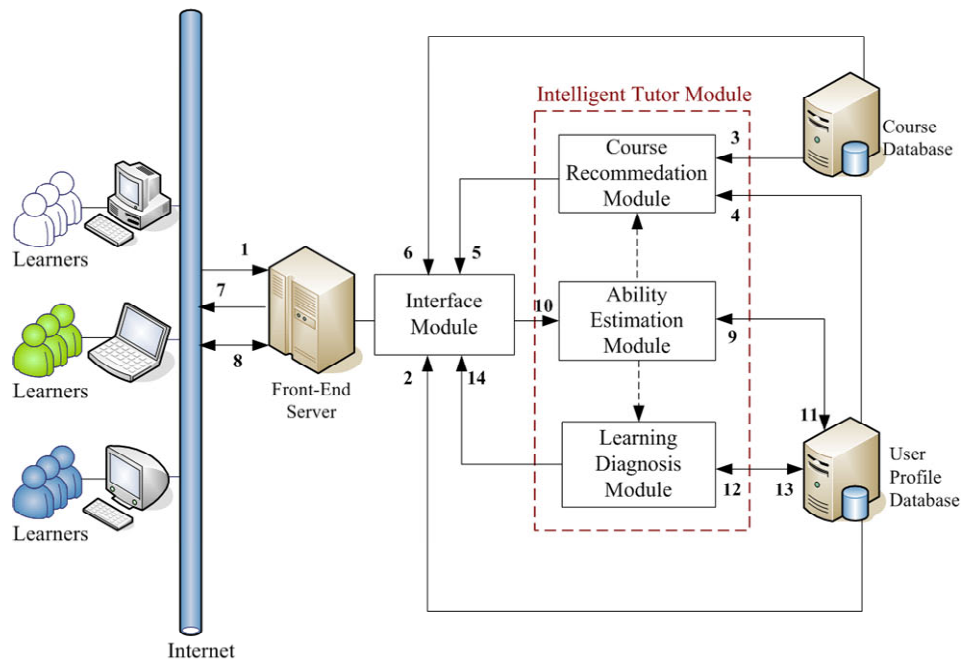


Figure 4. System architecture (The labeled numbers indicate the procedure of system operations.)

Based on the system architecture, the details of the system operations are described as follows.

- Step 1** Authenticate a learner’s identification when receiving a login request through the Internet.
- Step 2** Retrieve the learner’s learning portfolio from the user profile database.
- Step 3** Load the difficulty levels of course units that have not been studied from the course database.
- Step 4** Load the learner’s ability level from the user profile database. A moderate ability level is assigned to new learners after their first login.
- Step 5** Recommend a list of course units. Course units are ranked based on the degree of information they provide to the learner’s current ability level.
- Step 6** Fetch and launch the selected course unit from the course database.
- Step 7** Deliver the selected course unit to the client via the Internet.
- Step 8** Deliver the learning questionnaire: “Do you completely understand this course unit?” and collect the feedback after the learner finishes a course unit.
- Step 9** Load the learning feedbacks of the learner from the user profile database.
- Step 10** Re-estimate the learner’s ability based on the learning feedbacks (completely understand recommended course unit or not).
- Step 11** Update the learner’s ability in the user profile database.
- Step 12** Diagnose the learning behavior by using the Learning Caution Indexes to detect aberrant learning patterns.
- Step 13** Record the result of diagnosis to the user profile database.
- Step 14** Activate the computer tutoring agent to encourage a learner with a detected aberrant learning pattern.

Repeat Steps 3 to 14 until the learner finishes all course units. This process may be suspended by learner’s logging out of the system and be resumed at learner’s next login. The flowchart of the personalized e-learning system from the user’s view is illustrated in Figure 5.

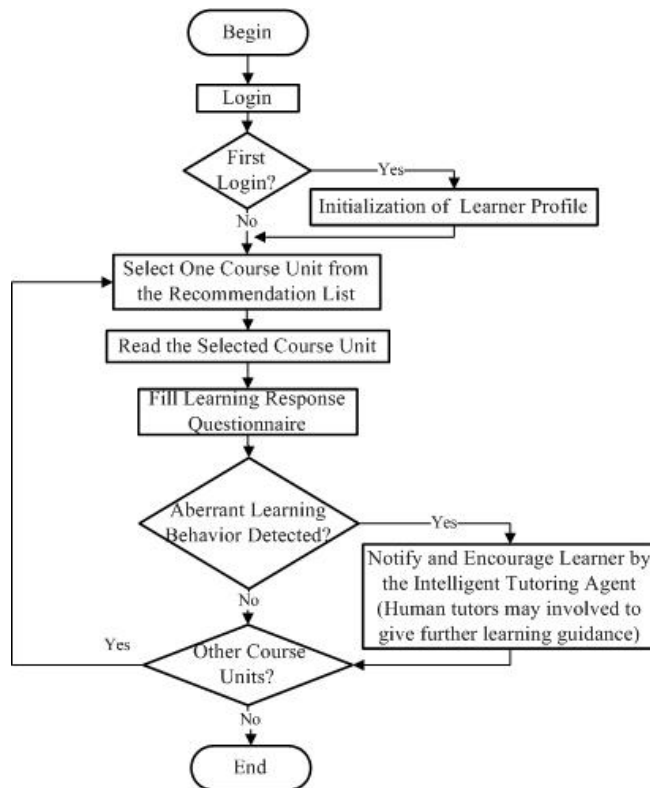


Figure 5. The flowchart of personalized e-learning system from user's point of view

Evaluations and Results

Experimental setup procedure

The experimental procedure was carried out as follows. The main differences between the experimental group and control group were the course recommendation, learning diagnosis, and the targets of periodical learning guidance from human tutors, as shown in Table 2. Learners in experimental group took both additional course recommendation by the IRT model and learning diagnosis by the Learning Caution Indexes. In the experimental group, human tutors gave learning guidance to learners with detected aberrant learning patterns; in the control group, human tutors gave learning guidance to randomly chosen learners because the learning guidance from human tutors is a control variable and therefore must be given in both group.

Table 2. The comparisons of experimental group and control group

Group	Course recommendation	Learning diagnosis	Human tutoring
Experimental group	IRT model	LCI	Periodical learning guidance to learners with detected aberrant learning patterns
Control group	None	None	Periodical learning guidance to randomly chosen learners

A total of 62 freshmen (other from these 375 freshmen who had participated in the exam for estimating difficulty parameters of course units) enrolled in the "Library Tutorial". The students were randomly divided into experimental group and control groups. After learners had logged in for the first time, they were asked to complete a pretest with 20 test items (both in experimental group and control group); after completing all course units in the "Library Tutorial", the learners were asked to take another 20-item post-test to evaluate their learning achievements.

Evaluation of the performance

The one-way Analysis of Covariance (ANCOVA) was performed to test the difference of achievements between the experimental group and the control group. Since the pretest had been administered, the scores in the pretest were used as the covariate in the analysis. The scores in the post-test were used as the dependent variable.

The descriptive statistics for the ANCOVA analysis are depicted in Table 3, whereas Table 4 presents a summary result of the ANCOVA analysis on the overall post-practice achievement test. The ANCOVA results ($F=5.14$, $P=0.027$) indicate that the experimental group scored significantly higher than the control group in the post-test. It can be concluded from the experimental results that the Learning Caution Indexes can significantly improve the learning achievements for students who used the proposed personalized e-learning system. In table 3, although it seems that learners from the control group had very little improvement of knowledge during the learning process (their mean of scores only increased from 47.74 to 51.77). However, the standard deviation of the post-test scores in the control group (25.35) is much higher than the standard deviations in pretest (16.58) and in experimental group (20.47). We believe that learners with aberrant learning patterns need some proper support; otherwise, they might soon give up learning and get poor learning achievements which not only decrease the mean but also increase the standard deviation of post-test scores as in the control group.

Table 3. Descriptive statistics of the scores of the pretest and posttests

Group	N	Post-test scores		Pretest scores (covariant)	
		Mean	SD	Mean	SD
Experimental Group	31	65.97	20.47	43.23	19.38
Control Group	31	51.77	25.35	47.74	16.58

Table 4. Summary results of the ANCOVA analysis on the posttest scores

Source	SS	d.f.	MS	F	P
Between Group	2713.24	1	2713.24	5.14*	.027
Error	31148.90	59	527.95		

* $P<0.05$

In our experiment, totally 33 aberrant learning patterns (in which 42% were reported by Learning_OUTFIT and 58% were reported by Learning_INFIT) were detected in the experimental group. 15 learners finished all course units without any detected aberrant patterns. 5, 7, 2, and 2 learners had 1, 2, 3, and 4 detected aberrant patterns respectively.

Evaluation of the degree of satisfaction

Questionnaires were applied to evaluate the learners' degree of satisfaction in the experimental group. We collected learners' responses to determine whether the recommended course materials meet most learners' requirements. The proposed system collected learners' responses to the questions: "Do you understand the content of the course material?" and "How do you think about the difficulty of the recommended course material?". The result listed in Table 5 seems to show that most recommended course materials were moderately difficult. We may interpret the results as that the proposed system recommended suitable course units to learners.

Table 5. Learners' degree of satisfaction for the recommended course materials

Question	Answer: Learners' choices					Total
	Yes	No				
(a) Do you understand the content of the recommended course materials?	1062 (86%)	178 (14%)				1240
(b) How do you think about the difficulty of the recommended course material?	Very easy 83 (7%)	Easy 353 (28%)	Moderate 664 (54%)	Hard 103 (8%)	Very hard 37 (3%)	1240

Furthermore, learners were asked to fill in three designed questionnaires after s/he finished the whole learning process. The five-point Likert scale was applied to evaluate the degree of satisfaction with the proposed system. Table 6 displays learners' responses. Experimental result shows that the personalized service of the proposed system is quite acceptable for learners.

Table 6. Learners' degree of satisfaction for the proposed system

Question	Answer: Learners' choices					Total
	Very suitable	Suitable	Moderate	Unsuitable	Very unsuitable	
(a) How do you feel that the course materials recommended by our system are appropriate?	5 (16.1%)	13 (41.9%)	11 (35.5%)	2 (6.5%)	0 (0.0%)	31
(b) Do the personalized services provided by our system satisfy your requirement?	6 (19.4%)	16 (51.6%)	7 (22.6%)	2 (6.5%)	0 (0.0%)	31
(c) Does the learning diagnosis provided by our system satisfy your requirement?	3 (9.7%)	14 (45.2%)	10 (32.3%)	4 (12.9%)	0 (0.0%)	31

Empirical cases from experimental data

Two empirical cases are discussed to demonstrate the capability of the LCI for detecting aberrant learning patterns. The course units in these two cases were presented in different orders because different course units were recommended by our personalized e-learning system according to each learner's abilities.

Learning_INFIT and Learning_OUTFIT often exceeded their thresholds in the initial phase of ability level estimation. In other words, Learning_OUTFIT and Learning_INFIT were not stable in the first few course units, because the estimation of learner's ability level was not reliable due to insufficient sample size of learning outcomes. However, both the Learning Caution Indexes and learner's ability level became stable and reliable with sufficient sample size (after 3 to 6 course units). In this study, all false alarms in initial phase were ignored by our system.

In the first case shown in Figure 6, learner's ability level became stable after initial phase but had a sudden drop after the fifteenth course unit. At the same time, the value of Learning_OUTFIT, which is sensitive to carelessness/sleeping pattern, exceeded the threshold (1.72) and our system raised a warning about that aberrant learning pattern. The value of Learning_INFIT also increased but did not exceed the threshold (1.16).

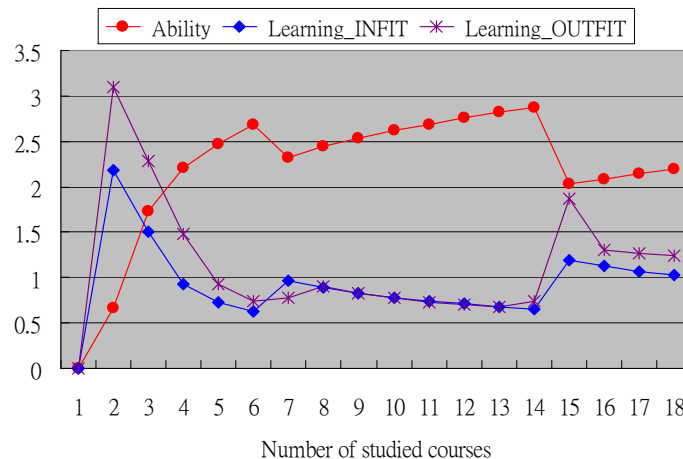


Figure 6. Detection of aberrant learning patterns using LCI: A learner with sleeping/careless pattern. The y-axis represents the values of ability level, Learning_INFIT, and Learning_OUTFIT respectively

Aberrant learning patterns are not necessarily accompanied by sudden changes of learner's ability level. However, the LCI has the capability to detect precisely such aberrant learning patterns without sudden changes of learner's ability level. In the second case, the learner performed well (the '1' responses) in course units with difficulty level 2.34, 2.27, 2.29, 2.28, and 2.31 but failed (the '0' responses) in some easy course units with difficulty level 2.09, 2.13, and 2.14 as shown in Figure 7. However, learner's ability level was surprisingly stable after the initial phase. In such cases, aberrant learning patterns could still be identified. Learning_INFIT, which is sensitive to special-knowledge pattern, detected the aberrant learning pattern after the ninth and the thirteenth course units. The thresholds of Learning_INFIT and Learning_OUTFIT are both 1.20 which accepts response strings manifesting fewer than 20% unmodeled noise. Due to the 20% noise-tolerance capability of LCI, aberrant learning patterns are detected after accumulating enough number of '1' responses in some difficult course units and '0' responses in some other easy course units.

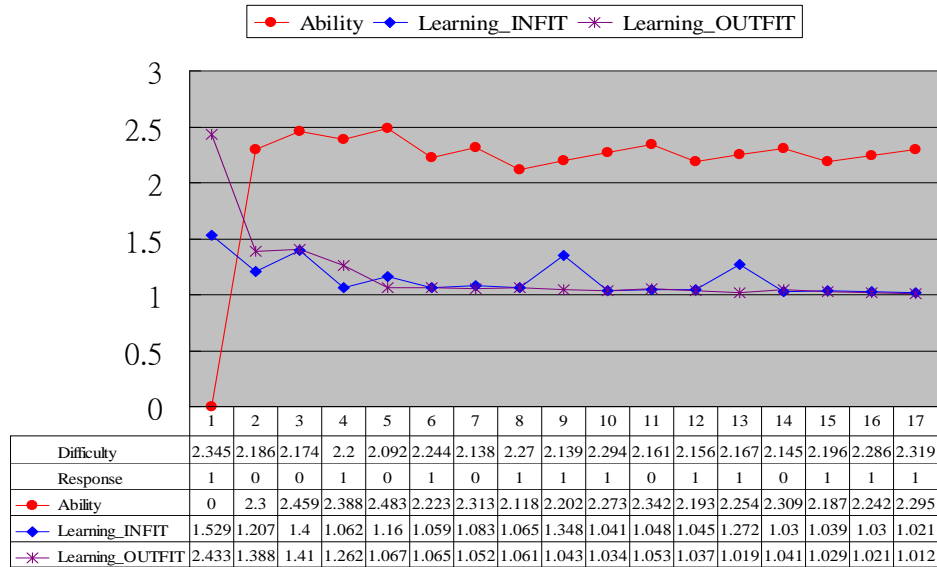


Figure 7. Detection of aberrant learning patterns using LCI: A learner performs well in difficult course units but fails in easy course units (special-knowledge pattern)

Conclusions

The Learning Caution Indexes were proposed in this study to detect aberrant learning patterns by comparing the expected learning achievement with the observed learning achievement. We proposed a mechanism to diagnose whether the personal state of a learner is appropriate for learning by analyzing their explicit learning feedback collected from a learning questionnaire. Our system raises a warning to notify the learner who has a possible aberrant learning pattern. Furthermore, human tutors are involved to offer further learning guidance to support learners with aberrant learning patterns. Experimental results exhibit the effectiveness of the personalized e-learning system with the Learning Caution Indexes.

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A WordNet-Based Near-Synonyms and Similar-Looking Word Learning System

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ABSTRACT

Near-Synonyms and Similar-Looking (NSSL) words can create confusion for English as Foreign Language Learners as a result of a type of lexical error that often occurs when they confuse similar-looking words that are near synonyms to have the same meaning. Particularly, this may occur if the similar-looking words have the same translated meaning. This study proposes a method to find these NSSL words and designed three experiments to investigate whether NSSL matching exercises could increase Chinese EFL learners' awareness of NSSL words. Three primary findings arose from the study. **First**, a performance evaluation of the experiment showed good results and determined that the method extracted suitable NSSL words whose meaning EFL learners may confuse. **Secondly**, the analysis results of the evaluation of Computer Assisted Language Learning (CALL) software showed that this system is practical for language learning, but lacks authenticity. **Thirdly**, a total of ninety-two Chinese students participated in this study and the findings indicated that students increased awareness of NSSL words and improved in ability of NSSL word distinction while still maintaining the knowledge one month after they had completed the matching exercises. **Additionally**, students' feedback expressed that they had benefited from discovery learning and that they thought it was not difficult to discover the differences among NSSL words. Further research might extend the method proposed in this study to distracter choice of automatic question generation.

Keywords

Vocabulary learning, Discovery learning, WordNet, Near-synonyms, Similar-looking words

Introduction

Vocabulary knowledge is essential for reading texts in a foreign language (Chen & Hsu, 2008). Language teachers generally train students to make use of **two important skills to understand the meaning of unknown words**: (a) the skill of **guessing** (i.e., the ability to use contextual and structural clues to obtain the correct meaning of the words); (b) the ability to efficiently **use the dictionary** (i.e., to quickly refer to the page that contains the target word and to read the interpretation of the word).

Many vocabulary learning systems, such as the **electronic dictionary** and **corpus-based software**, have been developed for learning English vocabulary. With the electronic dictionary, learners can quickly look up an English word. The electronic dictionary not only reduces the learner's querying time but also provides the same information as non-electronic dictionaries (Nagata, 1999). Beyond the electronic dictionary, corpora can be consulted as they provide more linguistic information than the electronic dictionary, such as how frequently words occur, which words tend to co-occur, and how the language is structured. The research of Cobb (1997) and Lee and Liou (2003) showed that a corpus-based approach can be used to scaffold the learning of students with low vocabulary skills and improve the results of vocabulary acquisition.

However, a *word* is described as a set of features. It is necessary to acquire the various features of a word in order to master that word completely. This includes features of its spoken and written forms, meanings, grammatical behavior, associations, collocations, frequency, and register (Richards, 1976). Many learners use the electronic dictionary **only for obtaining** one word with the simple translated gloss of the native language (see Figure 1). The inquirer **only acquires the superficial meaning and is very apt to forget it** (Martin, 1984). Heavy reliance on electronic dictionaries will negatively influence English reading fluency (Yeung, Jin, & Sweller, 1998). Another digital source, a corpus, can be consulted with concordance software. Most corpus-based systems focus on lexical choice, sorting the results based on their frequency and diction within the database queried. Only a few studies have attempted to use lexical structures, such as those pertaining to semantic relations for learning. Shimodaira et al. (2006) pointed out that some students queried words, whose meaning they already knew, to find the lexical relations

of those words with other words. Nevertheless, these systems neglect the fact that a learner’s native language is one of the most important factors that may negatively influence the learning of foreign language vocabulary.

English has an alphabetic writing system that emphasizes the knowledge of sound-to-spelling correspondence. The Chinese characters have evolved from their earliest form of hieroglyphs that emphasize word-specific knowledge in pronunciation and spelling (Baron & Strawson, 1976). The meaning of a Chinese character may directly be inferred by part of the word. The results of neurolinguistic research revealed that Chinese native speakers perceive reading Chinese characters in both hemispheres of the brain. However, English native speakers perceive reading English words **only in the left hemisphere** of the brain. This research proves that there is a **difference** in the cognition of English words versus Chinese characters, and that this has an influence on learning (Cheng & Yang, 1989; Tzeng, Hung, Cotton, & Wang, 1979). On the other hand, because of the environmental limitations of their L1, Chinese students are relatively weak in sound-to-spelling competency in English. Therefore, for the Chinese EFL student, **competency in sight-word recognition is more important**. These students prefer organizing similar-looking words into groups to aid recall. Learning groups of similar looking words together can form handy chunks in memory to aid recall (Ellis, 1996). Nevertheless, with regard to some near-synonyms and similar-looking (NSSL) words, Chinese learners are often confused and find it **difficult to learn both at the same time**.

Two NSSL words can be defined as two similar-looking words that have a similar meaning. However, they are not synonyms, and thus cannot be substituted one for the other. For example, the two words, “transform” and “transfer,” are NSSL words. First, they have the same initial, “transf.,” second, the dictionary shows that they share the meaning of ‘change’ (as shown in Figure 1). But a more precise look reveals that they have different concepts and are **only near-synonyms**. The word “transform” is defined as, “to change somebody or something completely,” and the word “transfer” is defined as, “to move from one place to another,” (see Figure 2). Confusion of near-synonyms and similar-looking (NSSL) words is **a type of semantic lexical error** that Chinese EFL students typically make. The Chinese learner will likely confuse their meaning as a result of learning groups of NSSL words together.

Therefore, the focus, of this research is to develop a semantically-related NSSL word learning system, and then to apply discovery-learning theory to help Chinese students practice English vocabulary.



Figure 1. Definitions of “transform” and “transfer” in YAHOO! English-Chinese Dictionary (<http://tw.dictionary.yahoo.com>)



Figure 2. Definitions of “transform” and “transfer” in MSN English Dictionary (<http://encarta.msn.com>)

WordNet semantic lexicon and discovery learning

WordNet and semantic relationships

WordNet is an English lexical database developed under the direction of Miller (Fellbaum, 1998). Its main content is made up of two major parts; one part contains sets of synonyms called “synsets,” and the other contains the semantic relations between these synonym sets. These two parts are explained as follows:

- *Synsets*: WordNet organizes English words into sets of synonyms called synsets, the minimal unit of the WordNet lexicon. When a word participates in several synsets, the relationship among those words is called a polysemy. WordNet quantifies this by frequency score. Synsets are displayed in the order of frequency.
- *Semantic relations*: Most synsets are connected to other synsets via semantic relations. These semantic relations are organized into WordNets, such as synonymy/antonymy, hypernymy/hyponymy, and meronymy/holonymy. For example, Figure 3 shows that the word “brother” is an antonym of the word “sister,” the phrase “organic substance” is a hyponym of the word “substance,” and the two words “arm” and “leg” are meronyms of the word “body.”

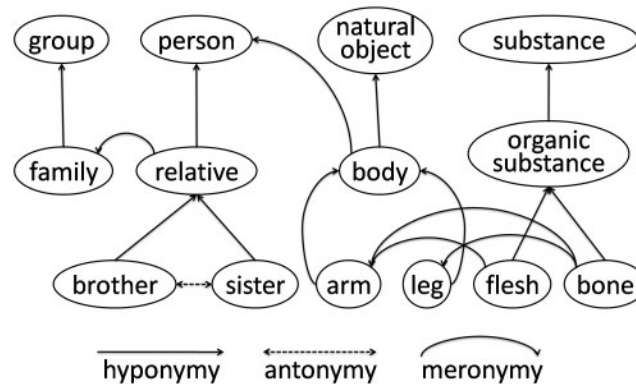


Figure 3. Network representations of three semantic relations in WordNet (Miller, 1990)

The WordNet lexicon offers a good semantic structure for computing the semantic similarity between words. The semantic structure of WordNet can be regarded as a tree graph. The nodes of the tree graph are synsets and the edges of the tree graph are semantic relations. Our research measured the semantic relations by calculating the lowest super-ordinate depth (Wu & Palmer, 1994). The concept behind this method is, as the depth of the lowest super-ordinate of the two concepts becomes deeper, the similarity of the concepts increases.

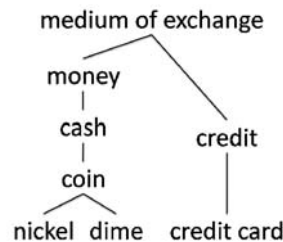


Figure 4. An example of a similarity tree (Resnik, 1999)

Besides Wu and Palmer's edge-counting approach, there is another type of semantic similarity on the WordNet hierarchy called the information-based approach (Resnik, 1999). Resnik's approach is a method of measuring semantic similarity between two concepts in an IS-A taxonomy; that is the degree to which they share information in common. From the perspective of teachers' practical teaching experience, Wu and Palmer's semantic similarity was chosen because calculating the lowest super-ordinate depth allows for teacher intuition in identifying the difficulty in distinguishing two similar concepts. For example, in Figure 4, if a student fails to distinguish between "dime" and "credit card," it may be because he/she did not sufficiently learn the more abstract concept "medium of exchange." In this case, teachers would suggest the student study the less difficult concepts "money" and "credit" more thoroughly to learn "medium of exchange" before attempting "dime" and "credit card." However, the information-based

approach, with less use of the structure of the taxonomy, may increase the teachers' difficulty in distinguishing students' possible misconceptions.

Combining discovery learning theory with the NSSL word learning system

Discovery learning theory was proposed by Bruner in the 1960s (Bruner, 1971). This theory emphasizes that learning is not the passive receiving of knowledge, but that it is active discovery connecting various kinds of information. Novel knowledge is acquired by inductive reasoning. By linking novel knowledge with existing knowledge, learners can distinguish the difference between concepts. Through problem-solving activities, learners can memorize longer items, have a deeper understanding, and experience a smoother transfer of learning.

Our research developed an English NSSL word learning system based on the discovery learning theory. The operating procedure of the proposed system is shown below:

1. The user **inputs a query word** and a corresponding sentence that includes this word.
2. The system then **shows** a group of sentences containing **NSSL words** and the definitions of these words.
3. The user **matches the sentences** with the definitions by intuitive thinking.
4. The system provides **feedback** from the results of step 3.

In step 2, the proposed system filters out a group of NSSL words via our proposed method thereby avoiding learners having to rely only on blind discovery. In addition, the system provides matching items that are a group of sentences and the corresponding definitions. The matching exercise gives learners the opportunity to distinguish between some confusing concepts. This approach allows learners to actively solve problems via inductive reasoning and not simply be passive recipients. Moreover, this approach causes learners to link novel knowledge with existing knowledge through deeper thought processes. Consequently, the learning process in this system can assist learners not only in improving their retention and understanding of words, but also in guessing the meaning of the word in a similar context, thus, resulting in a better transfer of learning.

Method for finding near-synonyms and similar-looking words

By applying the proposed learning system, the user can input a query word to find its NSSL words. The proposed method is shown in Figure 5.

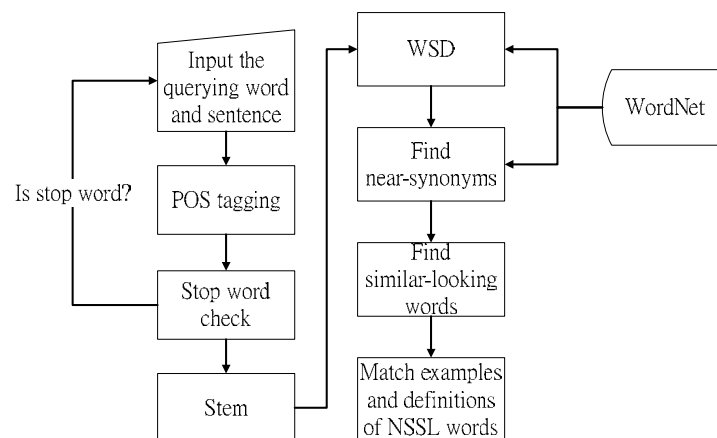


Figure 5. The process of the NSSL word learning system

Part of speech tagging (POS tagging)

This step parses all words of the input sentence. A POS tagger will **mark up each word to a particular POS** (such as verb, noun, adjective, or adverb). Our procedure uses **Brill's tagger** (Brill, 1992); first it uses statistical techniques to extract information from training corpus and then uses a program to automatically learn rules. Brill's tagger has an

accuracy of up to 97.2% when trained in contextual rules of 600,000 words in the Penn Treebank tagged Wall Street Journal Corpus with a 150,000 word test set (Brill, 1995).

Stop word check

Some words often appear in a sentence, but they are extremely common and semantically non-selective in the text. These words, called “stop words” (Manning, Raghavan, & Schütze, 2007), include such words as subject **pronouns** (I, you, he), **prepositions** (in, to, at), and **conjunctions** (and, but, while). WordNet does not include stop words in its database, so these words are shown to the user as stop words and then the system returns to the input query step.

Stem

The stem of a word usually inflects its ending to a derived word according to its grammatical function in a sentence. For example, word groups such as "transform," "transformed," and "transformation" are conflated into a single stem. However, words with a common stem will usually have similar meanings. In order to make the search faster and more precise, our procedure uses the **Porter Stemming algorithm** (Porter, 1980) to reduce the derived word to its stem.

Word sense disambiguation (WSD)

A word may have more than one sense, which leads to ambiguity. Word sense disambiguation is the process of finding out the most appropriate sense of a word for its use in a given sentence. **Lesk's algorithm** (Lesk, 1986) is often used in knowledge-based disambiguation. This algorithm uses WordNet as its comparison dictionary, which provides the possible senses, definitions, and examples of a word. Lesk's algorithm is processed in three major steps: first, utilizing WordNet to **search for polysemy** in the query sentence and retrieve every sense of polysemy. Second, **compare** examples and definitions of each sense to the query sentence and count the number of words that are the same between the two groups. Third, the polysemic word **is assigned** to the sense whose examples and definitions have the largest number of common sense meanings in the query sentence. Seventy percent accuracy can be achieved with Lesk's algorithm when using a typical learner's dictionary. In addition to the automatic WSD, the frequency score provided by WordNet, a count indicating how often a word appears in a specific sense of all its polysemic senses, assists users in choosing the correct sense.

Finding near-synonyms

There are two steps in this procedure:

1. Use **breadth-first searching** (BFS) to find neighboring words around the query word. These neighboring words are related to each other through WordNet hypernymy-hyponymy relation. The maximal search depth is set to four in order to avoid an enormous search space.
2. Use Wu and Palmer's semantic similarity equation (Wu & Palmer, 1994) [Eq. (1)] to measure the similarity between the query word and the neighboring words found in step 1. **One hundred words** with the greatest values of $sim_{wp}(c_1, c_2)$ [see Eq. (1)] are selected as candidate words for the next procedure.

$$sim_{wp}(c_1, c_2) = \frac{2 \times depth(lso(c_1, c_2))}{len(c_1, lso(c_1, c_2)) + len(c_2, lso(c_1, c_2)) + 2 \times depth(lso(c_1, c_2))}, \quad (1)$$

where c_i is a concept or a word,

$depth(c_i)$ is the shortest distance from the root to node c_i ,

$len(c_1, c_2)$ is the path length from node c_1 to node c_2 ,

and $lso(c_1, c_2)$ is the lowest super-ordinate of node c_1 and node c_2 .

For example, to determine the semantic similarity between “transform” and “transfer,” this procedure first finds the **lowest super-ordinate** (LSO) of “transform” and “transfer” in the hypernymy-hyponymy semantic tree graph (see

Figure 6), and “change” is the LSO with $depth(change) = 1$. It can then obtain the $len(transform, change) = 1$, and $len(transfer, change) = 2$. From Eq.(1), the semantic similarity of “transform” and “transfer” is equal to 0.4.

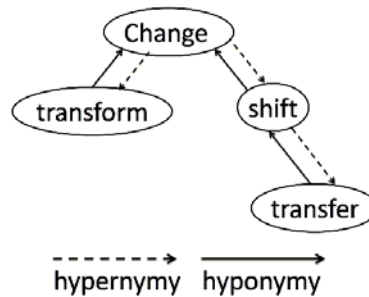


Figure 6. An example of the hypernymy-hyponymy semantic structure of “transform” and “transfer”

Finding similar-looking words

The one hundred near-synonyms obtained through the previous procedure are used as the input of this procedure. The two most similar-looking words are found by computing the **Levenshtein distance** (also called the edit distance) (Levenshtein, 1966). The edit distance between two strings is defined as the minimum number of operations needed to transform a source string into a target string, where an operation may be an insertion, deletion, or substitution of a single character. The smaller the edit distance, the more similar two words are in appearance. Only two words with the smallest edit distance and higher frequency score are selected, considering that the clarification of context sentences retrieved from WordNet has the limit of length and quantity. Too many words may increase the difficulty of matching exercises in the following step and may cause difficulty for the learners in guessing the meaning of the word.

Match examples and definitions of NSSL

After obtaining a pair of NSSL words, our procedure retrieves definitions and examples of these two words from WordNet and **displays them as a matching exercise** for the learner. The learner needs to intuitively identify the definition of the word in each example. Based on the outcome of the matching exercise, the proposed system gives the correct match as **feedback** to improve the learner’s vocabulary knowledge.

Implementation

Figure 7 shows the **graphical user interface** of the NSSL word learning system. First, a learner inputs a query sentence [step (1)]. In step (2), the system parses the query sentence into separate words. The learner chooses a query word and enters step (3). In step (3), the learner matches examples with definitions. When the learner has finished the matching exercise, the system reveals the correct answers to the learner.

Experiments and evaluations

In order to prove the performance of this system, to evaluate this CALL software from teachers’ perspectives, and to test the system’s practicality by students’ experience, this study conducted **three kinds of experiments**. The first experiment was the evaluation of NSSL **word mining performance** in terms of precision and recall. The second experiment applied Chappelle’s (2001) **six principles to guide CALL evaluation**. The third experiment was the evaluation of students’ **learning performance** with achievement tests and their learning attitude with a **questionnaire**.



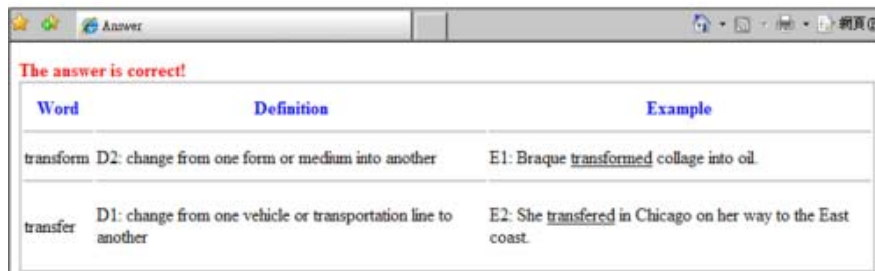
Step 1: A query sentence.



Step 2: The system parses the querying sentence into separated words so that learner can choose a query word.



Step 3: The learner matches examples with definitions.



Step 4: The system shows the correct answers to the learner.

Figure 7. A flow of the NSSL word learning system

Performance evaluation

The English reference word list used to evaluate the proposed NSSL word-finding method consists of 6,480 words collected by the College Entrance Examination Center, Taiwan (http://www.ceec.edu.tw/Research/paper_doc/ce37/ce37.htm). After extracting the verbs, removing those words found in WordNet but not in the English reference word list, and removing low frequency words, ninety words were chosen for this study. As mentioned in the section, “Method for finding near-synonyms and similar-looking words,” finding NSSL words should consider two important parameters, semantic similarity and edit distance. If each parameter is either too high or too low, the located words will not fit the definition of NSSL words. In this experiment, a few sample words were used to test with different settings and the resulting words were discussed with an English teaching expert. The results show that the semantic similarity (ss) is set to a range ($0.6 \leq ss < 0.7$) and edit distance (ed) is set to a range ($0.7 \leq ed \leq 1$), which could find the most suitable NSSL words whose meaning EFL learners may confuse.

The evaluation of NSSL word-finding performance is expressed in terms of precision and recall, as shown below, where W is the two word pair that students will likely confuse the meaning due to being near-synonyms and similar-looking:

$$\text{Precision} = \frac{\text{\# of sample correctly extracted as W}}{\text{\# of all samples output being W}} \times 100\%$$

$$\text{Recall} = \frac{\text{\# of sample correctly extracted as W}}{\text{\# of all samples that hold the target words W}} \times 100\%$$

The evaluation procedure was as follows. First, three college English teachers were asked individually to find the corresponding NSSL words from ninety words with the help of the NSSL word system. Next, precision and recall results were summarized via the teachers' majority voting. Finally, the resulting NSSL words from the system were collected by means of the NSSL word-finding method from the same ninety words and were compared with the teachers' results.

The experimental results show that the precision of this system was about 83.12% and recall was about 77.11%. Therefore, the NSSL words found through this approach have a high probability of causing confusion. Additionally, this approach found most of the NSSL words in this dataset. In order to confirm the mutuality within each group of NSSL words, the role of the NSSL word was interchanged in each group of NSSL words. For example, if the querying word is A, and the result word is B, the role of B is changed as an input querying to test whether the system finds A or not. The results obtained a 90.63% accuracy rate for mutuality, revealing that this NSSL finding approach is highly consistent.

Observed factors that decreased the precision of the NSSL finding method are as follows:

- Some pairs of words, such as even/level that are considered near-synonyms, could be accurately substituted one for the other in the general context. For example, in the sentence, “he evens/levels the ground,” the pair of words can substitute one for the other. This system also found variants of some words, such as prize/prise, and gray/grey. Thus, these types of interchangeable words could not be recognized as easily confused NSSL words.
- There are some NSSL words that differ due to their prefixes, such as ascend/descend, and number/outnumber. From the perspective of the system’s design, these types of words match the definition of NSSL words, having both characteristics of near-synonyms and similar-looking. However, from the perspective of teachers' practical teaching experience, some teachers argued that students could learn to recognize affixes first to assist them in differentiating between the meanings of the different prefixed NSSL words. Their divergence of opinions caused the precision to decrease.

Out of these two factors, the first is more often responsible for the decrease of the precision than the second one.

The main factor causing a decrease in recall were neighboring words that were in the selected range of Wu and Palmer’s semantic similarity but did not satisfy the selected range of the edit distance. This study could not set a range of semantic similarity and edit distance within a time to extract all of the target words.

Table 1. The evaluation of the NSSL word learning system

Qualities	Rate
Language learning potential	Good
Meaning focus	Good
Learner fit	Good
Authenticity	Not authentic
Positive impact	Positive
Practicality	Good

CALL software evaluation

The same three college English teachers that participated in the performance evaluation applied Chappelle's six criteria to evaluate the NSSL word learning system. The criteria were intended to evaluate not only the software but

also the task-appropriateness. In this evaluation, a questionnaire based upon a six point rating-scale was developed to rate each of Chappelle's six criteria to determine their appropriateness. Each rating-scale item has some guided sub-questions proposed by Chappelle (2001) to assist teachers' judgment in each criterion. Table 1 shows the results of their combined ratings. How the NSSL word learning system meets these criteria is discussed below.

- *Language learning potential*, the degree of opportunity present for beneficial focus on form: the task provided by the NSSL word learning system is the **matching test** where the learner can first analyze and understand the difference in the forms and the meanings of the particular NSSL words in focus, and then use the context of example sentences to practice the word usage. The system then gives the correct match as **feedback** on the matching exercise. A learner can focus **both on the similar looking** forms of given NSSL words **and on how to distinguish** between their meanings.
- *Meaning focus*, the extent to which the learners' attention is directed toward the meaning of the language: as this paper has already mentioned in the "Language learning potential" criteria, since learners need to **comprehend the meanings** of the definitions and examples of NSSL words to do the matching exercises, there is a focus on meaning.
- *Learner fit*, the amount of opportunity for engagement with the language under appropriate conditions given learner characteristics: this activity was tailored to the learners' vocabulary level in that the proposed system could be set to limit the located NSSL words to the English reference word list collected by the College Entrance Examination Center, Taiwan. This **word list classifies 6,480 words into six levels** selected on the basis of word frequency and the level of English or Chinese cultural background required to understand the word.
- *Authenticity*, the degree of correspondence between the learning activity and target language activities of interest to learners outside of the classroom: The task planned by teachers focused on some systemic NSSL words for students' vocabulary growth. This task **was not intended** to be like tasks that learners would **engage in outside** the classroom unless learners choose to do so specifically for individualized vocabulary study. Therefore, the learners may not see this task of finding NSSL words as an authentic match with their future language use.
- *Positive impact*, the positive effects of the CALL activity on those who participate: Instructors and learners tended to have positive teaching and learning experiences with the NSSL word-learning system because it mined many relevant, potentially confusing words and attached matching exercises for distinguishing between these words, thereby enriching the range and flexibility of classroom materials.
- *Practicality*, the adequacy of the resources to support the use of the CALL activity: this system is developed on the web, so it does not need to be installed. The on-screen instructions and help information is clear and readily accessible. Most of the students **had no difficulty in using the system**.

Students' learning evaluation

The hypothesis predicts that learners will perform well in differentiating between the different meanings of the NSSL words when they use the proposed NSSL word learning system. This study also asks the students for feedback on the online materials.

A one-group pre-posttest design was adopted to address the issue under investigation. **Twenty graduate students and seventy-two undergraduate students** who participated the entire time period of the experiment (**over three months**) were selected for this study. Most of the students received formal English instruction for six years prior to their junior and senior years of high school. The participants took either "Advanced Digital Learning" or "Applications of Internet" as an elective course. Both courses were conducted in computer laboratories and reviewed a topic related to computer-assisted learning. Before conducting this experiment, the lectures introduced the topic of computer-assisted learning, and then this experiment was carried out as an example of the introduced topic. Subjects were told that their experiment outcome will not impact their final grades; therefore, participation in this study was voluntary.

Two types of instruments, a test and a questionnaire, were used to collect data for the educational research hypothesis. The **pretest** contained 15 groups of NSSL target words (a total of 30 words) and 10 distracters. The 20 sentence-completion test items that made up the pretest, posttest, and delayed posttest were **identical but sequenced differently** in each of the tests. The **questionnaire** had 10 items for examining students' **perception of using** the system after the experiment. Each item had a five-point Likert-type scale.

The procedure is as follows. First, all participants received a **training course** for fifteen minutes on how to use the proposed NSSL word learning system, and then they were invited to take the **pretest in the first week**. Next, in the

five-week treatment stage, teachers taught the definitions and gave examples of the target words. Students went on to query the target word by using the NSSL word learning system, and then they completed the matching exercises of the NSSL word learning system that applied discovery learning strategy in the exercises. They were given 5 minutes of in-class time and had to complete the rest after class each week. In total, 30 words, that is to say 15 pairs of NSSL words, formed the target word list that was equally distributed over the five units, one unit per week. Last, in the posttest stage, students took the immediate posttest and filled out the evaluation questionnaire. Then, four weeks later, students took the delayed posttest. The results of the tests and student feedback on the system are presented and discussed below.

Learners' Performance and Retention as Measured in Controlled Tests

Comparisons were made to see if there were significant differences between (1) the scores of the pretest and the immediate posttest (see Table 2) and (2) the scores of the immediate posttest and the delayed posttest. The posttest scores (in which each item was assigned 5 points, 75 points in total for each test) were significantly higher than those of the pretest ($p=0.000<0.01$), and no significant difference was found in comparing the immediate posttest and the delayed posttest ($p>0.01$). Hence, the positive results indicate that students' knowledge of NSSL words had increased significantly in the controlled tests. Additionally, students generally did not show much regression in the delayed posttest, as indicated by the comparison of both posttest scores. The results confirmed our hypothesis that the NSSL word-learning system did enhance students' learning of NSSL words, and the effects were maintained over four weeks when learning was again measured by the same test items.

Table 2. Paired sample t-test on pretest and the immediate posttest, and on the immediate posttest and delayed posttest

	Mean	Std. Deviation	Sig.
Immediate Posttest – Pretest	18.12	6.91	.000
Delayed Posttest – immediate Posttest	-.07	7.86	.937

Learners' Perception of the NSSL Word-Learning System

The developed questionnaire was verified by conducting factor and reliability analysis. Conducting the principal components factor analysis, this study identified the 3 factors as follows:

- factor 1, explaining 35.97% of the variance, shows the usefulness of learning with the NSSL word-learning system;
- factor 2, explaining 12.79% of the variance, shows students' perception of the design of the fifteen online learning practices;
- factor 3, explaining 10.44% of the variance, shows students' overall attitude toward the matching exercise and their future use of the NSSL word-learning system.

The principal components explained 59.19% of the variance. The associated Cronbach alpha reliabilities, the principal components factor analysis, and students' responses to the questions are shown in Table 3.

In the responses to the questionnaire, a great majority of students (95%) indicated that they liked NSSL word learning; a mere 5% held a neutral attitude. A total of 75% of the students strongly agreed (37%) or agreed (38%) that they will utilize this system to learn NSSL words in the future; a mere 25% of students held a neutral attitude. More than half of the students (62% and 61%) reported that they had no difficulty in making distinctions among NSSL words and in understanding example sentences. A total of 78% of the students (45% plus 33%) thought that the provided matching exercises helped them consider the differences among the NSSL words. These results concerning the, "perception of the design of the matching exercises" indicate that learning two NSSL words at a time in a matching exercise is sufficient for discovery learning and that the difficulty of the mined words by the proposed approach was adequate for the students' English proficiency level. The overall results of the five questions pertaining to "usefulness of Learning" show that more than half of the students (57%, 68%, 56%, 61%, and 58%) responded that our system had helped them learn English NSSL words effectively. Furthermore, it seems that the NSSL word-learning system was more effective than using a typical dictionary.

Table 3. Results of students' evaluation of the proposed system

Questions	Percentage of Respondents % (n=92, $\alpha=0.78>0.7$)					Mean (SD)
	Strongly Agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly disagree (1)	
Overall attribute & future use						
I liked trying to induce the exact meaning of NSSL words from the matching exercises provided by this system.		95	5			3.95 (0.23)
I will utilize this system to learn NSSL words in the future.	37	38	25			4.12 (0.78)
Perception of the design of the matching exercises						
In discovery learning, I found it effortless to make distinctions between NSSL words.	9	62	25	4		3.75 (0.67)
In discovery learning, I felt that the example sentences were not difficult.	2	61	34	3		3.62 (0.59)
In discovery learning, I felt that doing the matching exercise helped me consider the subtle differences between the collocations of NSSL words.	45	33	22			4.23 (0.79)
Usefulness of learning						
I feel that I understood the exact meaning of NSSL words better by doing the matching exercises in this system than I would have by looking up the word and reading the English or Chinese definition in a more typical dictionary.	33	57	1			4.22 (0.63)
I feel that, after submitting my answer, the feedback message to re-do the incorrect questions was helpful.	16	68	16			4 (0.57)
I feel that the layout of the online practice was easy to read.	22	56	22			4 (0.66)
I feel that the matching exercises helped me understand the word when reading it in context.	16	61	23			3.93 (0.63)
I feel that, after completing these exercises, I will be able to distinguish word meanings more precisely when reading.	14	58	28			3.86 (0.64)

Related works

Before presenting our conclusions and future work, one more point about related studies must be clarified. Because vocabulary test construction is time-consuming and expensive, some studies (Hoshino & Nakagawa, 2008; Jonathan, Gwen, & Maxine, 2005; Sumita, Sugaya, & Yamamoto, 2005) have tried to solve this problem by proposing a method of automatic question generation. There are two differences between their studies and ours in the applications of the research and in the methods of determining distracters. First, the two kinds of studies focused on different applications of the research. The automatic question generation studies tried to improve Computer-based testing (CBT), whereas our study tried to improve CALL. The two different applications of the research also resulted in two different experimental methods: the automatic question generation studies designed their experiment for the purpose of evaluating test validation (Tao, Wu, & Chang, 2008). Our study, on the other hand, designed the experiment for the purpose of evaluating the effectiveness of the learning. Second, in selecting similar words, most studies determined the distracters for their questions through machine-readable dictionaries (Hoshino & Nakagawa, 2008) such as an in-house thesaurus (Sumita et al., 2005) or WordNet (Jonathan et al., 2005). In the research using an in-house thesaurus, had a different thesaurus been used, the distracter candidates would most likely differ. On the other hand, in the research using WordNet, distracters were chosen directly from one-dimensional semantically related words (synonyms, antonyms, hypernyms, hyponyms, etc.) of the target words. In contrast, our study

determined the distracters for the matching exercises with the dynamic two-dimensional NSSL words (near-synonyms and similar-looking) through WordNet.

Conclusions and future work

While most vocabulary learning systems provide only one-dimensional semantically related words (synonyms, antonyms, hypernyms, hyponyms, etc.) of the target words, this study enhances the previous vocabulary learning systems by providing dynamic two-dimensional NSSL words (near-synonyms and similar-looking) through WordNet; then this research investigated whether NSSL matching exercises could increase EFL learners' awareness of NSSL words. Our research questions first addressed the effectiveness of the proposed NSSL generating method and the proposed NSSL word learning system, and then addressed measurement of students' learning gains in this system.

To address the first question, three college English teachers were invited to participate in this study in the aspects of performance evaluation and CALL software evaluation. After testing our proposed NSSL word mining method, their performance evaluation assigned good results. This method extracted suitable NSSL words whose meaning EFL learners are likely to confuse due to a misunderstanding with similar-looking words that are near synonyms and have the same meaning. Particularly if the similar-looking words have the same translated meaning the EFL learners would be confused about the exact meanings of the NSSL words. The results of the analysis of the CALL software evaluation showed that this system is good for practical language learning with the exception of the lack of authenticity. The lack of authenticity could be solved by teachers' designing real-life material for students. However, CALL software analysis is always situation specific (Chapelle, 2001). Hence, the main purpose of applying CALL software analysis is providing a means for deciding whether to try the task in a language class or whether to attempt to improve the weak task.

To address the second question, twenty graduate and seventy-two undergraduate students were invited to participate in the study and offer their evaluation of the learning experience. Although the results showed that the students' test scores had increased between pretest and posttest and still maintained the knowledge of NSSL words over one month, these findings do not say that the proposed system applied a discovery learning strategy that caused these learning effects. It would be better to say that the proposed NSSL word learning system facilitated EFL learners' to increase the "awareness" of NSSL words. Further, they are willing to learn these kinds of NSSL words through the proposed match exercise or other preferred individual learning resources. Students' overall feedback, which showed that they had a positive attitude toward the usefulness of the proposed system and were willing to use it in the future, may also explain the benefit of the NSSL word learning system.

A pedagogical implication can be drawn for EFL teachers from this study. Unlike homophones, NSSL words do not seem to get any special treatment in the vocabulary curriculum, perhaps because of a lack of awareness of the particular features of similarity that lead to the confusion between them. The students usually use a dictionary or the skill of educated guessing to find the meaning of unfamiliar words. When, on the other hand, the words look similar, or are near-synonyms to more familiar words, they may not waste their time on checking them. The importance of this erroneous strategy should not be overestimated in the case of words that seem familiar to the students. English teachers of Chinese students should spend more of their teaching time on distinguishing the exact meaning between these NSSL words.

It is important to note that this method of investigation is not thoroughly flawless. First, the study design does not record the differences in student performance with respect to the time he or she has spent with the learning system. It is not known how many learning effects were caused by the proposed system. Secondly, considering the clarification of context sentences retrieved from WordNet has a limit of length and quantity the matching exercises only provide two matching items at a time. Any extra resources, such as corpus, could be used to enrich the context sentences of WordNet. Finally, a larger number and variety of participants is needed to make further generalizations of results. Further research, that includes these and other issues, needs to be conducted to draw more rigorous claims.

There are two potential issues for future study. One is the possibility of extending and applying the methods used in this study to the distracter choice in automatic question generation. The other is applying other related ontology-

based similarity measures or string-based similarity measures such as SimPack (Bernstein, Kaufmann, Kiefer, & Bürki, 2005) to investigate the potential for more effective learning.

Acknowledgments

This work was supported in part by the National Science Council (NSC), Taiwan, ROC, under Grant NSC 97-2511-S-006-001-MY3 and NSC 98-2631-S-024-001.

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Enhancing Health and Social Care Placement Learning through Mobile Technology

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ABSTRACT

Health and social care students spend up to 50% of their course in practice. Placements are distributed across a wide geographical area and have varying degrees of IT access and support. Consequently, students may feel isolated from peers, academic staff, and resources required for effective learning. Mobile technology has considerable potential to enhance the learning of these students. This paper presents the development and implementation of the Centre for Excellence in Professional Placement Learning's mobile learning project and the principles that both drove and emerged from this work. Handheld devices were matched to students' pedagogic need. Principles covered areas such as pedagogy, partnership working, technology, inclusivity, evaluation, and research. Collaboration across sectors and institutions and an understanding of professional cultures and contexts were seen as key in instigating and embedding mobile learning to support students on placement.

Keywords

Mobile learning, Placement, Pedagogy, Students

Background

Mobile learning (m-learning) refers to the use of emerging technologies to enhance students' learning experiences. The m-learning literature continues to debate the pervasiveness and ubiquity of mobile devices and their potential use for learning (Alsaadat, 2009; Moore, Hu, & Wan, 2008). Supporting technological structures enabling wireless connectivity are now embedded (Sharma & Kitchens, 2004), such as General Packet Radio System (GPRS), Universal Mobile Telecommunications System (UMTS). In addition, other 3D-derived technologies, such as High-Speed Downlink Packet Access (HSDPA) and the attributes of mobile technology, have the ability to attract young people in particular to learning (e.g., Attewell, 2005).

Despite the potential freedom afforded by the paradigm shift from e-learning to m-learning, researchers and developers of this technology must address the diversity of applications, relevance, users' needs, roles, and contexts in order for the use of mobile technology to become truly pervasive (Moore et al., 2008). However, although in 2004 there were estimated to be 1.5 billion mobile phones in use across the globe in comparison to less than half a billion personal computers (Prensky, 2004), the use of these devices for learning cannot be assumed (Kennedy, Judd, Churchward, Gray, & Krause, 2008).

The most recent UK Office for National Statistics (2008) survey reported an increase of one million households (16 million) having Internet access between 2007 and 2008. However, of the adults surveyed, only 32% consulted the Internet for learning compared to sending/receiving emails (87%). Despite the high use of the Internet in both the 16–24 and 25–44 age groups (77% and 72%, respectively, reported daily use) only five percent of adults surveyed had accessed the Internet in the last three months via wireless hotspots (although this was double the number for the previous year). Further, recent adult Internet users reported accessing the Internet via the following mobile devices: laptop (23%); mobile phone (GPRS) (15%); palmtop/PDA (4%); mobile phone (UMTS) (4%). Therefore, although the general population's access to the Internet and broadband in the UK is rising sharply, there is still some way to go in terms of equalising this figure, first with accessing the Internet via mobile devices and second in terms of using the Internet for learning activities.

As with e-learning, there is a danger that discussion regarding technology may eclipse discussion in relation to pedagogy (cf. Orrill, 2002; Dalsgaard, 2005). Nationally and internationally, higher education establishments have engaged with m-learning. For example, Duke University in the USA (2005) has provided freshman students with iPods preloaded with orientation information to use for downloading course content and recorded lectures. In New Zealand, nursing students have been supported on placement through the use of Short Message Service (SMS) via

mobile phones (Mackay, 2007). In the UK, Centres for Excellence in Teaching in Learning (CETLs) have used personal digital assistants (ALPS CETL) and location-based global positioning systems (GPS) (SPLINT CETL) to meet the needs of students at a distance from the university campus. However, the Higher Education Academy Subject Centre for Education (Escalate) observes regarding Becta's recent report, ". . . in spite of the evidence, 'technology is fully exploited by only 20 percent of schools and colleges' and it might be difficult to argue the figure for higher education is very different" (Gulc, 2008, p.2).

McNeely (2004) proposes that higher education needs to meet four challenges in order to maximise the potential utility of m-learning. These include: funding for devices and associated costs, access and skills to use facilities, the ability to interact using devices, and relevance of use, that is, "using technology for some practical purpose, and not just for the sake of technology" (McNeely, 2004, p. 49). Higher education establishments will need to shift resources and skills in order to fully exploit the potential benefits of mobile technology for learning.

Mobile technologies do not offer just another way of doing what is already done, but open up new possibilities in terms of learning and teaching. The m-learning literature focuses on changes in the learning environment, characterised by the pervasiveness and ubiquity of the technology, and on the changing characteristics of higher education students in relation to their use of mobile devices for learning. Further, there is the issue of educators, who are likely to be "digital immigrants" (Prensky, 2001), and their ability to facilitate the enhancement of learning with these technologies.

It is widely recognised that students born within the net generation (Tapscott, 1998) are digital natives (Prensky, 2001); they have incorporated the use of the Internet, and more recently handheld devices, into their everyday lives. However, studies have shown that it cannot be assumed that digital natives will transfer their use of emerging technology to their learning. Caruso and Kvavik (2005) found that while most of the 18,000 students in their sample were at ease in the use of a defined set of technologies for learning, technologies outside this set, which enable social networking for example, were constrained to use outside the classroom (although the authors posit that this may be due to lack of uptake of this provision by staff). Similarly, Kennedy et al. (2008) found that students were reluctant to use technologies beyond those that were considered entrenched in their usual learning activities. Although the above studies recognise the positive relationship between past experience with technology and increasing use of new technology for learning, there are issues that need to be addressed so that use for learning becomes routine.

M-learning in practice: The case of health and social-care students

There is an increasing focus on the significance of placement or work-based learning as part of higher education and further education programmes of study, the assumption being that this will better prepare students for the world of work. Practice environments are vital in enabling students to gain valuable experience, building both confidence and competence (Benner, 1984; Schön, 1987). Further, early practice experience and contact with service users is essential in enabling students to understand the application of academic theory (DoH, 2001).

Although the potential benefits of work-based learning environments are well documented, they can be limited by challenges such as access to learning resources. Additionally, many authors report increasing pressures in placement environments: staff shortages, increased numbers of placement students, and the competing demands of being both a learning and service environment. Such pressures can compromise the quality of the placement learning experience (Harrison, 2004; Orton, Prowse & Millen, 1993). Shortcomings in placement support for learners have also been repeatedly highlighted (e.g., White, Davies, Twinn, & Riley, 1993; Phillips, Schostak, Tyler, & Allen, 2000). Orton et al. (1993) found that placement managers felt unable to cope with the number and diversity of students when staffing levels were perceived to be barely adequate to provide care to service users. In more recent research, Hutchings, Williamson, & Humphreys (2005) found that those supporting learners in practice felt anxious about their ability to support learners when the placement environment was busy.

The professional bodies that govern health professions and their respective professional training programmes emphasise the importance of research in underpinning evidence-based professional practice (Health Professions Council, 2007; Nursing and Midwifery Council, 2008). Therefore, it is crucial that students are able to access appropriate resources whilst on placement in order that their practice is supported by current evidence. Barriers to achieving this can range from a lack of access to networked PCs (Mailer, 2006; Walton, Smith, Gannon-Leary, &

Middleton, 2005) to the strictness of mentors who are supporting students in practice (Callaghan, Doherty, Lea, & Webster, 2008a). At the most basic level, the introduction of mobile devices specifically for learning has the potential to meet students' needs by reducing the physical and hierarchical barriers to resource access (Callaghan, Lea, Charlton, & Whittlesea, 2008b). Further, mobile devices offer a potential solution as they are portable, enable any time/any place connectivity, offer flexible and timely access to resources, provide immediacy of communication, may empower and engage learners, and provide active learning experiences (JISC, 2005).

This paper reports on the Centre for Excellence in Professional Placement Learning's (Cepl) exploration of this potential through a programme of research using a number of devices with a range of functionality to meet the diverse needs of students on placement. In particular, this paper focuses on the processes involved in developing and delivering m-learning to placement students.

Method

Following the award of a significant research grant, a three-year programme of research into mobile learning was initiated. The programme encompassed thirteen fully evaluated mobile learning trials involving students on different health and social care programmes and in different placement contexts (e.g. hospital, community settings, and service users' homes).

The researchers adopted participatory evaluation (PE) to engage and empower stakeholders in the evaluation process. Two factors are crucial in promoting empowerment: first that the evaluation directly meets the needs of stakeholders, and second that actions developing from the evaluation are utilised (Papineau & Kiely, 1996). In engaging with stakeholders throughout the three years of the study, we assumed Burke's (1998) PE principles, which have power sharing, utilisation of findings, sensitivity of context, and reflexivity at their core. Although a proportion of groups and/or individuals will choose not to engage (Lennie, Simpson, & Hearn, 2002), methods and initiatives undertaken should promote choice in terms of depth and method of participation in order that the methods themselves do not induce barriers to participation.

Participants

The disciplines involved were: podiatry ($n = 80$), social work ($n = 20$), clinical psychology ($n = 25$), post-registration cognitive behavioural therapy ($n = 6$), post-registration consulting skills ($n = 8$), and learning disability nursing ($n = 5$). Undergraduate (all levels) and post-registration students (i.e., those who have acquired a first degree leading to professional registration and are embarking on further graduate or post-graduate study) participated. The length of placement varied depending on discipline and year of study (from four weeks to three months). Students used loaned devices for the length of their practice placement.

Procedure

Initially it was anticipated that all students would complete questionnaires to evaluate their experience of using mobile devices for learning. Questionnaires were devised and piloted. Unfortunately, this method of collecting data proved unsuccessful; few students completed the questionnaires. Follow-up investigation revealed that students' busy professional programmes disinclined them to complete questionnaires. Additionally, in order to be sensitive to placement contexts and mindful of the ethos of PE (discussed above), qualitative methodology was then selected as the most appropriate method of data collection.

Individual interviews were selected to achieve detailed feedback from students. An interview schedule was devised and piloted. Sixty interviews were conducted across a range of disciplines and levels of student. Participation was voluntary, in line with research ethics approval. However, this process yielded a diverse range of interviewees, both technophobe and technophile, with both positive and negative experiences. In addition to the formerly gathered research data, researchers and staff collected and collated all anecdotal feedback throughout every trial. For example,

when students returned their device or asked for assistance, staff would engage them in discussion about their experiences.

The fundamentally participatory nature of the research meant that academic and practice staff worked in partnership with the researchers on the trials. Consequently, the ethos of the research did not lend itself to the traditional “researcher-researched” relationship when it came to evaluating staff experiences of mobile learning. Therefore, in collaboration with staff, their experiences were documented throughout the project in written emails, meetings, and conversations with the researchers.

In total, the programme of research yielded a vast quantity of qualitative data, which was analysed using thematic content analysis (Smith, 1992). This analysis informed the generation of ten principles for the implementation of effective mobile learning.

Trials: Setting up the Cepl’s m-learning project

The following section provides details of the development and implementation stage of the Cepl’s m-learning project and introduces the principles that emerged and guided this process.

From the outset it was important that the use of mobile devices in placement areas was driven by student need as opposed to a desire to use technology for its own sake. Therefore, the first principle that guided the project was as follows:

1. The use of mobile devices for learning should be driven by pedagogy (student need) rather than technology (the device).

While it would appear obvious that pedagogy should drive the use of technology for learning, unfortunately, this is not always the case (Laurillard, 2007). Consequently, a workshop was held to explore the use of mobile technology to support placement learning to which all health and social work staff members at the university were invited. The aims of the workshop were to identify academic staff who were keen to explore the use of mobile technology to meet their students’ needs; to map out those needs; and to begin to consider how mobile technology could be harnessed to meet those needs.

The workshop was attended by Cepl staff, academic staff from a range of disciplines, staff from the university’s computing services and education and learning technology unit, and employees from TwoFour (a television company with an interest in training educators and using mobile technology to support education). This active engagement of staff across university divisions and experts from beyond the university ensured that the necessary skills and knowledge to implement m-learning were available and that, in the longer term, the use of mobile technology to support learning could be sustained. It also allowed all aspects of implementing m-learning to be evaluated.

Stakeholder involvement in setting up the project had a number of benefits, including the identification of champions to take forward a new teaching and learning initiative. Champions have been shown to be powerful ambassadors of organisational change and “transformational leaders” (Thompson, Estabrooks, & Degner, 2006, p. 695). Although initially it was not possible to include students as a stakeholder group (due to the required purchasing time limitations on the funding within the summer vacation), their placement learning needs were articulated by staff that supported them directly in practice. Consequently, the identified needs were based on both formal and informal student feedback about their placement learning experiences. The success of this initial workshop and the subsequent partnership that drove the project led to the development of a second principle:

2. All stakeholders involved in the education of the learner must be involved at all stages when developing, implementing, and embedding mobile learning initiatives: dialogue, dialogue, dialogue.

Although it was relatively easy to achieve commitment from academic staff because they volunteered for the project, it was considerably more difficult for practice staff who voiced a number of concerns, including the ethical issues of using mobile technology in sensitive contexts, their level of confidence in using the device if a student asked them about it, and a concern that m-learning was another thing to take on in an already pressured environment where teaching and practice often represented competing priorities. It was considered vital, therefore, that opportunities were facilitated for ongoing open dialogue between *all* stakeholders.

Finally, the workshop enabled the identification of an appropriate multidisciplinary project team. Each trial was developed and implemented by an academic subject-specific team supported by the multidisciplinary team. A core team of learning technologists and staff from the university's Computing and Information Services provided the appropriate expertise and worked collaboratively with academic staff to develop m-learning resources and support and to ensure that such resources were consonant with the university IT systems. The team also included research psychologists, who carried out the evaluation and subsequent research. This partnership was deemed necessary for the optimal implementation of all trials and provided the basis for the third principle:

3. A multidisciplinary team of academic and support staff is optimal for developing and supporting mobile learning.

Following the identification of students' learning needs on placement and of teams who would take the work forward, a critical appraisal of currently available mobile technology was undertaken to ascertain how devices might meet needs. This led to the formulation of the following three principles that framed the subsequent work and were evaluated throughout it:

4. Mobile devices for learning should be user-friendly and easy to operate.
5. As far as possible, notwithstanding the rapid advancement of technology, mobile devices should be future-proof to maximise their sustainability.
6. The software used to create content should be free, accessible, easy for academics to use with some guidance (thereby avoiding a heavy and expensive reliance on learning technologists), and work across a range of devices.

Taking these principles into account and after considerable research into available options, a range of devices was selected and purchased. These included: iPods, digital camcorders, PDAs, and WAP mobile phones. As shown in Table 1, each device was explicitly linked to each cohort's learning needs, as identified via the methodology outlined above (refer principle 1).

Table 1. Examples of mobile learning trials

Discipline/Context	Need	Device
Podiatry (training clinic, community)	Reflection; evidencing learning outcomes; peer mentoring	Camcorder
Post-registration cognitive behavioural therapy (community)	Reflection; supervision of practice	Camcorder
Post-registration consulting skills (community)	Reflection; supervision of practice; evidencing learning outcomes; peer and tutor feedback	Camcorder
Podiatry (hospital, community)	Access to lectures and video podcasts on clinical skills	iPod
Podiatry, clinical psychology & learning disability nursing (hospital, community)	Tutor and peer support; access to email; access to library resources; access to practical placement information	Mobile telephone
Social work (community)	Access to podcasts of lecture material	iPod

Feedback from students and staff was collected throughout the project period and changes were made in response to the feedback. Thus, the technical strand of the project was explicitly developmental and iterative rather than waiting until the end to discover difficulties or problems. For example, some students had difficulty downloading files onto iPods; therefore appropriate and timely support was provided to ensure that all students were able to benefit from their participation in a trial.

Having identified pedagogic need and potential technological solutions, one of the challenges that arose was meeting this need in an equitable and inclusive way. This led us to formulate a seventh principle:

7. The use of mobile devices to support learning must be inclusive; no student should be disadvantaged by not being able to afford or access the required mobile resource.

An issue that faced the project team was whether devices should be loaned or given to students. While giving devices to students would no doubt constitute a reward for them (in line with the funding body's concern to reward students with funding), loaning devices would provide more students with access. For this reason, the decision was taken to loan devices to full cohorts of students for time periods related to their learning need. This approach enabled the flexible use of devices to meet specific student need. For example, a cohort might borrow an iPod preloaded with

clinical-skill videos for one placement and a digital video recorder to film their performance of a clinical skill for another. Moreover, it represented an inclusive approach because students did not have to purchase the equipment to facilitate their learning, which might have disadvantaged students on lower incomes.

Careful consideration was given to the best way to loan devices to students. The decision was made to use the same system that the university employed for loaning library books. The advantages of the system were that it was familiar to staff and students; it enabled reports to be pulled across individuals, devices, or trials; and it was linked to the generation of fines in line with university policy.

A further facet of an inclusive approach is that students and staff do not just have equal opportunity to access the device, but are also able to use it effectively. Clearly, there are differences in terms of the skills that students and staff have in relation to using mobile devices. While some users can be considered digital natives (Prensky, 2001) and are tech-savvy, a substantial proportion of our students are not affiliates of the net generation (Tapscott, 1998) and even regard themselves as technophobes. This led to the formulation of our eighth principle:

8. All students engaged in mobile learning and all staff supporting such learning should receive appropriate training in the use of devices as well as ongoing support.

Training students to use the devices effectively for learning was seen as crucial to the success of the initiative. Workshops were held with every student cohort prior to their departure to placement areas. This had a number of aims: to issue the devices, demonstrate the device functions, enable students to become familiar with the device, provide students with the opportunity to ask questions and voice anxieties, introduce the evaluation team and begin the evaluation, and provide details of ongoing support. Further support entailed email and telephone access to a learning technologist or face-to-face appointments.

The project was framed by an integrated approach to evaluation, which was utilisation focussed in order to situate the operational use of the findings as the vanguard of the evaluation's purpose (Patton, 1986). Thus, evaluation was embedded at all stages and levels of the project, rather than included only at the end. This enabled the team supporting the students to gain up-to-date, relevant information in order to provide timely and optimal support. This upheld Rutman and Mowbray's (1983) assertion that the role of evaluation is to engage in "evaluation for improving programme delivery and making it more responsive to client needs" (p. 23), and led to the development of the ninth principle below:

9. Systematic evaluation should be integrated into the mobile learning and teaching experience.

The final principle originated from the researchers' desire to ensure that the project both enhanced placement learning and teaching through the PE process and contributed to knowledge within the field of m-learning and educational technology.

10. Existing theory and research should inform an understanding of how students might use mobile devices for learning.

Existing theory and research, in particular social cognition theory, was used, therefore, to understand the determinants of m-learning behaviour and student motivation to engage in this form of learning.

Tribulations and triumphs! Application of the principles in practice

As noted, pedagogic need was initially defined by staff. However, through ongoing evaluation, students confirmed that they faced a range of challenges on placement. The potential of mobile devices to meet these needs was perceived as a positive and exciting development by students, offering them access to information and support where previously unavailable or where access to IT was limited. Students also felt that certain mobile devices would enable them to share with and learn from other students on placement, and that this would enhance their learning experience overall.

Students and staff generally reported positively on the use of devices in different learning contexts. In all of the trials, the selected device met the identified student need, and in some cases exceeded it. For example, the majority of students felt that the camcorders were easy to use and offered a large number of benefits to learning as the following quotation illustrates:

“...it’s quite good for reflection purposes, because some things . . . um . . . you may not realise you do in clinic, but you look back and think, ‘oh, I shouldn’t have done that,’ or ‘this part was good; I’ll do it again.’”

Preloaded and downloadable video and audio information was seen as useful for quick reference and revision. Typical student comments included the following comment from the podiatry cohort:

“I think, like I said, it’s easy to go to it to re-cap on something. Um, it’s another reinforcement of your learning isn’t it?” and “It’s concise, condensed, and it’s appropriate and um relevant to what we learn.”

Generally, students enjoyed engaging with the additional method of learning that mobile devices offered them. Typical comments included the following:

“I think it was good to have a different sort of source of learning rather than just the books or . . . just like a bit of variety keeps your interest a bit more” and “It was easier to access other than like trawling through a book.”

Ensuring that pedagogy drives the use of technology in educational settings resulted in successful outcomes for students and staff in terms of enhancing students’ learning and meeting their learning needs.

The relationship between academic and practice staff became a key issue in the trials. In those disciplines where this relationship was characterised by regular dialogue and mutual support, the introduction of this new initiative generally went smoothly. However, in one trial, practice staff felt that the use of mobile technology to support learning had “been imposed by the university” and there was considerable resistance to it. In fact, this situation led to a closer working relationship as resolution was achieved and to substantial and growing support from the practice area for the use of mobile technology to support learning.

Ongoing dialogue and partnership between academic and practice staff and students were key to the successful implementation of m-learning. This was maintained through regular planned and ad hoc communication via email, telephone, and meetings, as well as through training sessions. Through dialogue significant obstacles were overcome. One of the most challenging of those obstacles was the use of mobile devices in sensitive settings and the host of concerns that this generated, including patient confidentiality, consent, data protection, and infection control. These concerns were systematically resolved through close and collegial working across higher education institution and practice environments, resulting in the production of documentation that governed the issues and enabled devices to be used ethically in practice for student learning.

While dialogue within each discipline was crucial, the overall success of implementing m-learning was dependent on a multidisciplinary team that included learning technologists, psychologists, and library and computing staff. A number of unexpected outcomes accrued from this approach, most notable being the benefits of working across academic and support boundaries. While it is obvious that academic and support staff represent two halves of a coin in delivering high-quality education to students, the divide between academic and support staff within universities is rarely crossed. Yet joint working resulted in enhanced provision for students, fostered collegial working relations, and enabled the reciprocal transfer of knowledge and skills. For example, the researchers ran workshops for library staff on focus-group facilitation to evaluate their services, and library staff provided training in the use of the library system to book out devices. Evaluation showed that the most successful trials in terms of students’ positive experience of learning with a mobile device were those where a closer working relationship was apparent between academic and support staff, enabling the development of academically sound and technically efficient resources.

In line with our principle that the mobile devices chosen should be user-friendly and easy to operate, students reported that trialled devices had been beneficial because they were “portable,” “great to use when travelling” (e.g. from one clinic to another), “useful to listen to in the car while driving,” “saved space rather than carrying books and lecture material,” and were “easy to use.” A few students were so taken with the iPod that they stated their intent to buy their own when the trial ended. Students also reported using their devices beyond the intended remit of the trial, either using functions available on the device that were not explicit in the trial (e.g., the production of a health and safety video) or extending the use of the selected function beyond that which was required of them (e.g., downloading additional reusable learning objects that students had found themselves).

A number of students did report issues with the devices that were not easily solved. Some found small screens difficult to get used to and the text too small to read, especially when they were tired. One student explained that one of their resources involved “lots of different columns” so she “couldn’t find where things were quickly.” A number of students found the device “another piece of equipment to drag around on placement,” when they already had their own mobile devices. A couple of students reported that listening to audio files while driving from one placement context to another was too distracting while a number of others wished for more detailed content within podcasts. Attempts to future-proof the technology were always going to be limited given the rapid rate at which mobile technology is advancing. However, the majority of students were excited to be given mobile devices and these were generally either of a higher specification than devices they owned themselves or the students did not own the device at all. Thus, over the three-year period attempts to future-proof the devices were successful and this equipment continues to function well in supporting learning.

The third principle relating to technology concerned the use of free, readily available software that was relatively easy to use and would work across a range of devices. This principle, however, was possibly the most difficult to achieve for two main reasons. First, technical staff have their own preferences regarding software, which can cause confusion to academics, particularly as the project had a high turnover of technicians for reasons beyond its control. For example, an academic would work with a learning technologist to develop a trial. However, if that technologist left their employment, the new technologist might be unfavourably disposed to the software used and the way in which the technology had been developed, suggesting that the trial and resources should be redeveloped with an alternative package. As academics often do not have the technical expertise to know what is or is not really necessary, this process could be very disempowering and potentially detrimental to the trial. A second issue was that some academic staff struggled to find the time to develop mobile content and manage mobile systems of support in addition to their workload. Thus, like e-learning, the development of m-learning also requires the frontloading of resources and can occasionally tax even the most committed academics. Therefore, while this principle was achieved in practice, the implementation thereof was challenging.

Loaning devices via the library system proved to be an effective way of ensuring that the devices were accessible and returned appropriately. Despite initial concerns raised about loaning students expensive devices, students were responsible and accountable in looking after and returning them. They did not abuse the cost ceiling, set in terms of texts, talk, or downloading, and returned devices in a timely manner. Interestingly, the few problems that were encountered were with staff members who did not return devices or ran up bills for talking and texting.

Ongoing evaluation led to the continuous improvement of the training offered. It became apparent that more was better — for both students and staff. Furthermore, it was discovered that the link between the identified learning need and the way in which the device could be used to meet that need had to be made explicit during training, even if they were familiar with the device. The specificity required for this training was made clear in an early trial involving podiatry students’ use of digital camcorders. Students were encouraged to use the device to meet their learning needs however they wished. Yet, while a minority of students produced outstanding creative work, the majority were unsure how to use it for learning and subsequently did not engage. The evaluation data from this and other trials resulted in modification of the training package to include making the link explicit between the device and learning. This led students to engage more fully with trials and, hence, become more confident in their exploration of the device for other learning-related uses.

The evaluation also revealed that the enthusiasm and commitment of staff to m-learning contributed to the engagement of students with the initiative and ongoing use of the devices. Therefore, wherever possible, training included all of the stakeholders including academic and clinical staff, who would support students in practice, thereby ensuring all educators and learners understood how mobile devices were being used to facilitate learning.

The evaluation and research elements of the project were conducted by the Cepl’s research team and included interviews with students at appropriate points. The utilisation-focussed evaluation was constructive in enabling timely response to any issues that presented themselves in the course of trials to ensure that the potential benefits to learning were realised. Further, the research programme provided understanding of the characteristics and beliefs of students and the effect that these can have on engagement with m-learning.

Conclusions and moving forward . . .

Student involvement in new learning and teaching initiatives is crucial, and it was hoped that the project team would include a student voice. Although a digital arts placement student provided some of the technical support, unfortunately, and not unusually, it was not possible to fully achieve this objective because the health and social care students who were the focus of this project were unable to devote the time required for such involvement. Thus, while students were involved in the evaluation at all stages of the project, they were not directly involved in developing and designing learning resources. In the future, this could be overcome through linking student involvement to their programme of study; for example, through enabling students to achieve their learning outcomes through membership of the project team.

The role of champions in promoting a new learning and teaching initiative remains crucial. Without that passion, determination, and commitment effecting change and engaging stakeholders would be virtually unachievable. As Hall (2006) noted, it is vital to ensure that academic staff are engaged in developments or they may become disengaged and “lost.” Facilitating change through frontline subject specialist teachers (i.e., from the grass roots up) and an organic process ensured the sustainability of mobile learning initiatives.

Understanding departmental and university culture and context has been seen to be essential in embedding m-learning initiatives (Traxler, 2005). In the case of placement learning of health and social care students, further account needs to be taken of the ethical and safety issues impacting on learning within a diverse range of environments, and the cultural issues concomitant with these. It has become clear during the course of this project that a combination of communication and an understanding of placement area needs within the multiple contexts of the higher education and the health and social care sector are vital in ensuring the acceptance of m-learning across placement settings.

In conclusion, our experience has highlighted the value of working within an interprofessional team committed to enhancing learning. Our findings are based on a large three-year programme of research that was unique in both the diversity and scope of trials. On this basis we believe that success in mobile learning needs to be based on a clear set of principles to ensure effective pedagogy for both staff and students.

Acknowledgements

This work was funded by the Higher Education Funding Council for England’s Centres for Excellence in Teaching and Learning initiative.

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Online Behavior in Virtual Space: An Empirical Study on Helping

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ABSTRACT

Although previous studies have acknowledged that helping behavior has many potential benefits, little research has aimed at understanding which factors would possibly enhance helping behaviors among team members in CSCL environment. Accordingly, this study was intended to identify underlying factors leading learners to collaborate in virtual CSCL settings. A total of 100 undergraduate students enrolled in organizational behavior course participated in this study. Participants were divided into 20 work teams and were asked to collaborate with team members to successfully complete their team report on time. This study corroborated that social identity was a critical preceding antecedent of the engendering of learners' helping behaviors. According to our empirical results, learners strongly identifying themselves with the team perceived a high sense of norms of collaboration and a strong trust in team members, which in turn would result in the delivery of more helping behaviors. Implications for educators and instructors to enhance helping behaviors among team members in CSCL environment are also discussed in this paper.

Keywords

Social identity, Norms of collaboration, Trust, Helping behavior, CSCL

Introduction

The advent of computer supported collaborative learning (hereafter CSCL) brings more opportunities for learners to conduct peer-to-peer interactions in e-learning environment. It is therefore easier for learners to realize knowledge exchange by providing help to team members dispersed geographically. Therefore they can learn from one another in many ways, such as recognizing and resolving different viewpoints (King, 1992; Webb, Farivar, & Mastergeorge, 2002; Webb & Palincsar, 1996). Although previous studies have acknowledged that helping behavior has many potential benefits for the immediate work team and the organization (Moorman & Blakely, 1995; Organ, 1990; Podsakoff, MacKenzie, Paine, & Bachrach, 2000; Van Dyne & LePine, 1998), few studies have aimed at understanding which factors would possibly enhance helping behaviors among team members in CSCL environment, thereby the issue stands out as particularly important.

Based on the social identity theory (SIT; Tajfel, 1972; Tajfel & Turner, 1986), this study postulates social identity as a preliminary determinant in explaining one's helping behaviors in CSCL context. There are two reasons for us to draw on SIT to sustain our speculation. First, social identity is defined as a sense of belonging to a team, which is consistent with the premise of collaborative learning proposed by Rourke (2000). He argued that students need to trust each other, feel a sense of warmth and belonging before they engage in collaboration. Finally, from a psychological perspective, through social identification individuals perceive themselves as psychologically intertwined with the fate of the team (Hewstone, Rubin, & Willis, 2002; Lewicki & Bunker, 1995; Rimal & Real, 2005; Tanis & Postmes, 2005; Tanis & Postmes, 2007) and are more likely to internalize the normative behaviors as they identified with their team (Haslam, Postmes, & Ellemers, 2003; Postmes et al., 2005a; Postmes et al., 2005b). While works in SIT argue that simply categorizing individuals into a common team is enough to increase their altruism toward the team (Tajfel, 1981; Tyler, 1999), it seems reasonable that making social identity salient is also conducive to increase cooperation. Thus, in this study SIT was referred to as an insightful framework to explain learners' helping behaviors in CSCL settings.

Literature Review

Helping behaviors

Several studies have demonstrated that students derive numerous benefits from working in collaborative teams, for example, by giving and receiving help, sharing knowledge, building on each others' ideas, recognizing and resolving

contradictions between their own and other students' perspectives (Webb & Palincsar, 1996). From Vygotsky's (1981) view, cognitive potentially benefit from the helping behaviors embedded in the social interactions, such as giving help and receiving help. It is not the intention of this study, however, to consider the cases of receiving help, because research has corroborated that the impact of giving help on learning performance is stronger than receiving help (King, 1992; Palincsar et al., 1993). Furthermore, our focus is on investigating how learners' helping behaviors are engendered.

Trust in team members

Empirical evidence has corroborated that trust is important for successful online interactions (Jarvenpaa & Leidner, 1999; Kanawattanachai & Yoo, 2002). Research in this field commonly regards trust as a psychological phenomenon. Psychological states are referred to as affective or cognitive process associated with situational contexts and may be influenced by the person's interaction with the situation (Lewicki & Bunker, 1995). McAllister (1995) thus defined interpersonal trust as "the extent to which a person is confident in, and willing to act on the basis of, the words, actions, and decisions of another" (McAllister, 1995, p. 25). In this study, our focus is put on interpersonal level of trust in team members, because it would be influenced by the person's interaction with situations (Bhattacharjee, 2002; Jarvenpaa & Leidner, 1999; McAllister, 1995).

The willingness of team members to harmoniously collaborate is likely to be contingent on whether their collaboration would put them at risk of being taken advantage of by a partner (Mayer, Davis, & Schoorman, 1995). In this regard, trust refers to a belief about the dependability of the partner, which results in one's willingness to be vulnerable to others because of an expectation that others will perform actions favorable to his/her interests (Mayer et al., 1995). In situations with high levels of trust, people are more willing to take risks (Dirks, 1999) because they feel safe to do so. Furthermore, trust also refers to an effective means to promote knowledge sharing (Williamson, 1985) and exchanging resources (Tsai & Ghoshal, 1998) among team members to accomplish ongoing tasks. These processes mark trust as an important factor in collaborative interaction to solve problems. Therefore, team members who trust each other tend to feel psychologically safe to facilitate helping behaviors because "it alleviates excessive concern about others' reactions to actions that have the potential for embarrassment or threat" (Edmondson, 1999, p. 355).

In conclusion, trust generally refers to the belief that people maintain about the other party's future behavior. Empirical evidence was supported by Dirks's (1999) study, which proposed that members in high-trust teams demonstrate more helping behaviors when individuals anticipate that others will not take advantage of their assistance. In this regard, trusting team members is a kind of psychological safety condition which provides individuals with the assurance that knowledge and information will be used for the ongoing task. Based on this perspective, we propose that:

H1: Learner's trust in team members will significantly affect his/her helping behaviors.

Norms of collaboration

Norms are shared patterns of thought, feeling, and behavior within a team. It refers to a guideline that tells members in a team what they can and cannot do (Hogg & Tindale, 2005; McGrath, 1984). According to Hackman's (1992) definition, norms typically regulate activity that is important to the team. Furthermore, from theoretical perspective, social comparison theory (Festinger, 1954) suggests that we make assessments about appropriate modes of conduct by comparing ourselves with others in our social midst. When we are unsure about how to behave in a new or unfamiliar situation, we look to the behaviors of others (Tanis & Postmes, 2007).

One type of normative belief that may become codified as a beneficial norm in work teams is the expectation that members will cooperate with one another (Cialdini, 2001; Wageman, 1995). Because normative behavior is reinforced by society, knowledge that others are behaving in a specific fashion should create pressure on a person to also do so (Festinger, 1954). Specifically, people may reason, "If everyone is doing it, it must be a sensible thing to do" (Cialdini, Reno, & Kallgren, 1990). In this regard, team norms for helping partners may signal that assisting other members is an approved and sanctioned behavior (Cialdini, 2001). Therefore norms in this study specifically

represented norms of cooperation because it was the major concern of this study. In addition, individuals make assessments about benefits and cost that are likely to result in and they judge the acceptability of the behaviors, leading to a high possibility of formation of beneficial norms in problem-solving teams (Rimal & Real, 2005). This is also one of the central tenets of social cognitive theory (Bandura, 1977).

In sum, when a team has a strong team norm for cooperation, members expect each other to engage in information sharing and other behaviors to enhance the completion of task (Cialdini, 2001; Rimal & Real, 2005; Wageman, 1995). Many exchange relationships are driven by a quid pro quo orientation, in which individuals cooperate and help each other to compensate for past help received or in anticipation of help needed in the future (George & Jones, 1997). This shared expectation therefore creates a collective relationship, consequently enhancing learners to feel obligated to help each other and feel responsible for doing so as well, and thereby leading to increased helping and cooperation (George & Jones, 1997). In contrast, teams with weak cooperative norms tend to highlight independence rather than cooperation, diminishing helping behaviors. Accordingly, the following hypothesis is then proposed:

H2: Learner's norms of collaboration will significantly affect his/her helping behaviors.

Social identity

Social identity was defined as "individual's knowledge that he belongs to certain social teams together with some emotional and value significant to him of this team membership" (Tajfel, 1972). Social identity theory (SIT) argues that people classify themselves as belonging to various social categories according to age, gender, socioeconomic status, interests, skills, etc. (Tajfel & Turner, 1986). The underlining assumption of SIT is that the individual feels affinity and desires connection with the referent team, which in turn influences their behaviors (Tyler, 1999). The present study therefore adopted perspective from SIT and assumed social identity to be the antecedent of team norms and trust in team members because studies have shown that we are influenced not only by the behaviors of others but even more so by behaviors of similar others (Bandura, 1977; Postmes et al., 2005a; Rimal & Real, 2005).

People tend to perceive members of their own teams in relatively positive terms (Hewstone et al., 2002). Indeed, several studies have noted that under conditions of collective identity, other team members are perceived as more trustful (Rimal & Real, 2005; Tanis & Postmes, 2003; Tanis & Postmes, 2005; Tanis & Postmes, 2007). In addition, although trust is expected to have a positive effect on the individuals' cooperative, voluntary contributions to the team (Dirks, 1999; Edmondson, 1999; Tsai & Ghoshal, 1998), trust alone may not be enough to induce the learners' discretionary efforts, namely helping behavior in the present study. Drawing on Social Identity model of Deindividuation Effects (SIDE; Reicher, Spears, & Postmes, 1995), empirical evidence also has documented that a strong team identity leads individuals to think that their members are more dependable and to display positive evaluations of in-team members (Tanis & Postmes, 2007). Thus, when social identity is reinforced, fellow team members will be evaluated as more trustful. Based on the above line of reasoning, the following hypothesis is proposed:

H3: Learners' social identity will significantly affect learners' trust in team members.

It is assumed that the norms express important aspects of the team's identity and that team members are motivated to act in accordance with the team norms because it is perceived as the right and proper thing to do (Tajfel & Turner, 1986). Based on this perspective, once identified, individuals are viewed through the lens of the relevant team prototype and are represented in terms of how well they embody the prototype. In fact, this assertion can be derived from several theoretical perspectives, including Social Cognitive Theory (SCT; Bandura, 1977) and Referent Informational Influence Theory (RIIT; Turner, Wetherell, & Hogg, 1989). In line with SCT, we are influenced by the actions of the models whom we aspire to become because of the individuals' outcome expectation. Likewise, RIIT also postulates that when people categorize themselves as a team, their perceptions of the team norm become more extreme. As a result, in the absence of the social identity, there is no reason to expect team identity to affect the individuals' behavioral choices. Rather, as the individuals' identity with members of reference team grows stronger, their compliance with the team behavior will be more observable to other team members. In line with this theoretical reasoning, it is assumed that when a team identity is salient, a shared norm of cooperation will be likely to be adopted and replicated. Accordingly, the following hypothesis is then proposed:

H4: Learners' social identity will significantly affect norms of collaboration.

Research Methods

Based on the aforementioned literature review, our research framework was then depicted as Figure 1. Social identity is the most precedent factor in this study, which was expected to have an influence on learners' perception of trust in team members and team norms. In turn, trust in team members and team norms would take effect on learners' helping behavior.

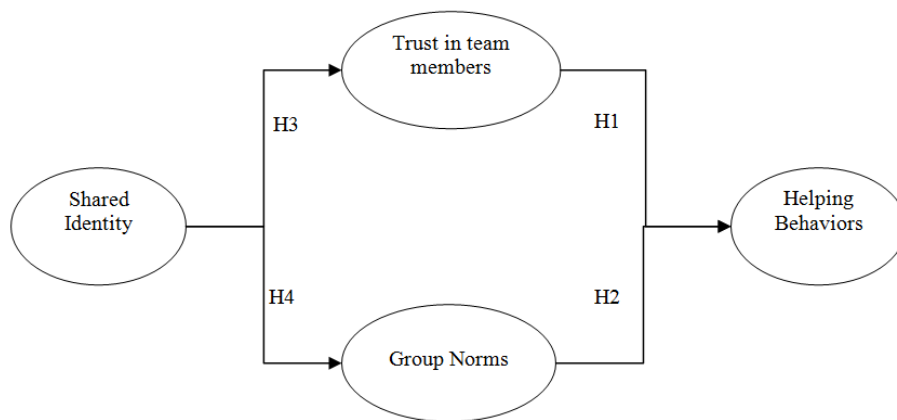


Figure 1. Research model

Samples

Two classes of undergraduate students were recruited in this study. The total number of participants was 100, each class having 50 participants. These two classes were chosen because one is in night school Bachelor's program, whereas the other is in normal Bachelor's program. The course title was organizational behaviors. Although the course was held in both two classes, the instructor of the two classes was identical. In general, the instructor delivered fundamental knowledge concerning organizational behaviour to learners in traditional classroom every week. Learners were asked to referring to the online material, which was launched in the self-developed CSCL system. Participants in the course were encouraged to access the content to better understand the underling theories that drive employees' behaviour in a company. The aim of the course was to equip learners with the capability to elaborate one's behaviour from various perspectives based on the theories. Considering the lecture time of the two classes was quite different, this study divided participants into 20 virtual groups, each consisting of 5 members. Despite the fact that most lecture time was different, the instructor arranged for the chance of face-to-face twice in the semester. The first was held for the purpose of announcing the member list of each group for them to have a first interaction with the members. The last one was held for the purpose of presenting the outcome of each group. Participants were informed that quantity of conversation would be automatically recorded by the system and then as part of their final grade. However, it was impossible for this study to prohibit participants from using other communication tools such as MSN, Skype and so on. Obviously, it was one of the limitations in this study to entirely preclude the possibility that learners exploited other communication tools they were more familiar with as alternatives to interact with one another.

Procedures

After the middle examination has been held, each team expressed its preference for a real-world business cases and then was assigned a particular case, which they presented to the class at the end of the semester. All of the real-world business cases to be solved generally included the development of a strategy based on marketing principles; in some cases they required the design of a product. Although no team took redundant case as its learning task, the natures of all cases were equally unstructured. The requested final product about the task was a case write-up and a twenty-minute presentation, both of which were evaluated by the instructor according to specific written guidelines that were given to students in the course syllabus. During the eight-week web-based team collaboration period, participants

were asked to complete a team-based assignment to successfully complete their team report on time. All participants would then be notified that the team assignment was required to complete by the way of virtual team collaboration. They would, in addition, be told that the nature of the requested assignment is highly interdependent because all members were required to participate in the task and would receive the same team score as part of their final grades.

Throughout the eight-week teamwork, students needed to access the self-developed CSCL web-based system to communicate with other team members. In this study, we developed an online discussion board system which allows group members contribute their ideas on the case problem and inquire others' comments on their proposed solutions. Every poster and its correspondence were all recorded automatically by the system. The self-developed CSCL system included two main sub-windows; one was for learners to read course material, and the other was for learners to post any message they want to share. Each group had a unique discussion board in cyberspace to enhance a sense of group. Thus, participants read a shared material content in a sub-window and accessed the message dedicated to their groups in the other at the same time. The system provided threaded discussion spaces for learners to asynchronously contribute their viewpoints on the case problem, clarify or elaborate their solutions on the case problems. Each team has a corresponding threaded discussion board in the system to enhance a sense of team.

Measures

We used five measures to assess corresponding constructs. Subjects were asked to answer each question according to their perceptions on the degree they agreed or disagreed with the statements (ranging from 1, strongly disagree to 5, strongly agree).

Social identity was measured by 6 items adopted from Tyler (1999). Tyler's items were chosen because the scale was originally developed for identifying one's feeling about the closeness to his friends, which more satisfy with the purpose of this study. *Trust in team members* was measured by 7 items from McAllister's (1995) and Kanawattanachai and Yoo's (2002) scales. *Norms of collaboration* were measured by 4 items adapted from Wageman's (1995) cooperation norm scale. We chose the scale because group norms may not always be beneficial. From a brief literature review, one type of normative belief that may become codified as a beneficial norm in work teams is the expectation that members will cooperate with one another, which is the construct that Wageman's scale attempts to measure. *Helping behavior* was measured by 7 items from Van Dyne and LePine's (1998) scale. We adapted items from their scale because helping behaviors, according to their study, is a kind of affiliative-promotive behavior. Specifically, cognitive potentially benefit from the helping behaviors embedded in the affiliative-promotive interactions. Therefore, we adopted their scale and chose some items associating with helping behavior as the measurement.

Result

Assessment of the research model was conducted using Partial Least Squares (PLS) Version 3.00 Build 1058 to test the model. PLS places minimal restrictions on measurement scales, sample size, and residual distributions (Chin, Marcolin, & Newsted, 2003). All of the participants in this study answered the questionnaire. The high response rate was easily achieved because they were all enrolled in the class and were asked to filled out the questionnaire at the end of the semester.

Table 1. Correlation matrix of study variables

Construct	AVE	1	2	3	4
1. Share identity	0.66	0.81 ^a			
2. Trust in team members	0.58	0.74	0.77		
3. Group norms	0.72	0.62	0.71	0.85	
4. Helping behavior	0.54	0.59	0.66	0.71	0.73

^aIn Table 1, diagonal elements (shaded) are the square root of the AVE of each construct. Off diagonal elements are the correlations among constructs. For discriminant validity, diagonal elements should be larger than off-diagonal elements.

Table 2. Summary of measurement scales

Indicators	Items	Mean	S.D.	Loading
Social identity (SI)				
Composite reliability = 0.92, Cronbach's alpha = 0.89				
SI1	What my team members care is what I desire.	4.33	0.60	0.78
SI2	I am proud to tell others that I am part of the team.	4.06	0.86	0.85
SI3	Being a member of this team distinguishes me from other people.	4.02	0.84	0.79
SI4	I am always with my team members.	4.18	0.77	0.88
SI5	In my team, we have the same value.	4.20	0.64	0.84
SI6	I feel like I really fit in with this team	4.20	0.74	0.74
Trust in team members (T)				
Composite reliability = 0.90				
T1	I can rely on other teammates not to make my job more difficult by careless work	3.99	0.73	0.71
T2	Most of my teammates can be relied upon to do as they say they will do	4.14	0.64	0.77
T3	If I shared my problems with my team, I know (s)he would respond constructively and caringly	4.05	0.67	0.81
T4	I would feel a sense of loss if one of us was transferred and we could no longer work together	4.18	0.69	0.76
T5	Most of my teammates approach his/her job with professionalism and dedication	4.20	0.80	0.75
T6	I can talk freely to my team about difficulties I am having at work and know that my team will want to listen	4.02	0.89	0.73
T7	I see no reason to doubt my teammates' competence and preparation for the job	4.27	0.69	0.81
Norms of collaboration (NC)				
Composite reliability = 0.88				
GN1	In my team, we expect everyone to assist one another in order to benefit the team.	4.26	0.60	0.86
GN2	My team's norm is to help one another with our assigned team tasks.	4.20	0.57	0.81
GN3	In my team, we think that everyone should volunteer to do things for the team.	4.17	0.68	0.86
GN4	I can count on the team to help me when I need help	4.20	0.74	0.74
Helping Behaviors (HB)				
Composite reliability = 0.89				
HB1	I have provided needed resources to support other team members.	4.45	0.59	0.71
HB2	I have encouraged my team members to make the collaboration in a pleasant atmosphere.	4.32	0.60	0.68
HB3	I have presented information or have discussions with other members to improve our work.	4.24	0.53	0.71
HB4	I have helped other team members with their work responsibilities.	4.04	0.62	0.73
HB5	I have explained what should be done to my team members who encounter problems with the task at hand.	4.09	0.67	0.79
HB6	I would get involved to benefit the team.	4.15	0.63	0.76
HB7	I would volunteer to do things for the team.	4.15	0.72	0.76

Measurement model

The square root of the AVE, according to Fornell and Larcker (1981), is suggested to be greater than the correlation shared between constructs. Table 1 listed the correlations among constructs, with the square root of the AVE on the diagonal. The diagonal values exceed the inter-construct correlations, which indicated a satisfactory discriminant validity. Convergent validity means a highly correlated among the indicators. Convergent validity of the scale in this

study was examined followed the criteria proposed by Fornell and Larcker (1981). First, factor loadings should be significant and exceed 0.70. Second, AVE of each construct must greater than 0.5. AVE ranging from 0.54 to 0.72 (Table 1) indicated that all constructs have demonstrated a good convergent validity.

As shown in Table 2, items for each construct were listed. In addition, Table 2 also showed the mean, standard deviation for each item, as well as the Cronbach's alpha coefficient and composite reliability of each construct. The Cronbach's alpha coefficients for each construct were all well above 0.7, which indicated that the scales employed had a good reliability (Robinson, Shaver & Wrightsman, 1991). Most items had a loading of higher than 0.7 on their corresponding constructs, providing evidence of acceptable item convergence on the intended constructs. One exception was the second item of the helping behavior scale, which loading was 0.68. By and large, the overall reliability of the scale was acceptable (Robinson, et al.).

Structural model

As shown in Figure 2, the effects of trust in team members ($\beta = .254, p < 0.05$) and team norms ($\beta = .511, p < 0.05$) on helping behavior were significant. These results showed that trust in team members and team norms were significant factors in enhancing helping behaviors in CSCL environment. Hence Hypothesis 1 and Hypothesis 2 were supported. Hypothesis 3 posited a positive link between social identity and trust in team members. The path was positive and significant ($\beta = .742, p < 0.001$), supporting the contention that social identity increases the level of trust in team members. Hypothesis 4 supposing that social identity enhances team norms was also supported. We found that social identity had significantly positive effect on team norms ($\beta = .657, p < 0.001$). This result indicated that learners having higher level of social identity perceived higher level of norms of collaboration, thus supporting Hypothesis 4.

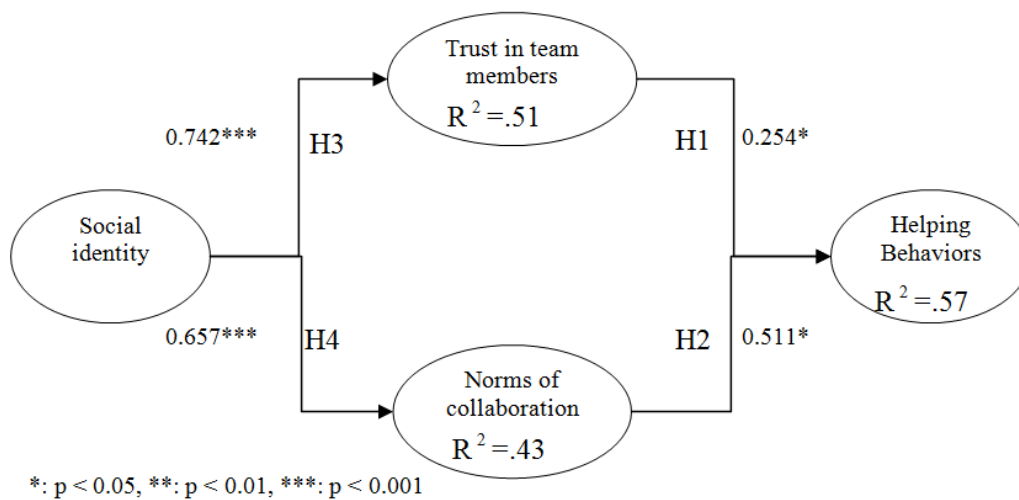


Figure 2. Path coefficient in the proposed model

Given that Hypothesis 3 and Hypothesis 4 were supported, we were also interested in assessing whether social identity would directly affect helping behavior or if there is any interaction effect. To evaluate this relation, we followed the four-step procedure outlined by Baron and Kenny (1986) to test the mediating effects of team norms and trust in team members. As can be seen in Table 3, the models examining team norms and trust in team members as potential mediators indicated that these factors only partially mediated the effects of social identity. However, team norms and trust in team members in the same step revealed that, in combination, both variables fully mediated the effect of social identity. Furthermore, a moderator means that the relationship between two variables changes with the level of another variable/construct. Interpretation of moderators is more difficult because a moderator becomes more highly related to either of the other variables involved in the analysis. Therefore, the analysis of moderator is easiest when the moderator has no significant relationship with either the predictor or the criterion. The lack of a relationship between the moderator and the predictor and criterion variables helps distinguish moderator from mediators. Taken together, these models suggested that one pathway through which learners' social identity shaped their helping behaviors was by influencing their perception of team norms and trust in team members.

Following Baron and Kenny's (1986) suggestion, we used moderated regression analysis to further test the moderating effects of team norms and trust in team members. As can be seen in Table 3, the interaction effect for social identity and team norms was not significant. Likewise, the interaction effect for social identity and trust in team members was not significant too.

Table 3. Results of mediated regression analysis and moderated regression analysis

Variables	Beta coefficients	
Group norms	.418***	
Trust in team member		.297**
Shared identity	.402*	.307*
Shared identity × Group norms	.278	
Shared identity × Trust in team member		.266
R ²	.441	.481
Adj. R ²	.282	.461

*. p < 0.05, **. p < 0.01, ***: p < 0.001

Discussions

A PLS model usually is analyzed and interpreted in two stages: 1) the assessment of the reliability and validity of the measurement model, 2) the assessment of the structural model. The measurement model consists of the relationships between the constructs and the indicators used to measure them. Based on the empirical evidence shown in Table 1, both factor loading of the indicators and AVE of the studied constructs followed the criteria, which specifically implies the acceptability of the convergent and discriminant validity of the research instrument.

The empirical evidence revealed that social identity had indirect effects on enhancing helping behaviors through trust in team members and norms of collaboration. Based on our findings, we further asserted that maintaining a high level of trust in team members and norms of collaboration may be due to a high level of social identity. A high level of social identity encouraged members to trust their partners, and thereby enhanced their willingness to provide help. By giving and receiving help, each team member shared knowledge and internalized problem-solving processes that emerged during team work (Webb & Palincsar, 1996), thereby increasing team performance. Therefore, we concluded that teams whose members with a strong social identity will outperform other teams. Future research may examine this assertion to see if it is supported.

Regarding trust in team members, this study found trust had positively associated with helping behaviors. To our knowledge, a common problem prevail in collaborative groups is occurrence of negative effects such as social loafing (Latane, Williams, & Harkins, 1979) and sucker effect (Kerr, 1983). Social loafing is the phenomenon that individual effort usually reduces when working in groups compared with the individual effort when working alone. Similarly, sucker effect is the tendency that one does little or no work because other group members contributes almost nothing to the well being of the group, and thereby decreasing the whole group's performance. In sum, both of which suggest that groups refuse to further support noncontributing members and thereby reduces their individual efforts and hampers the entire group benefit. With a high level of trust in team members, learners seem have no reason to doubt their members' competence and preparation for the task, and thereby increasing helping behavior, which, we believe, can effectively diminish social loafing and sucker effect in the virtual group. Since learners in virtual settings cannot frequently and physically monitor other members' effort, it seems that a mechanism to facilitating distant trust among team members is an essential ingredient towards developing successful helping behaviors. This would be helpful for learners to share problems with other members to obtain constructive and caring response. Accordingly, an urgent issue is how to promote trust in team member. But the solution seems rather complicated. This study has acknowledged the notion that trust plays a critical role in collaborative activities; however, given the absence of a shared work history, and the limited options of communication channels, working in a CSCL setting can possibly be disastrous because it seems harder for group members to gather information and evaluate one another's behaviors in virtual settings. Accordingly, educators and instructors should be aware of that managing learners' trust in virtual peers is a novel and crucial factor, while designing online activities in CSCL settings. Consequently, educators and instructors should refer to learners' perception of trust in team members as a crucial mechanism in CSCL.

Another factor that had a direct effect on enhancing helping behaviors was team norms. Group norms is another factor enhancing helping behaviors among team members. Some learners may take a greater role in leading the group and do a major share of the work, while others do less work or none at all. It is clear that assigning students to groups does not necessarily mean that they will work collaboratively. Group norms have characteristic of reciprocity that benefits individuals and particularly the whole group. Consequently, for educators in CSCL, this may imply that much attention needs to be paid to develop strategies that help the formation of a reciprocal norm. Rather than attempting to enhance all types of interaction, instructors should consider focusing on certain types of interaction which is helpful in establishing norms of cooperation to enhance learners' thinking of their party is "us".

However, having no explicit cues to realize virtual members' reactions, one may choose to "not to contribute" ideas or efforts to the groups. In this regard, instructors or educators may wish to urge learners to formally regulate courses of actions, especially when personal cues are seldom available in online environments. According to justice theory (Lerner, 1981), procedural justice and distributive justice are critical variables, while groups making rules for members to obey. Procedural justice reflects the extent to which an individual perceives that the subtasks of finishing the work have been fairly allocated. The use of fair procedures helps communicate that counterparts are value and equal. In this case learners have to participate in task allocation and justify if someone contribute less effort. Distributive justice considers if the distribution of the needed resources to complete the subtask is acceptable. Learners are likely to choose not to contribute effort, if either one is not fulfilled. Assuming every member is fairly assigned a piece of work, but the one who is in charge of surveying data from different libraries is not supported by needed resources, such as money or cars. The student may choose not to respond to any feedback or finish the work lately and reluctantly because of strong feeling of injustice, thereby frustrates the group norms. In this point of view, this study suggests that educators should play an active role in forming group norms that comply with procedural and distributive justice. For example, practitioners may involve in every group and help make informal norms as formal rules. Technically, system developers can also consider implementing an interface that can visualize the resources allocation and progresses of each subtask of a group. The involvement of instructors in making norms as rules, to some extent, would sustain the requirement of procedural and distributive justice in virtually collaborative activities, which could keep the norms beneficial and effective.

CSCL providers and educators should actively seek ways to enhance learners' shared identity, because it has significant effects on learners' perception of trust and norms to help others. In the presence of a strong shared identity, members of in-groups are subsequently evaluated more favorably than those considered part of out-group (Hogg & Tindale, 2005). However, this may lead us to a pitfall, namely taking for granted that a shared identity will automatically occur just because CSCL allows online collaborative group learning. Thus, future research considering shared identity as an antecedent would further enhance our understanding of helping behavior in CSCL environments. As long as the shared identity is activated, the ongoing process of trusting in team members and group norms formation will link learners to be more willing to help each others. Therefore, future research can examine whether intrinsic motives and extrinsic motives have any influence on the formation of share identity.

Following Baron and Kenny's (1986) guideline to examine the mediating and moderating effects of group norms and trust in team members on helping behavior, this study found an inconsistent result while comparing with Tanis and Postmes's (2005) finding. In sum, their results showed that individuals' trusting behavior (transferring money) was based on expectations of reciprocity (they would be rewarded), not on perceived trustworthiness. However, our results documented that helping behavior was based on both group norms and trust in team members. As a result, there might be a potential moderator variable which leads to unexpectedly inconsistent findings (Baron & Kenny, 1986). We thereby suppose that whether trust has an impact on group members' certain behaviors may be contingent on the explicitness of a shared goal in the group. While lacking of a shared goal for each group in Tanis and Postmes's study, there was an explicit objective for each group to accomplish in this study, and therefore group members were highly interdependent. Under the frame of a shared mission needed to finish, learners were more likely to conduct a reciprocal helping, because they knew that not helping other members in need, the group task may not be finished successfully. Therefore, as long as learners have adopted the collective mission and have trusted in their partners, the possibility of mutually beneficial exchange behaviors becomes more probable.

Conclusion

Results of this study represented a first step in understanding the engendering of learners' helping behavior in CSCL setting, but several limitations need to be considered. One of the limitations of this study is that most participants in

this study were acquainted with one another. Familiarity contributes to shared understanding, thereby may have provided learners with social identity before their collaboration online. Although we do not know if there is difference between the social identity generated collocate and social identity generated distantly, it is obvious that learners' perception from the social context may change over time when they are getting familiar with one another. Therefore, it is reasonable to suspect that team member familiarity may have influenced learners' perception of social identity. In particular, familiarity may have led individuals to serve as central inputs, making individuality and individual distinctiveness a defining feature of the team (Postmes et al., 2005a). As a result, learners may have developed specific norms before participating in this research. Accordingly, future studies should reduce the potential impact of team member familiarity by administering the treatment at different geographic locations (e.g., different campuses).

Furthermore, the data was only gathered from college students, further research is necessary to verify the generalizability of our findings. In addition, common method bias exists due to same respondents provide information on both independent and dependent variables. Finally, team trust in this study is an overall general trust although many researchers considered trust to be multi-dimensions. Future research may decompose trust into several dimensions and examine their respective effects.

Finally, many factors that might have impacts on the variables been discussed in this study are excluded. However, it does not mean that what variables we studied is much significant than that we miss. Actually, one's social and psychological status is much complex than that been stated in this study. Considering the limitation of a experiment that can only focus some factors of interest, we chose some variables that most probably follow the framework of social identity theory. However, self-efficacy and group efficacy are two potential factors explaining one's helping behaviors. These two constructs focus on micro level and macro level, respectively. Other possible determinants of helping behaviour are reputation, accountability, and so on. Future research of interest in this domain may take these constructs into account to deepen our understating.

Acknowledgement

This study was supported by a grant from the National Science Council awarded to Jung-Lung Hsu, under the grant number: NSC 98-2511-S-424-001.

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Computer Games versus Maps before Reading Stories: Priming Readers' Spatial Situation Models

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ABSTRACT

The current study investigated how computer games and maps compare as preparation for readers to comprehend and retain spatial relations in text narratives. Readers create situation models of five dimensions: spatial, temporal, causal, goal, and protagonist (Zwaan, Langston, & Graesser 1995). Of these five, readers mentally model the spatial dimension least well (Rinck, 2005). Studying maps before reading improves retention of general details from non-narrative readings (Kulhavy & Stock, 1996). The current study investigated how playing interactive computer games compared with studying a computer-based map as a preparation for reading a narrative. The dependent variables were: 1) evidence of monitoring spatial relations while reading stories, and 2) comprehension and retention of spatial relations in stories. Evidence of monitoring of the spatial relations was measured by average times, in milliseconds, for reading individual sentences with changes in protagonist location. Comprehension and retention of spatial relations in stories were measured by multiple-choice posttests of spatial relations in the stories. Eighty 11-year-olds participated in all three experimental conditions: 1) studying a map with sound and animations but no interaction, 2) playing an interactive computer game, and 3) completing a filler task. Each condition was followed by reading a narrative and then taking a spatial posttest. In terms of multiple-choice posttests, map condition had the highest average number correct, closely followed by the computer game. Filler task condition was a distant third. No between-condition differences were found for the reading times on sentences with changes in protagonist location. Results suggest that maps may be superior to computers games as preparation for spatial reading.

Keywords

Reading comprehension, Situation models, Computer games, Maps, Spatial

Introduction

Video games have become ubiquitous in contemporary adolescent culture. Perhaps unaware that they are doing so, children playing video games are learning skills that can be transferred into practical learning situations. For example, computer-game play can improve spatial skills such as spatial orientation, mental rotation, and spatial visualization (Larish & Andersen, 1995; Okagaki & Frensch, 1994; Greenfield, 1994); develop attention-dividing strategies (Greenfield, deWinstanley, Kilpatrick, & Kaye, 1994); improve spatial integration skills (Greenfield, 1993); and improve understanding of iconic languages (Greenfield, Camaioni et al., 1994). While building spatial visualization can aid gamers in computer-game play, those skills may also aid students in improving reading comprehension.

Comprehension of a text is not only parsing of words and sentences, but is also constructing a situation model of the story (Zwaan, Radvansky, Hilliard, & Curiel 1998). Reading is quite complex; readers must create and update the situation model along five dimensions: temporal, spatial, protagonist, causal, and intentionality (Zwann et al., 1995). The spatial dimension is typically hardest for readers (Hakala, 1999; O'Brien & Albrecht, 1992). Yet spatial understanding is crucial to a host of disciplines (Casey, Nuttall, Pezaris, & Benbow, 1995; Humphreys, Lubinski, & Yao, 1993; Pribyl & Bodner, 1987). Evaluating the relative strengths of priming activities designed to stimulate the creation of the situation model prior to reading is an important area for empirical study as it can inform design of multimedia materials for education.

Readers who study a map prior to reading have better retention of material than readers who study the map after reading (Kulhavy & Stock, 1996). This may be the result of priming the spatial dimension of the reader's situation model prior to reading. For example, icons on the map activate both visuospatial and semantic networks that facilitate comprehension of spatial sentences in the text. It could be that some of the hand-eye activities of computer-game interaction (if they involve maps or other visuospatial stimuli) might initiate an even greater priming of the readers' spatial situation models, as computer-game interaction involves both visual and kinesthetic encoding.

Understanding how readers create spatial mental models is essential for instructional designers. It is also an important design factor for new interactive book technologies, such as the interactive map-book (patent pending), which combines hardcopy books with paper-based computer games (via pen-top computers such as LeapFrog's FlyPen and microdot paper) in such a way that readers must complete the paper-based computer games to read further (Smith, 2008). The purpose of this study is to explore to what extent adding interactivity to the reading experience will improve the reader's ability to form their spatial situation models.

Literature review

One of the fundamental abilities that education attempts to impart to students is the ability to read, and yet many children leave the school systems with only a basic level of reading (Biancarosa & Snow, 2004; Strommen & Mates, 2004). Apparently in the United States, reading instruction does not result in students' acquisition of high-level comprehension (Biancarosa & Snow, 2004; RAND Education, 2005). According to Leonhardt (1998), "The sophisticated skills demanded by high-level academic or professional work—the ability to understand multiple plots or complex issues, a sensitivity to tone, the expertise to know immediately what is crucial to a text and what can be skimmed—can be acquired only through years of avid reading" (p. 29). The ability to read skillfully remains important in the digital age. Although multimedia abounds on the Internet, much of the information available in the digital age is still textual. Krashen (1993) argues that while free voluntary reading (FVR) is not sufficient for higher-level reading skills, developing these skills without FVR is impossible. Krashen also suggests that when children get "hooked on books" that "they acquire, involuntarily . . . nearly all of the . . . language skills many people are so concerned about" (p. 124). Unfortunately, the steady decline in reading among adolescents (National Endowment for the Arts, 2007) combined with the decline of reading comprehension has resulted in a culture of students who never become "hooked on books" (Krashen, 1993, p. 124) and are losing the ability to understand what they have read.

According to the most empirically supported theoretical model, readers process text at three levels: the surface code, textbase, and situation model (van Dijk & Kintsch, 1983; Graesser, Mills & Zwaan, 1997). The surface code is the verbatim wording of the text. The textbase is the propositional structure of the text. The situation model is the "cognitive representation of the events, actions, persons, and in general the situation, [i.e., what] a text is about" (van Dijk & Kintsch, 1983, p. 11–12). Zwaan, Langston, and Graesser (1995) proposed the event-indexing model, the currently accepted theoretical model of how readers create and update an internal mental model from a text narrative. This event-indexing model suggests that as people comprehend a text narrative, they relate successive events in the story to their internal situation model comprised of five dimensions: spatial (where events occur), temporal (when events occur), causal (how events cause changes in the flow of the story), protagonist (the main character), and intention (character goals). When events in the story suggest discontinuities in these dimensions, such as a change of location, a flash forward or back in time, entrance or exit of a character, etc., the reader updates the state of their internal situation model of the story. Of the five dimensions of the situation model, the spatial dimension is the least well formed. Hakala (1999) performed experiments using both naming and reading times that demonstrated readers had access to spatial information when instructed to focus on spatial details, but not when asked to read for comprehension. O'Brien and Albrect (1992) showed that subjects were not aware of contradictions in statements about spatial information unless they were instructed to read from the perspective of the protagonist. Wilson, Rinck, McNamara, Bower, & Morrow (1993) performed a series of experiments that indicated that subjects were aware of the physical layout of a narrative only in a general way, even if the subjects learned the physical layout before reading the narrative.

Given the importance of situation models for learning from a text, enhancements to text presentation that potentially improve situation models (and comprehension) are important. In the case of the spatial situation model, this may be particularly true in subject areas that rely on spatial abilities, such as geometry (Battista, 1990), other higher forms of mathematics (Battista, 1990), chemistry (Pribyl & Bodner, 1987), and academic areas that use maps such as geography, social studies, and history.

A number of enhancements provided to learners, prior to reading expository texts, provide preparation for learning. Advance organizers, which provide learners with a contextual overview or "advance introduction of relevant subsuming concepts" (Ausubel, 1960, p. 267), improve retention (Ausubel, 1960). However, theoretical explanations for this effect vary. Ausubel (1960) suggested that advance organizers help learners build hierarchical cognitive structures surrounding the content. Mayer (1979) suggested that advance organizers help learners assimilate new

knowledge with relevant prior knowledge. Alternatively, advance organizers may be part of an orientation phase to student learning, gaining the student's attention and providing them with an agenda to internalize, a precursor to effective learning within the zone of proximal development (Haenen, 2001; Vygotsky, 1987). Visual representations, or graphic organizers, may be quicker to absorb and thus better for learning than text-based advance organizers (Robinson & Kiewra, 1995).

However, for highly spatial reading, the subject of the current investigation, maps are a more commonplace visual reading enhancement that has been used traditionally for narrative non-fiction as well as for narrative fiction. Kulhavy proposed the co-joint retention theory based on the idea that the text and map are processed by different memory systems, semantic and visuospatial, and that the image of the map, stored in long-term memory, can be searched with relatively low overhead. Thus, the map with text supplies two types of cues, semantic and visuospatial, for recall of propositions from the text (Verdi & Kulhavy, 2002). Kulhavy's theory also predicts that the ordering of the map-text presentation influences effectiveness. The superiority of map before text (versus text before map) ordering has been demonstrated experimentally (Kulhavy & Stock 1996; Verdi & Johnson, 1997). However, the informational texts used in these experiments were not true narratives, since the sentences could be reordered in virtually any way without loss of meaning. The current research focuses more on true narratives and the spatial dimension of readers' situation models.

Another body of research suggests that spatial skills may be improved by interactivity. Larish and Andersen (1995) used a pilot-copilot experimental setup in a flight simulator to demonstrate that interactivity improved sensitivity to changes in spatial orientation. Other researchers have shown that interactivity improved recognition of objects (Harman, Humphrey, & Goodale, 1999), driving awareness (Gugerty, 1997), learning anatomy (Garg, Norman, & Sperotable, 2002), polygonal puzzle solving (Smith, 2001), and spatial priming (Smith & Olkun, 2005). Interactive computer games such as Tetris can improve mental rotation and spatial visualization skills (Okagaki & Frensch, 1994).

There is also evidence that reading concrete sentences involves resonant activation of motor systems and, conversely, that manual manipulations can tap into this motor resonance to facilitate language processing (Fischer & Zwaan, 2008). Hand positions and small hand interactions can prime syntactic parsing during reading (Zwaan, & Taylor, 2006). People holding their fingers open, as if to grasp a small object, judged the sensibility (versus "nonsensicality") of word pairs such as "squeeze-tomato" or "squeeze-milk" more quickly than did people not holding their fingers open (Klatzky, Pelligrino, & McCloskey, 1989).

In an "action-sentence compatibility effect," subjects answering yes or no questions about whether short sentences made sense ("open the drawer" versus "boil the air") responded faster when the direction of finger movement on the "yes" or "no" buttons (either towards or away from their body) was consistent with the direction of the movement in the sentences, either towards or away ("Andy delivered the pizza to you/You delivered the pizza to Andy") (Glenberg & Kashak, 2002). The same action-sentence compatibility effect also worked with relatively more abstract sentences ("Liz told you the story/You told Liz the story"). These results support the indexical hypothesis, consistent with situation model theory, that words and phrases are indexed to perceptual symbols, based on brain states similar to the perception of the referenced objects.

Given that maps before text improve recall of propositions (Kulhavy, Stock, Peterson, Pridemore, & Klein, 1992), that interactive computer games can improve spatial skills (Okagaki & Frensch, 1994), and that motor processes and reading are interconnected (Fischer & Zwaan, 2008), it is logical to ask how playing computer games and studying maps (both before reading a text narrative) compare in terms of priming readers' spatial situation models and subsequent retention of spatial details from stories. To begin this investigation it is necessary to define what is meant by a game. The Educational Games Commons of Penn State University (2007) provides a thorough review of the literature on the definition of a game. The authors adopt their definition of a game as a voluntary rule-based activity that motivates the player to achieve a goal state via conflict.

The authors hypothesize that either playing a computer game or viewing a static map before reading a text narrative will improve spatial comprehension compared to reading a text with no visuospatial assistance. Given the power of interactivity to motivate, as well as an affordance (Gibson, 1979), the authors also hypothesize that computer games may be more effective in boosting situation models than static maps. However, unlike static maps, computer games

involve more overhead for players to learn the structure of the game and involve more challenging design factors that potentially mediate their effectiveness for improving readers' situation models.

Research question

The current study investigated the following research question, which revolved around the impact of computer-style interaction on readers' spatial situation models as they read text narratives. How do playing an interactive computer game, viewing a static map (with animations and audio added), doing a non-related activity compare as preparation for reading a text narrative in terms of the reader's comprehension and retention of spatial relations in a story?

Independent variables

The main independent variable was the presence or absence of computer-game play interaction as preparation for reading text narratives. The three values of the independent variable investigated were interaction with map, no interaction with map, and no map as preparation for reading a story.

Dependent variables

A spatial discontinuity in a text narrative is defined as when "the incoming event occurs in a spatial setting that is different from the prior event" (Graesser, Millis, & Zwaan, 1997, p. 179). This change of spatial setting may be signaled by a transitional phrase, such as "We moved to the living room," or may be implicit through naming or describing a new location in the context of describing an event. As long as the before and after locations are discretely different, they may be adjacent, close, or distant. The change in spatial setting may be via character movement or change in narrator focus ("Meanwhile back at the ranch . . ."). Current authors operationally assume that any change to another spatial location referred to by a short location noun phrase, for example, dining room or living room, is a change of location in a spatial discontinuity sentence.

Typically, readers not comprehending the spatial relations in a story are not expending the extra cognitive effort needed to monitor the spatial situation in a story (Rinck, 2005). All other things being equal, readers monitoring spatial situations in a narrative will expend more cognitive effort, and thus time, reading spatial discontinuity sentences than readers not monitoring the spatial situations (Zwaan, Langston, & Graesser, 1995). One dependent variable, time reading spatial discontinuity sentences, is operationally defined as the average time a reader spends reading sentences containing spatial discontinuities.

If readers monitor the spatial situation in a story, they should, after reading, have better retention of the spatial relations in the story. The second dependent variable, retention, is operationally defined as the persistence in memory of visuospatial or verbal information, facts, behavior, or experiences after an interval has elapsed in which there has been no related performance, practice, or reinforcement. Retention will be operationally measured through recognition, when a person is presented with the correct answer as one choice of available answers on a multiple-choice test.

Method/data sources

Participants

Eighty-three fifth-grade students (average age 11.5), 43 males and 40 females, participated in the study. The participants attended an average-sized public elementary school in Florida. The school had a diverse enrollment, comprised of nearly 20% minority students. Additionally, 20% of the students were considered economically disadvantaged.

Materials

Three text narratives were developed by the lead author and were calibrated so that each story was comparable with the other stories in terms of length (average of 1,123 words), complexity of the spatial settings, numbers of objects, number of characters, and movements of characters. In each story, a protagonist was faced with a suspenseful situation that required moving around a limited spatial area of five rooms, described in detail as the setting of the story (see Figure 1).

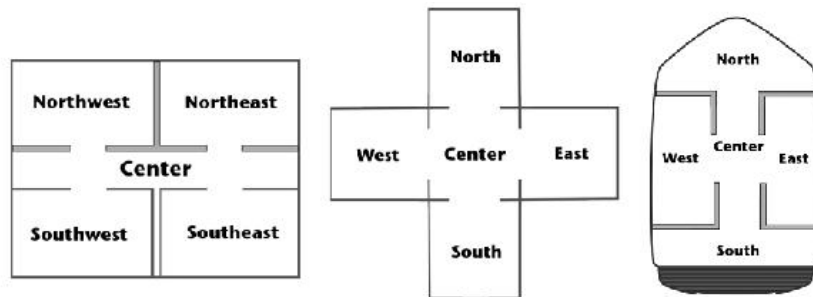


Figure 1. The maps of the three stories used in the posttests

Protagonist movement from one room to another was described in sentences of 20 syllables each. This was done because one of the dependent variables was time spent reading spatial discontinuity sentences, and a major factor in time spent reading any sentence is the number of syllables. As mentioned earlier, readers monitoring the spatial situation tend to take longer reading spatial discontinuity sentences, as they need time not only to read the sentence, but also to update their spatial model of the story.

Before reading, the participants were exposed to one of three separate conditions: a) computer game, b) map with animations and sound, but no interactions, or c) non-related filler activity. It was intended that the computer game and map conditions would foster the mental modeling of the space subsequently described in the story.

The maps were designed using a graphic software application, and the described animations and interactions were added with The Games Factory, a game-development authoring system (<http://www.clickteam.com/eng/tgf2.php>). Before viewing the map, participants were told they would view a map. The map itself was labeled “map,” which encouraged a map-viewing mindset that changes how people visually process a graphic (Kealy & Webb, 1995).

The computer games used in the treatment were created with a game-authoring system, The Games Factory. Each game displayed a full-screen map of the location described in the associated story. Screenshots of the three games are included below in Figure 2. The player controlled an animated virtual character that started in the middle of the map. The player was tasked with retrieving objects from each of the five rooms in a particular order and in a limited amount of time, receiving points based on their performance. Each room’s function was identified by one or more icons, for example, table and chairs identified the snack room. The object to be retrieved in each room was visible only when the onscreen character was in that room. Therefore, to retrieve a particular object, participants had to deduce, by the room’s icons, which room to go to. For example, a drink might be found in the snack room, identified by its table and chairs. To acknowledge a correct move, a short audio sounded when an object was retrieved. If the objects were retrieved out of order, an appropriate sound played and the participant was required to restart the game. There were two levels to complete in 90 seconds, each level having a unique set of items. The activity qualifies as a game under the working definition of a game, voluntary rule-based activity that motivates the player to achieve a goal state via conflict (Educational Games Commons of Penn State University, 2007), because the activity has rules, a goal state, and sets up conflict (time, order, obstacles). The computer games also had design features such as challenge, performance feedback, and fantasy, which players found motivating (Malone, 1981). Before playing, participants were notified that they would play a computer game, establishing a mindset of playing a computer game.

In the map treatment, the game was replicated as closely as possible, omitting only the game-play interaction of moving the character around the space, retrieving objects, etc. The identical graphic appeared on the participants’ screen, and periodically throughout 90 seconds, the same objects from the game appeared in the same rooms as in the game, and the same sound played simultaneously. The objects and sounds appeared and played in the same order of

the task list in the game. A short amount of time, 90 seconds, was used to minimize boredom while viewing the static map. It was necessary to mirror that time in the game treatment to control that variable.



Figure 2. Screenshots from the three computer games

The elementary school provided the use of its computer lab where the participants took part in the experiment. The interactive games, maps, stories (which were read sentence by sentence on the computer), and the posttests were all hosted on web pages. Data from these are sent to a database on the server.

Procedure

Participants took part in three experiments during a 45-minute session in a school lab. Each experiment consisted of receiving a treatment, reading a story, and then taking a posttest of multiple-choice questions about locations of events and locations of objects in the stories. Figure 3 shows a time line for each experiment.

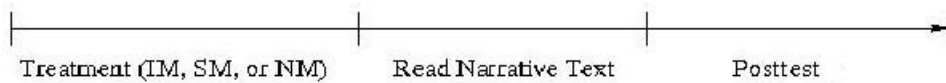


Figure 3. Experiment timeline

During each experiment, participants received one of three types of treatments: playing an interactive computer game based on a map of the story setting, such as an interactive map (IM), before reading a text; viewing a static map (SM) with animation and sound before reading a text; or engaging in an unrelated filler task with no visual map before reading a text, or no map (NM). The study employed a within-subject design over three experiments. All participants received all three experimental treatments and read the same three text narratives.

The participants were randomly assigned to one of three groups, and the groups received the treatments as per the schedule shown in Table 1. The experiment was counterbalanced in terms of treatment condition, narrative, and the order of reading the narratives to minimize the effect of order and having taken previous posttests. Groups receiving the no map (NM) treatment were given a filler task (viewing a series of cartoons) before reading the text. Participants were given 90 seconds to play the computer game, 90 seconds to view the map, and 90 seconds to view the cartoons.

Table 1. Group treatment schedule

	Session 1	Session 2	Session 3
Group 1	NM	SM	IM
Group 2	SM	IM	NM
Group 3	IM	SM	NM

The posttest consisted of ten multiple-choice spatial questions related to the locations of characters and events in the story setting. Each multiple-choice question had five possible answers, and included a map of the story setting

without the room names. The following is a typical posttest question, which was accompanied by the leftmost map in Figure 1:

“At the end of the zoo keeper story, which room was Rolf in? A) north-west B) north-east C) center D) south-west E) south-east”

Each participant received all three treatments over the course of three experiments during one 45-minute class period. The investigators also closely observed all participants during the course of the experiment, taking notes about any behavior that might affect the experiment. Close to the end of the 45-minute session, participants took part in a focus group where they discussed relative effectiveness of the three treatment conditions and other aspects of the experimental design.

Results

Significant between-condition differences were found for the multiple-choice posttest of retention of the spatial relations in the story. However, no between-condition differences were found for the reading times on the spatial discontinuity sentences.

The average times for reading spatial discontinuity sentences by the three conditions are shown in Table 2. There were no significant differences between the conditions. A one-way within-subjects (repeated measures) ANOVA comparing average times reading spatial discontinuity sentences revealed no significant differences between the treatment conditions, $F(2, 70) = .129, p < .879$. Contrary to investigator expectations, participants in the computer-game condition read the spatial discontinuity sentences the fastest, followed by those in the map condition and then in the control condition. However, these differences were not significant.

Table 2. Average reading times of spatial discontinuity sentences (milliseconds)

Treatment Condition	Mean	Std. Deviation	N
Computer Game	4839	2073	80
Control	4988	2714	80
Map	4918	2184	80

Table 3 shows the fraction correct on the posttest across all three sessions. Note that with five possible answers to each multiple-choice question, the fraction correct for both computer game and map treatment are well above what would be expected from random guessing. The map condition had the highest average number correct, followed by the computer game, then by the control condition. All of these differences were significant.

Table 3. Average fraction correct on the posttest across all three sessions

Treatment Condition	Mean	Std. Deviation	N
Computer game	.380	.245	80
Control	.263	.2	80
Map	.471	.268	80

A one-way within-subject (repeated measures) ANOVA comparing effects of treatments (computer game then read; map then read; and filler task then read) on multiple-choice, spatial posttest revealed significant differences, $F(2, 79) = 19.7, p < 0.0001$. Based on the pair-wise hypotheses, that is, that computer games would be superior to control condition, that maps would be superior to control condition, and that computer games would be superior to map condition, some pair-wise a priori comparisons were made. An a priori comparison between the map condition and the control condition (dependent-samples paired *t*-test) was significant, $t(1, 79) = 6.4, p < 0.0001$ (two-tailed), $d = .9$. A similar comparison between the computer-game condition and the control condition was also significant, $t(1, 80) = 3.9, p < 0.0001$ (two-tailed), $d = .5$. A third comparison between the computer-game and map conditions was also significant, $t(1, 79) = 2.3, p < 0.023$ (two-tailed), $d = .3$.

Despite counter-balancing of conditions across the three sessions, investigators wanted to further eliminate possible effects that the posttests might have on participants reading behaviors in subsequent sessions. In other words, the posttest in the first session probably influenced how participants read the stories in the second and third sessions. To

provide an analysis without the effects of prior posttests, investigators analyzed the first session results by themselves. The times for reading the spatial discontinuity sentences again produced no significant differences. However, the first session results for the multiple-choice spatial posttest did produce significant differences. Table 4 shows the fraction correct on the posttest for session one. A one-way between groups ANOVA for the fraction correct on the first session multiple-choice spatial posttest was significant, $F(2, 79) = 7.28, p < 0.001$. An a priori comparison between the map condition and the control condition, for the first session one multiple-choice posttest, (independent-sample t -test) was also significant, $t(1, 53) = 3.66, p < 0.001$ (two-tailed), $d = 1.0$. A similar comparison (of session one multiple-choice posttests) between the computer-game condition and the control condition was also significant, $t(1, 52) = 2.62, p < 0.01$ (two-tailed), $d = .7$. However, the third comparison between the computer-game and map conditions, for session one multiple-choice posttest, was not significant, $t(1, 53) = 1.46, p < 0.15$. So for the first session multiple-choice posttests, the map group did significantly better than the control group, the computer-game group did significantly better than the control group, but there was no significant difference between the map group and the computer-game group. These results from the first session are largely consistent with results across all three sessions, suggesting that the effect of posttests on reading behaviors in subsequent sessions was negligible.

Table 4. Average correct on the posttest for session one only

Treatment condition	Mean	Std. Deviation	N
Computer game	.374	.218	27
Control	.230	.186	27
Map	.479	.306	28

Investigator observations during the experiment revealed that for the computer-game treatment, the time limit of 90 seconds provided insufficient time for some participants to both learn the game and then play it. In the judgment of the investigators, more time than 90 seconds was needed to obtain a full effect from playing the computer game. The participant comments during the focus group confirmed that the time was too short for the computer-game play. Nevertheless, participants expressed much more eagerness to play the computer games than to view the maps.

Discussion

There were two main outcomes for this experiment. First, there were no between-condition differences for times reading the spatial discontinuity sentences. Second, there were significant between-condition differences for the multiple-choice posttest on spatial relations from the story. The map condition had the highest average number correct, followed by computer-game condition. The filler condition was a distant third.

Despite no significant between-condition differences on the times for reading spatial discontinuity sentences, there were significant differences in the multiple-choice posttest, suggesting between-condition differences in retention of spatial details in the story. Based on the prevalent views from research, one might have expected readers in the game and map conditions to take longer reading spatial discontinuity sentences because, in addition to reading, they were expending cognitive effort to update their spatial situation models, while readers in the text-only condition might not monitor the spatial situation, and might therefore not spend time updating a spatial mental model. However, the sense of urgency created by the 90-second time limits for playing/viewing games/maps may have caused readers in the map and computer-game conditions to update their spatial situation models quickly. This seems plausible considering the instantaneous decisions computer-game players often make. Further, in mental rotation tests, time pressure is a prerequisite to encourage people to actually visualize shapes rotating (Lohman, 1979). Without time limits, some subjects may employ analytic strategies that circumvent the intent of the test designers to make people mentally rotate (Hegarty, 2009; Lohman, 1979). So, in the current study, the time pressure in the map and computer-game conditions may actually have encouraged subjects to visualize the story setting. On the other hand, the 90-second time limit for both learning and playing the computer game may have favored the map condition, which, in contrast to the computer game, did not require time to figure out the structure of the game.

Retention of spatial details from the story was significantly greater for both the computer-game and map conditions than for the control condition (medium to large effect sizes), yet the map condition was generally better than the computer-game condition (except in session one). This finding is consistent with the map and (non-narrative expository) text experiments of Kulhavy and Stock (1996). However, investigators observed during the experiment,

and fifth graders commented during the focus group, that 90 seconds was not enough time to learn the computer game and then complete the level, indicating that imposed time limits on game play affected the ability of the participants to effectively engage in the interaction. Further, the sounds and animations included in the map condition offered visual interactions to the participants, who were engaged with the graphic without having to learn the rules of a game. These visual interactions set the map condition apart from traditional static maps, which fail to offer incentives for viewing. In the final analysis, the current results suggest that both maps and computer games can be used to improve spatial understanding of a text narrative. However, with a limited amount of time to learn a game and short narratives (approximately 1,000 words), maps, with their lower overhead, may be superior to computer games in priming readers for spatial understanding of a narrative.

In terms of implications for practice, for computer-based reading of short narratives, both maps and computer games may be effective preparation for comprehending and retaining spatial relations in text. The animation and sound added to the static maps in the current study might help students view maps longer. Computer games, although more appealing, require more design and more overhead for students to learn the game play.

Further research

Since the current study sought to isolate interaction as a variable, the “map” condition was unlike a traditional map in that it included sound and animation. A good follow-up study would be to compare a more traditional-style map, with no sound and animation, to a computer game, to observe the effects of each format on readers’ situation models. Further, the projected follow-up study will have participants learn a similar computer warm-up game prior to the experiment proper, so that no time is spent learning the computer game during the experiment. Longer time limits could be used to minimize any sense of urgency that might potentially carry over into reading the story. Alternatively, a similar experiment with no time limits might reveal the implicit effects of maps and computer games on reading.

Acknowledgment

This research was generously supported by funding from the College of Education at the University of South Florida.

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Reflections on Cyberspace as the New “Wired World of Education”

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ABSTRACT

Developments in Information Technologies (ITs) like the Internet have transformed information exchange. Moreover, since information exchange and analysis are key aspects of the learning experience, these developments have had an important impact on education. Within this context, the important question concerns the sort of educational relationships that exist (or fail to exist) when information exchanges and analyses are structured by the use of ITs such as the Internet. In this paper we use ideas from writers not normally linked to discussions about IT use in education, Levinas and Aristotle, to argue that there are important kinds of relationships that, ideally, emerge within face-to-face education settings but not, typically, within education entirely mediated by the use of ITs. Further, we will argue that the importance of the relationships that emerge within face-to-face educational settings suggest that, short of the appropriate adoption and use of enhancements potentially offered by increased bandwidth such as three-dimensional learning environments or broadband videoconferencing, Internet-based education should supplement, but not supplant face-to-face education.

Keywords

Information technology, Education, Levinas, Aristotle

Introduction

In the late 1980s and early 1990s, few people had heard of, or knew the meanings of words like ‘Internet’ or ‘Cyberspace’, yet by 1997, Cairncross (1997) was proclaiming how the communications revolution, exemplified by the Internet, meant the “death of distance”. Between 1997 and now, developments in Information Technologies (ITs) like the Internet have accelerated and further transformed information exchanges (See Guri-Rosenblit, 2005), and by 2007, Fuchs (2007) could legitimately begin his *Internet and Society: Social Theory in the Information Age* with the observation that the “Internet is ubiquitous in everyday life.”

Since information exchange and analysis are key aspects of the learning experience, it is not surprising that these developments have had, and will continue to have a significant impact on education. For example, according to an October 2003 supplement to the Current Population Survey, conducted by the U.S. Census Bureau, among U.S. children 3 to 17 years of age, 83.4% of children enrolled in school in 2003 used a computer at school, and 43.1% used the internet at school. (Day, Janus, and Davis, 2005; Also, see Rovai and Wighting, 2005) An even more recent survey by the Alfred P. Sloan Foundation, reporting 2009 statistics and information about online education in the United States, notes that for the past six years, 2003-2009, “online enrollments have been growing substantially faster than overall higher education enrollments.” (Allen and Seaman, 2010) This continues the earlier trend from 2004 when the same authors reported that 65% “of schools offering graduate face-to-face courses also offer graduate courses online”, while 63% of schools “offering undergraduate face-to-face courses also offer undergraduate courses online.” (Allen and Seaman, 2005) Within this context, the important question concerns the sort of educational relationships that exist (or fail to exist) when information exchanges and analyses are structured by the use of ITs such as the Internet.

If one carefully examines educational relationships, there is ample reason to believe that there is more to education than simple information exchange. (See Guri-Rosenblit, 2005) For example, while “multiple measures of learning success exist” (Song et al., 2007), in the United States it is common for universities and colleges to poll students on how “successful” the instructor has been in his or her teaching. (See Spencer and Schmelkin, 2002) Among the questions in such polls are those asking the students’ opinions whether the instructor was “enthusiastic about teaching the class”, whether the instructor “showed concern for students”, whether the instructor “had a genuine interest in students”, and whether the “instructor’s style of presentation held your interest during class.” At the very least, this suggests that successful educational relationships include much more than just the exchange of information; the manner/mode and context of information exchange also is important when it comes to assessing teaching. (See King, 2002) Thus, in what follows we will use ideas from writers not normally linked to discussions

about IT use in education, Levinas and Aristotle, to argue that there are important kinds of relationships that, ideally, emerge within face-to-face education settings but not, typically, within education entirely mediated by the use of ITs. Further, we will argue that the importance of the relationships that emerge within face-to-face educational settings suggest that, short of the appropriate adoption and use of enhancements potentially offered by increased bandwidth such as three-dimensional learning environments (See Dalgarno and Lee, 2010) or broadband videoconferencing (Smyth, 2005), Internet-based education should supplement, but not supplant face-to-face education.

Levinas

On the assumption that the manner/mode and context of information exchange is an important component of successful teaching, the question is how face-to-face educational relationships differ from those mediated by ITs such as the Internet. Put differently, just what is the effect of transplanting relationships - both educational and non-educational - from their traditionally embodied context into the disembodied, or “omnilocated”, context of cyberspace? Concerning face-to-face relationships, the French philosopher Levinas’ phenomenology of the ethical encounter with another human “face” suggests that the face-to-face encounter with another human being affects us in a way that interrupts consciousness’ processing of apophantic truths. The face-to-face encounter with another human being often invites us to experience *more than* “information” from, or about, another human being. Accordingly, in *Totality and Infinity* Levinas focuses on the apophantic aspect of a communication as “what is necessarily plastic in manifestation” and insists that:

The primordial essence of expression and discourse does not reside in the information they would supply concerning an interior and hidden world. [This essence is] not the *neutrality* of an image, but a solicitation that concerns me.... To speak to me is at each moment to surmount what is necessarily plastic in manifestation. (Levinas, 1969)

In contrast to the apophantic “image” that one may experience of another human being, Levinas insists that human sociality signifies a completely different intentionality:

I wonder if one can speak of a look turned toward the face, for the look is knowledge, perception. I think rather that access to the face is straightaway ethical. You turn yourself toward the Other as toward an object when you see a nose, eyes, a forehead, a chin, and you can describe them ... [But, when one turns toward the Other in this way,] one is not in social relationship with the Other. The relation with the face can surely be dominated by perception, but what is specifically the face is what cannot be reduced to that. (Levinas, 1985)

For Levinas, the crux of “social relationships” is not a more or less obscure perception of another’s “face.” A “clear” and “realistic” **picture** of faces (i.e., the type of representation that sophisticated IT increasingly fosters) does not adequately present the social significance of the person represented by such a visage. For Levinas we must treat ‘face’ as a verb (in the sense of “facing” another in order to present oneself to them). Understanding ‘face’ in this way reveals the openness and vulnerability within face-to-face encounters that grounds ethical attitudes. Indeed, the very act of formulating propositional content for the purpose of giving information - the act constituting what Levinas calls the “said” of communications - presupposes something more than mere avatars of information. Such acts presuppose a relational context for approaching another particular being, a context that Levinas refers to as the “saying”. The “saying” context, or “how” we communicate, extends further than the apophantic “said”, or “what” is communicated. “Antecedent to the verbal signs... is the proximity of one to the other, the commitment of an approach... [t]he original or pre-original saying [that] weaves an intrigue of responsibility....” (Levinas, 1998; Also, see Meskin, 2000)

The important point here is that the relational context in which information exchange occurs conditions that exchange. Nonetheless, it is increasingly easy to denigrate this relational context when we presume that the true meaningfulness of information can somehow be divorced from the affecting relationship that intends to initiate a specific sense of importance for the information exchanged. According to Levinas, “saying”, when we try to reduce it down to nothing more than an apophantic aspect of information, is mediated and attenuated. Levinas writes:

[The] pre-original saying does move into language, in which saying and said are correlative of one another ... [Yet] the subordination of the saying to the said, to the linguistic system and to ontology, is the... the price of a betrayal ... For thematization ... theory and thought ... are *motivated by* the pre-original vocation of the saying, by *responsibility itself*. (Levinas, 1998, italics added; Also, see Zembylas and Vrasidas, 2005)

Disproportionate focus on the informative aspect of a communication – whether in amount, efficiency, or kind of information exchanged – attenuates and ambiguates the relational context presupposed by the communication.

What Levinas is suggesting is that face-to-face communication cuts across two realms. One is the realm of conceptual thinking and thematization that conceives of “knowledge as power”. Levinas refers to this as a realm of “ontology” (a realm of existence) that is characterized by a “language of metaphysics”. In this realm, we strive to make sense of our world by compartmentalizing experience according to conceptual schema. This is the essence of what we have referred to above as the processing of apophantic truths. Beyond the “ontological world” of apophantic judgment and perception, human relationships solicit a different type of intentionality that Levinas calls the “straightaway ethical”. Within the context of this framework, we can understand the attenuation of relational context introduced above in Levinas-ian terms as a mediation of the straightaway ethical by an economy of images, or compartmentalizing schema, that would reduce communication down to mere information exchange.

The problem inherent in technology in general, and IT in particular, is that its power rests in an economy of images. According to Levinas, though, this is not bad *per se*. This is a key point for the Levinas-ian critique of technological practices: technological practices are necessary and valuable, but not, by themselves, enough. Because of this, Levinas attempts to conceptualize the “straightaway ethical” as something that is beyond the “techno-political” economy. It is important to consider ethics as a supplement to (and beyond) the specifically technological power of technological practices. Thus, the *ethical* question of what **ought to be done** takes priority over the technological question of what **it is possible to do**. This Levinas-ian perspective would suggest that a critique of technological practices is as necessary as the practices themselves. For example, in the educational realm it becomes particularly important to consider the full ethical scope of teacher-student relationships. It is true that the power of technological mediation lies in the ability to acquire wider access to many forms of information, more quickly and with less effort. Nevertheless, the key question is whether the responsibilities of teachers and students extend beyond this kind of efficiency. Might it rather be a teacher’s responsibility to encourage a more disciplined information exchange? Might it be a student’s responsibility to value a certain amount of intellectual exertion in absorbing information, over the concern for speed and ease in acquiring that information? Such considerations encourage a Levinas-ian critique of IT mediated education. Just because technologically mediated education delivery *can* make educational exchanges quicker and requiring of less effort, the question remains open whether such exchanges *should* be so quick and “easy”.

In asking this question, we approach what Levinas calls “a great paradox of human existence” (Kearney, 1995) affecting the ways we assess the value of technological practices. We cannot dismiss technology out-of-hand. It, of course, fulfills a valuable and sometimes necessary function in communication. Nonetheless, technological mediation poses certain problems for responsible communication, which demand a critical reflection upon technological practices that is proportional to the power and enthusiasm that the technology makes possible. An interviewer explicitly posed the question of this danger to Levinas: “We live in a society of the image, of sound, of the spectacle.... If this were to accelerate, would not our society lose humanity?” (Levinas, 2001) Levinas’ reply to the interviewer’s question focuses our attention on the problem: “Absolutely... I don’t wish to denounce the image. But I contend that in the audiovisual domain there is considerable distraction.” Levinas recognizes and acknowledges the potential ethical value of technology.” Levinas reinforces this point by writing:

I claim that without technology we would be in no position to feed the Third World. I know of no more frightening images than some of the scenes of African life shown on television; and those children! Nothing is nobler than exposing man’s misery. (Levinas, 2001)

Here is the key to what we would call a Levinas-ian critique of technological practices: the measure of the value of specific technological practices is not “technological” *per se*, it is ethical. The power of television, to take Levinas’ example, arises where it reinforces ethical concerns and not simply in its ability to uninhibitedly disseminate information to everyone while catering to a concomitant desire of participants to transcend the local, personal import

of that information. Ethical value is distinct from, and prior to, the values of technological efficiency, economy, or spectacle. To again turn to the increasing reliance on technological mediation and dissemination of information in education, we would question whether the motives driving such a shift is determined more by values of the prior kind, or more by the latter kind.

Of particular concern to Levinas was the idea that *ethical responsibility* is the bedrock of relational contexts structuring information exchange. When Levinas claims that apophantic language “is only mediating,” and that “antecedent to the verbal signs it conjugates”, there is a “pre-original vocation of the saying,” he means that *the subject* called into vocation remains essential. (See Levinas, 1969) The “truth” of propositional content is neutral with regard to *who* communicates that content, but insofar as ethical authority cannot remain similarly neutral, there is “an intrigue of responsibility” woven behind apophantic language (and the thought it encapsulates). It is for this reason that Levinas, in *Ethics and Infinity*, refers to the apophantic aspect of communication as “a content, which your thought would embrace” and claims that:

In this sense one can say that the face is not “seen”. It is what cannot become a content, which your thought would embrace; it is uncontainable, it leads you beyond [i.e., beyond “seeing”]. It is in this that ... the face is straightaway ethical. (Levinas, 1985)

Thus, our sense of ethical responsibility points us beyond the “said” to a “saying” that refuses to be reduced to apophantic thought. Concomitantly, the subjectivity attuned to moral authority also overflows the image of consciousness that would reduce subjectivity to a mere processing of the “said”. The concern is that one encourages just such a reduction of subjectivity by relying upon communications mediated by technologies such as the Internet. As Etzioni and Etzioni (1997) wrote in 1997, “[R]eal communities are better than virtual communities (at least as currently designed) in communicating affect, [and in] identifying participants and holding them accountable”. Although there appear to be advantages in affecting such reduction – e.g., the medium’s efficiency in transmitting information, the ability to transmit the information to places and people separated by large geographical distances – the point from Levinas is that essential human experiences, like a sense of responsibility and moral authority, extend beyond apophantic thought. As Kendrick notes, not everyone is worried that the use of a technology such as the Internet must lead to a reduction of an important kind of subjectivity. She writes (2001) that hypertext theorists have claimed that hypertext “truly reveals the subject, for it enacts the patterns of cognition in the human mind with its technologically created immediacy and its associative structure.” However, even if this is correct, there is still a challenge for educators – viz., how to use the Internet with its hypertext capability to reveal genuinely the student and teacher as subjects. In addition, we are also concerned whether communicative relations mediated by the Internet undermine a clear sense of other forms of authority (besides moral authority). Even if we discount the importance of teachers as authoritative sources of information, education must be concerned with the authority of the information itself (and the possibility of communicating to a student the skill of exercising such concern with regard to a particular piece of information).

From the perspective of a Levinas-ian analysis, communications and interactions of the sort required by an education that goes beyond the mere memorization of facts involves a personal commitment. Increasingly surrounded and enticed by the ephemeral world, and its “anonymous” and impersonal inhabitants, created by education delivered and mediated by ITs, what the participants miss and fail to learn is a passionate commitment to anything or anyone. In this connection, Bimber (1998) writes that “[O]n-line communication serves to insulate speakers from the consequences of their words and actions. Absent the normative force of face-to-face contact, it is not at all clear that the same degree of empathy, avoidance of conflict, and other mechanisms of social pressure exist.”

Of course, some view increased anonymity and impersonality to be a positive rather than a negative effect of the on-line environment. For example, Barnette welcomes these effects when evaluating his experience teaching Philosophy over the Internet:

There are no voices or accents, no noises, nor distinctions based on gender, race, ethnicity or age. Only ideas, and ideas about ideas, formulated, written, and rewritten, expressed and revisited. In fact, the ongoing discussion in the class *is* the set of ideas expressed. A participant becomes, in a sense, a Platonist in cyberspace, instantiated by material objects and electricity! (Barnette, 1998)

Barnette's (1998) experiences with his "Philosophy in Cyberspace" – PHICYBER – course was that the anonymity provided by technologically mediated education delivery engendered "more civility and concern for others, not less." Here we can contrast Barnette's exaltation of "Only ideas, and ideas about ideas" with Levinas' (1969) apprehension that "Philosophy itself is identified with the substitution of ideas for persons ... a whole philosophical tradition that sought the foundations of the self in the self, outside of heteronomous opinions." In contrast to Barnette's supposedly objective "ideas, and ideas about ideas," Levinas challenges us to question whether such supposed objectivity may not instead function to insulate interlocutors from the full, and ethically significant, force of each other's personalities. For this reason, we can understand Levinas' claim that heteronomy "invests" freedom as a formulation of his idea that "idealist" subjectivity is grounded in a more fundamental, ethical subjectivity.

Sullivan reports results consonant with Barnette. Based on his 2000 survey of female students who had taken at least one online college-level class, Sullivan (2002) concludes that the anonymity of the online environment was, for 42% of the reporting sample, "the most important aspect of the online environment." Nevertheless, it seems important to ask whether there something "healthy" –personally, professionally and pedagogically – about learning to deal with difficulties associated with non-anonymous interactions. Too often, our attempts to reach beyond the framework of traditional face-to-face relationships occur because we are trying to escape them. In the world of technologically mediated education delivery, we are relatively anonymous, often escape the consequences of our "information exchanges", and can find every position advocated and defended; thus, we need not commit ourselves to anything. This is a special concern for educational institutions and other organizations for which "ethical education and behavior" are important. For example, DeMaio (1991) writes:

I am suggesting, simply, that part of the emotional reinforcement one's conscience receives in a personal relationship is missing in an electronic connection. Therefore, any organization that believes it will automatically get the same level of ethical response when it substitutes a terminal for a voice or a face is wrong . . . because it is disregarding the importance of emotional reinforcement in promoting ethical behavior.

In this regard, we do well to question whether the face-to-face interactions of a real-world classroom might condition an "ethic of education" that, in some way, becomes "subverted" when we transplant the teacher-learner relationship into the "virtual classroom". Further, if Lyotard (1991) is correct that current ITs, exemplified by the Internet, remove "the close contexts of which rooted cultures are woven", then use of "virtual classrooms" may serve to fragment and trivialize the educational process. This is a theme found in the works of both Gadamer and Levinas. As Meskin (2000) writes, both Levinas and Gadamer "insisted with considerable originality that all thinking begins not with abstract axioms but rather with the concrete and given realities of language, of sociocultural organization, and of historical situation." Consequently, the challenge is to question the motivations for wanting to displace face-to-face, passionate and committed relationships with technologically mediated education delivery. What we need to do is acknowledge the ambiguities inherent in the technological shift in the delivery and setting of education, and be willing to question motives for it, rather than automatically deferring to presumed educational and social benefits.

Aristotle

If the use of electronically mediated communications places limitations on our sense of the relational context within which our information exchanges take place, then we may consider the effect that these limitations have on the **kinds of relationship** that develop out of these limiting encounters. Turkle (1995), in her consideration of the relational attitudes exhibited within "Multi-User Domains" (MUDs), captures the nature of the problem when she writes that:

Relationships during adolescence are usually bounded by a mutual understanding that they involve limited commitment. Virtual space is well suited to such relationships ... electronic meeting places can breed a kind of easy intimacy. In the first phase, MUD players feel the excitement of rapidly deepening relationship and the sense that time itself is speeding up ... In a second phase, players commonly try to take things from the virtual to the real and are usually disappointed...

Turkle's description of the "easy intimacy" typical on-line is reminiscent of Aristotle's description of adolescent friendship. In his *Nicomachean Ethics*, Aristotle (1999) writes that:

The cause of friendship between young people seems to be pleasure. For their lives are guided by their feelings, and they pursue above all what is pleasant for themselves and what is at hand. But as they grow up [what they find] pleasant changes too. Hence they are quick to become friends, and quick to stop; for their friendship shifts with [what they find] pleasant, and the change in such pleasure is quick. Young people are prone to erotic passion, since this mostly accords with feelings, and is caused by pleasure; that is why they love and quickly stop, often changing in a single day.

Aristotle (1999) contrasts this immature relationship to “complete friendship”:

... complete friendship is the friendship of good people similar in virtue; for they wish goods in the same way to each other insofar as they are good, and they are good in their own right ... Now those who wish goods to their friend for the friend’s own sake are friends most of all; for they have this attitude because of the friend himself, not coincidentally. Hence these people’s friendship lasts as long as they are good; and virtue is enduring.

In Aristotle, as in Levinas, we find the deepening of relationships, beyond that which Turkle sees so “well suited” to virtual space, as essentially dependent upon the ethical context shared by those bound together in face-to-face relationship.

For Aristotle, “complete friendship”, in which people work to help one another, depends on an ethical context because what is “loved” in the mature relationship is virtue itself. Thus, it is the virtuous character that each experiences in the other that binds people together in “complete friendship”. As Cooper (1980) writes, for Aristotle “a [complete or perfect] friendship exists only where you wish to the other party what is good for him, for his own sake, and this well-wishing is reciprocated.” Aristotle specifically distinguishes this form of “complete” or “perfect” friendship from an attraction grounded in mere utility or in titillating pleasures. (Aristotle, 1999) A key aspect of this distinction is that the actual person befriended gains a special centrality in complete friendship not found in the “lower” forms of friendship. As Aristotle (1999) puts it, in the lower forms of relationship people are drawn to a friend “not in his own right, but [only] insofar as they gain some good for themselves from him.” This, however, indicates the importance in a mature relationship of knowing **who the friend really is** (i.e., “in his own right”). This is a concern for discerning the character of the person with whom we engage in the relationship; and, it is a concern that is difficult to exercise without a real face-to-face encounter with the other person as he or she acts in the real world. As Aristotle (1999) writes, complete friendship requires time for the people “to grow accustomed to each other” and to share experiences with one another. The point here is that while simply exchanging information may, for Aristotle, be enough for a friendship based on utility, it is not sufficient for complete friendship where the object is development of a moral insight in practice. Development of this practical insight requires a kind of intimacy that, following Gadamer, comes from a “being-with or living-with each other.” (Walhof, 2006:) As Cooper (1977) notes, for Aristotle “one recognizes the quality of one’s own character and one’s own life by seeing it reflected, as in a mirror, in one’s [complete] friend.” Further, the importance of “being-with” to complete friendship runs counter to what Turkle (1995) suggests is characteristic of online relationships – an easy intimacy. The consistent and enduring life patterns established by a person’s actions, evident when observing the person “in action”, is the standard of evaluation that makes Aristotle’s “complete friendship” possible. For complete friendship, what is important is not the amount of information, but the kind and consistency of the information since, as Stallabrass 1995) notes, “the extreme mutability and multiplication of identity possible in cyberspace collides with the desire to build communities based upon honest communication ... Role-playing, and the potential for dishonesty which goes with it, militates against community.”

Aristotle, then, believed that education (in the sense of gaining the ability to act wisely on information) depends on the presence of this deeper kind of relationship. This is not surprising when we recall the close relationship, for Aristotle, between character and good deliberation on the ends of human activity (prudence; *phronēsis*): “... prudence is inseparable from virtue of character, and virtue of character with prudence. For the principles of prudence accord with the virtues of character; and correctness in virtues of character accords with prudence.” (Aristotle, 1999) In this connection, Miller (1997) writes that, for Aristotle, “because human beings are perfected or fully developed in part by entering into friendships or co-operative relations with others, they are not self-sufficient as individuals: they cannot achieve their ends in isolation from one another.” For Aristotle education is not simply the acquisition of facts (what Levinas calls the “said” of communication). Successful education also imparts the ability to make use of that information in a way that contributes to the well-being (happiness) of the individual (and

so too, to the society of which the individual is a member). Accordingly, from the Aristotelian perspective, part of what is important for the successful education of students is that they enter into cooperative relationships with their teachers wherein the teachers can “express virtues of character” and so create a context of a common ethical commitment to virtue and learning. (See Shuskok, Jr., 2008) Burnet (1967) expresses the point this way:

[The educator] is an artist who... produces goodness of character.... So much is this the case, that under different [ethical doctrines] the methods of education will have to be quite different.

It is just this characteristic of the teacher that is being assessed by the use of the criteria of successful teaching referenced at the beginning of the paper - *viz.* whether the instructor “showed concern for students”, and whether the instructor “had a genuine interest in students,” etc.

While remaining neutral about the claim that an important part of the educator’s task is to “produce goodness of character”, we do agree that the educational relationship, to be effective and successful, requires a maturity and commitment greater than the “easy intimacy” that Turkle believes characterizes those exhibited by MUDs and that Aristotle believes are typical of immature, adolescent relationships. Though it may not be the educator’s task to train these capacities in the student, Aristotelian virtue, “goodness of character”, linked as it is to prudence in the student, reflects specific capacities for good action essential for education. The following suggestion from Moravcsik (1995, italics added) about Aristotle’s ethics captures our concern:

What is ethically relevant is not the mere possession of these capacities [for good action], but the *creating of contexts which facilitate the manifestations of these capacities, or dispositions.*

The obvious question is whether cyberspace does an adequate job of creating a context that facilitates those manifestations of character that condition excellent educational relationships. This is not just an issue for the student-teacher relationship, but more broadly for the collaborative learning experience. As noted by Mitchell (1996), by the “1990s many academics found that they simultaneously inhabited local scholarly communities, which provided their offices and paid their salaries, and virtual communities, which supplied much of their intellectual nourishment and made increasing demands on their time and loyalties.” Thus, the dynamics of collaborative relationships between faculty members have themselves changed because of the introduction and use of IT in education.

Once again, these reflections on the **relational context** provided by technologically mediated communications suggest that we do well to question whether face-to-face interactions of a real-world classroom might condition an “ethic of education” that is undermined when we transplant the teacher-learner relationship into the “virtual classroom”. By placing undue stress upon the amount, efficiency, or kind of information exchanged, does the virtual classroom encourage relationships grounded in mere utility or titillating pleasures rather than eliciting a requisite deeper sense of relation? Similarly, we question whether the virtual classroom, at least in its current form emphasizing text and asynchronous image/video sharing, encourages a context that facilitates concern, on the parts of student and teacher, for something other than the expressions of character that make the best educational experiences possible.

Conclusion

We believe that the above considerations broaden significantly the challenges faced by the “virtual classroom.” That challenges are not simply – and perhaps not even *mostly* – due to problems of information exchange and access. In creating the “new wired world of education”, we must not become excessively enamored with the “mechanics” of how to disseminate and affect technological access. Rather, we agree with the claim of Aivazidis, Lazaridou and Hellden (2006) that the main purpose of integrating information and communication technologies “into schools would be to develop a new learning environment for educating the skills of communication, critical thinking, independence, and responsibility.” What this means is that we should concern ourselves with how to establish, within such a medium, the sense of personal responsibility and maturity that education requires of its participants. Varying the language in one of the key trends that the 2010 *Horizon Report* identifies, the “abundance of resources and relationships made easily accessing via the Internet” challenges us to revisit our roles as both educators and students (Johnson et al., 2010).

Elsewhere we have noted that it is often difficult, when relying **exclusively** upon IT mediated communication, for people to free themselves from the sense that they are talking to “a box” rather than another human being. (See Ward and Prosser, 2002) With “the box” standing between us, the reality of the situation is altered just enough, and we are permitted to feel just enough detachment and anonymity that the rules which bind us in embodied, face-to-face interactions are diminished. As Moody (1998), in a commentary for ABC News puts it, “[A]ny time we go online, we are replacing direct human contact... with an arid, indirect, stilted form of contact with strangers.” The lesson here is that successful educational relationships (for both teacher and student) rely upon a robust contact with other human beings, and not “an arid, indirect, stilted form of contact with strangers.” The importance of such contact is borne out by research suggesting that successful “E-learning” for K-12 children requires a supportive environment (Lord, 2002), as well as research on college student retention where “the evidence that novice college students need to spend time engaged in appropriate on-campus academic and social integration activities is overwhelming.” (Allen, 2006)

Let us be clear here. We are **not** claiming that it is impossible for appropriate uses of IT to carry us beyond the limitations suggested by Moody’s comment. We acknowledge the potential of ITs to break down barriers that, otherwise, would inhibit interactions between students. As Mitchell (2004) writes, “the introduction of campus wireless networks in the early 2000s, combined with portable wireless devices and the growth in electronic distribution of educational material, quickly began to break down the rigid person-to-person connections that had hitherto characterized campus life.” Making use of “engaging technologies”, such as social networking Websites and Instant Messaging, (See Junco and Cole-Avent, 2008) can, when used well, enhance the social presence of online students. Moreover, IT may provide access to formal institutions of education to people who might not otherwise have any access. Nonetheless, we believe that the ability to retain those elements present in face-to-face communications essential to successful and rewarding educational experiences is both the most formidable and the most urgent challenge facing the IT “revolution”, as exemplified in computer-mediated delivery of instruction, in its impact upon education. How do we make Cyberspace a context in which we can “look at the other and know that he or she has feelings, states, desires, that are different from our own ... see the other creature looking back at us, both of us knowing we are separate beings who nonetheless communicate”? (Ullman, 2002) Our intention in this paper has been to stress that this context, described by Carr (2000) as establishing “some form of personal contact with students” and by Levinas as the encounter with the “Otherness” of the “face”, is integral to genuine inter-human relationships, and thus necessary to whatever forms the delivery of education may take. It may be that as education makes increasing use of real-time video-streaming, virtual, interactive three-dimensional environments, and other consonant types of technological enhancements, entirely technologically mediated education will capture the essential inter-personal elements of education. However, for this transformation of the current state of technologically mediated education to occur successfully, we must understand just what the essential inter-personal elements of education are. This is not a trivial task, and ensuring that the needed interpersonal context of education is not lost amidst the “whistles and bells” of increasingly sophisticated technological deployments requires the kind of critical, thoughtful reflection we hope to have contributed to in this paper.

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Training in Mental Rotation and Spatial Visualization and Its Impact on Orthographic Drawing Performance

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ABSTRACT

This paper reports the findings from an experimental study based on the pretest posttest research design that studied mental rotation (MR) and spatial visualization (SV) training outcomes and their impact on orthographic drawing performance. The sample of the study comprised 98 secondary school students (36 girls, 62 boys, $M_{age} = 15.5$ years, age range: 15 -16 years) who were randomly assigned into two experimental groups and a control group. The first experimental group trained in an interaction-enabled condition, the second experimental group trained in an animation-enhanced condition and the control group trained using printed materials. The research instruments used were computerized versions of the Mental Rotation and Spatial Visualization tests. Data were analyzed using a Statistical Package for Social Science, SPSS version 14.0. The results reveal a significant performance gain in spatial visualization and mental rotation accuracy, but not in mental rotation speed. The training method seems to be interlinked with SV, as the interaction-enabled group outperformed the other groups. In addition, technology based training methods seem more efficient, as both experimental groups performed better than the control group in MR accuracy. Moreover, gender was a significant variable, with boys attaining differential improvement gains, as opposed to girls. The group gaining higher SV through training performed better in solving an Orthographic Drawing task, indicating that the training method is related to the application of the received mental processes, in solving the task. Additionally, this particular finding implies that the cognitive process invoked in solving an orthographic drawing may share similar process associated with spatial visualization. Implications of the research findings are also discussed in this paper.

Keywords

Animation, interaction, mental rotation, orthographic drawing, spatial visualization

Introduction

Spatial ability is one of the essential human abilities required for everyday chores and specialized tasks. Linn and Petersen (1985) conceptualized this ability as being multi-faceted based on three components namely spatial visualization, mental rotation and spatial perception. This ability was previously regarded as innate, but evidence from experimental studies suggests that significant improvement is possible through proper and specific training (Khairulanuar & Azniah, 2004; Olkun, 2003; Rafi, Khairulanuar & Che Soh, 2008; Turos & Ervin, 2000). Some studies have highlighted persistent and robust gender differences favoring boys especially in mental rotation (Linn & Petersen, 1985; Maccoby & Jacklin, 1974; Voyer, Voyer, & Bryden, 1995). Age was also found to mediate gender differences where spatial ability is relatively higher among girls at young age, but begins to favor boys as they approach adolescence. Environmental or experiential impacts resulting from diverging orientations or preferences in engaging spatial activities such as games and sports may also influence the development of this ability. Various training methods have been employed in training to improve spatial ability that mainly focused on the use of emerging technology and the effect of gender in training (Moyer, Bolyard, & Spikell, 2001; Rafi, Khairulanuar & Che Soh, 2008; Rafi & Khairulanuar, 2009; Turos & Ervin, 2000). Findings from these studies indicate that this ability is amendable to training, but training efficacy is mediated by training specificity, gender, practice duration and condition. Spatial ability has been established to be a strong predictor of success in engineering drawing courses (Kajiyama, 1996; Olkun, 2003; Rafi & Khairulanuar, 2007; Sorby & Baartmans, 2000; Strong & Smith, 2001). Students need to utilize two perceptual and cognitive processes when learning the subject matter which falls into two categories. First, students are required to represent a three-dimensional object onto a two-dimensional plane surface through multiple-view drawings. The second entails them to create three-dimensional perspectives by working from the two-dimensional representation of the object (Davies, 1973; Olkun, 2003). Both of these categories of learning constitute an integral part of the engineering graphics curriculum requiring a high level of spatial ability.

Shaw (2001) found that students had trouble in understanding orthographic projections than isometric projections. This concurs with the widely accepted assumption that mental synthesis of orthographic views into a three-dimensional form can be a difficulty skill to acquire (Wiebe, 1993). Likewise, Kajiyama (1996) found that freshman engineering students had committed numerous errors in interpreting multi-view drawings. Problems encountered by the freshmen demonstrating a poor ability to put a given view on its plane of projection accurately, to imagine spatial coordinates, and to calculate a geometrical relation of the point of intersection and vertex of an object. All these errors were attributed to low spatial ability in learning the subject matter. In addition, a study by Scales (2000) revealed that male students outperformed their female counterparts in the examinations and tests of technical graphics in colleges. Taken together these findings, female representations in the technical fields are at stake given the widely accepted notion that males are better in engineering and technology because the latter possess superior spatial ability than the former. The lack of research on the differential impacts of training based on training condition, gender effect, and training transfer provides the motivation for the researchers to conduct this study. Four research hypotheses to address the issues have been formulated as follows:

- (i) Students' spatial ability (i.e., spatial visualization, SV; mental rotation accuracy, MRA; and mental rotation speed, MRS) would be amendable to training,
- (ii) There would be differential training outcomes in spatial ability based on gender,
- (iii) There would be differential training outcomes in spatial ability based on training condition,
- (iv) There would be differential performances in engineering drawing task based on training condition.

Methods

Participants

The sample of this study comprised 98 secondary school pupils (36 girls, 62 boys, $M_{\text{age}} = 15.5$ years, age range: 15 - 16 years) who volunteered to participate. Random stratified sampling with proportionate allocation technique was employed to assign the participants into groups with the same male and female strata. Three groups were formed namely two experimental groups and one control group. The first experimental group (12 girls, 21 boys) trained in the interaction-enabled condition, the second experimental group (12 girls, 21 boys) trained in the animation-enhanced condition, and the control group (12 girls, 20 boys) trained using printed materials. All students were given monetary tokens for their participation.

Instrument and Materials

The authors developed a spatial trainer based on a web-based desktop virtual environment comprising virtual training objects for spatial visualization and mental rotation tasks or exercises. In the spatial trainer, each task requires a learner to read the instructions and to attempt answering to a question that is presented on the lower section of the monitor (see Figure 1). Solving each task enforces the learner to use the trainer's interface to interact with the training objects that are displayed on the top section of the monitor. The spatial trainer contains features that support training namely mouse-controlled interaction, animations and response feedbacks (see details in Rafi, Khairulanuar & Che Soh, 2008). The first training method was set up to allow only navigation and exploration (operationalized as interaction) with the virtual objects and response feedbacks. The second experimental condition involved training with animation and response feedback features. The control condition employed similar spatial exercises using printed materials. Pre-testing and post-testing of mental rotation and spatial visualization were carried out using an online Mental Rotation test (developed by Chay, 2000) and Spatial Visualization Test (Middle Grade Mathematical Project, 1983) respectively. The reliability coefficients of these instruments range from .72 to .88. The first test comprises 30 items and performance measure is based on the number of correct responses out of maximum 30 and the total time taken (recorded in seconds) by each participant in completing the test. The second test comprises 32 items and scoring is based on the number of correct responses out of maximum 32. A multi-view orthographic drawing was the instrument used to measure the participants' ability in solving a basic engineering graphic task. The maximum possible score for this task is 16. This test was developed by an expert in the engineering drawing instruction to ensure that it conforms to the accepted standard.

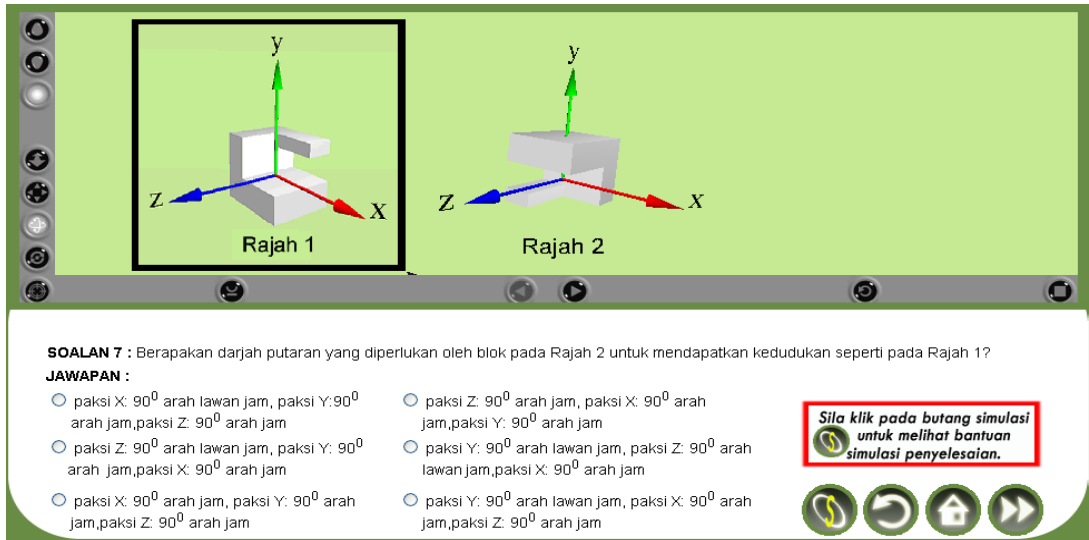


Figure 1. A snapshot of the mental rotation training exercise

Procedure

A multi-factorial (3 x 2) pre-test post-test experimental design procedure comprising two independent variables namely training condition (3 levels: interaction-enabled, animation-enhanced, and control) and gender (2 levels: female and male). The dependent variables in the study were the spatial ability (SV, MRA and MRS) measures providing both the pretest and posttest measures. Training involved 2-hour weekly sessions that spanned eight consecutive weeks. The experimental groups trained in two computer labs and the control group trained in a classroom on the same days throughout the sessions. All the groups trained using similar training contents, but in different conditions. The authors took turns supervising each group throughout the study to eliminate any experimenter bias. All participants had also indicated that they did not have any prior experience in technical graphics instructions that may confound the outcomes.

Findings

Differences that might be attributed to gender and group prior to training were investigated using *independent samples t-test* and *Analysis of variance (ANOVA)* respectively. The results showed that these differences were not significant prior to training. Table 1 summarizes the descriptive statistics for the spatial ability measures prior to and after training. After training, paired t-test procedure was used to compare the mean scores of the SV before and after spatial training revealing that the 98 participants had an average difference pre-test to post-test spatial visualization scores of 5.25 ($SD = 4.73$). This indicated that spatial training resulted in a highly significant increase in spatial visualization level, $t(97) = 11.00$, $p = .001$. Similar test also revealed that the participants had an average difference pre-test to post-test mental rotation accuracy scores of 3.37 ($SD = 2.14$) resulting in a significant improvement, $t(97) = 15.63$, $p = .001$. On the other hand, the average difference between pre-test to post-test scores in mental rotation speed was detected to be not significant, $t(97) = 3.36$, $p = .08$.

Table 1. Means and standard deviations of spatial ability measures before and after training

Training	Spatial ability measures		
	Spatial Visualization: <i>Mean SD</i>	Mental Rotation Accuracy: <i>Mean SD</i>	Mental Rotation Speed: <i>Mean SD</i>
<i>Before (N =98)</i>	14.37 (4.55)	19.42 (2.13)	111.79 (26.27)
<i>After (N = 98)</i>	19.62 (5.48)	22.79 (2.39)	115.15 (24.66)

Table 2 below summarizes the means and standard deviations for spatial ability measures after training by gender and training method.

Table 2. Means and standard deviations for spatial ability after training by gender and training condition

Condition	Gender	Spatial ability measures		
		Spatial Visualization Mean (SD)	Mental Rotation Accuracy Mean (SD)	Mental Rotation Speed Mean (SD)
interaction-enabled	girls (n=12)	19.42 (3.77)	22.71 (1.24)	115.50 (21.71)
	boys (n=21)	25.07 (3.28)	24.51 (1.53)	111.50 (27.57)
	total (n=33)	23.01 (4.38)	23.86 (1.66)	112.96 (25.32)
animation-enhanced	girls (n=12)	16.67 (3.54)	23.17 (2.31)	117.0 (22.10)
	boys (n=21)	18.65 (5.58)	23.82 (2.19)	116.33 (24.81)
	total (n=33)	17.93 (4.97)	23.58 (2.22)	116.58 (23.51)
Control	girls (n=12)	19.75 (3.58)	21.50 (2.19)	103.71 (20.07)
	boys (n=20)	16.73 (6.21)	20.51 (1.95)	123.33 (26.40)
	total (n=32)	17.86 (5.51)	20.88 (2.07)	115.97 (25.75)

Results of ANOVA revealed a statistically significant main effect of training condition in spatial visualization, $F(2,97) = 8.71, p = .001$, as summarized in Table 3 overleaf. *Bonferroni's post hoc test* was employed indicating significant differences among the three training conditions which favored the interaction-enabled condition. No significant main effect of gender was found suggesting that both gender improved after training, $F(1, 97) = 2.46, p = .12$. The interaction between training condition and gender was found to be statistically significant, $F(2,97) = 6.57, p = .002$, indicating that the effectiveness of training condition was mediated by gender. Boys tended to achieve differential improvement gains but girls improved regardless of the training condition used.

Table 3. Analysis of variance of spatial visualization after training

Source of variation	Sum of Squares	df	Mean Square	F	Sig.
Condition	379.645	2	189.823	8.708	.000**
Gender	53.6456	1	53.646	2.461	.120
Condition * Gender	286.192	2	143.096	6.565	.002*
Error	2005.285	92	21.797		
Corrected Total	2724.768	97			

** $p < .001, p < .01$

For mental rotation accuracy, ANOVA revealed a statistically significant main effect for training condition, $F(2,97) = 17.48, p = .001$, as summarized in Table 4. *Bonferroni's post hoc test* revealed that both the experimental groups outperformed the control group. No significant gender main effect was found suggesting that both gender improved after training, $F(1,97) = 1.44, p = .23$. The interaction between training condition and gender was found to be statistically significant, $F(2,97) = 3.97, p = .02$, indicating that the effectiveness of training condition was mediated by gender where boys were more accurate at mental rotation tasks in both the interaction-enabled and animation-enhanced conditions and performed poorly in the control group in comparison to girls.

Table 4. Analysis of variance of mental rotation accuracy after training

Source of variation	Sum of Squares	df	Mean Square	F	Sig.
Condition	130.750	2	65.375	17.486	.000**
Gender	5.396	1	5.396	1.443	.233
Condition* Gender	29.676	2	14.838	3.969	.022*
Error	343.967	92	3.739		
Corrected Total	509.789	97			

** $p < .001, p < .05$

Table 5 and Table 6 summarize the descriptive and analysis of variance statistics respectively for the measurement of performance in orthographic drawing. Results of the ANOVA revealed a statistically significant main effect for training condition, $F(2,97) = 6.51, p = .002$. Follow up post hoc test showed that the interaction-enabled group outperformed the other groups. Similarly, there was a significant main effect of gender, $F(1,97) = 20.61, p = .001$ where boys performed better than girls. The interaction between training method and gender was found to be not significant, $F(2,97) = 1.57, p = .21$.

Table 5. Means and standard deviations of orthographic drawing scores by gender and training condition

Gender	Training condition								
	interaction-enabled			animation-enhanced			Control		
	<i>n</i>	<i>Mean</i>	<i>SD</i>	<i>n</i>	<i>Mean</i>	<i>SD</i>	<i>n</i>	<i>Mean</i>	<i>SD</i>
Girls	12	9.71	1.37	12	8.42	1.35	12	9.13	2.09
Boys	21	12.10	1.93	21	10.38	1.72	20	9.93	2.01
Total	33	11.23	2.08	33	9.67	1.84	32	9.63	2.05

Table 6. Analysis of variance for basic orthographic drawing performance

Source of variation	Sum of Squares	df	Mean Square	F	Sig.
Condition	42.367	2	21.183	6.505	.002*
Gender	67.136	1	67.136	20.615	.000**
Condition* Gender	10.200	2	5.100	1.566	.214
Error	299.608	92	3.257		
Corrected Total	419.311	97			

** $p < .001$, $p < .01$

Closer examination revealed that the interaction-enabled condition that performed higher than the other groups in solving the orthographic drawing task (see Table 5) had gained significant improvement in spatial visualization (see Table 2). For mental rotation measures, the interaction-enabled group and animation-enhanced group performed equally well.

Discussion

The absence of significant gender differences prior to training contrasts earlier findings in the literature highlighting male advantage over females especially in mental rotation (Carroll, 1993; Halpern, 2000; Linn & Petersen, 1985; Maccoby & Jacklin, 1974). However, this finding seems to concur with recent studies suggesting that gender differences in cognitive tasks are getting smaller (Hyde, 2005; Roberts & Bell, 2000; Kang, David, Jean, & Jan, 2004; Sanz de Acedo & Garcia, 2003). The extent of training in spatial visualization (SV) and mental rotation accuracy (MRA) was significant, which supports the first hypothesis that this ability is amendable to training. Participants made fewer errors in solving the spatial tasks compared to their previous performances during pretesting indicating that training had improved their spatial skills. However, for the mental rotation speed (MRS) measure, there is no evidence to support the first hypothesis as the difference between mental rotation speed before and after training was not significant. Main effect of gender was found to be not significant, which fails to support the second hypothesis of differential trainings outcomes based on gender. Both genders were observed to attain equivalent performance in the spatial tasks in this study. By contrast, main effects of training condition for SV and MRA were detected that support the third hypothesis of differential training outcomes based on training condition. For SV, the interaction-enabled group achieved higher gain compared to the other groups. For MRA, the interaction-enabled group and the animation-enhanced group made similar gains with both groups outperforming the control group.

More important, interaction effects between training condition and gender were observed in the SV and MRA training. For SV measure, boys achieved differential training outcomes that favored the interaction-enabled condition. On the other hand, girls made equivalent gains irrespective of the training conditions employed. For MRA measure, the boys in the interaction-enabled condition and animation-enhanced condition outperformed the boys in the control condition. Again, girls in all the three conditions gained equivalent improvement after spatial training. For multi-view orthographic drawing performance, participants who trained in the interaction-enabled condition outperformed those in the other conditions which supports the fourth research hypothesis. Also gender difference was observed in the performance favoring males thus verifying the influence of gender in solving this task. The contrast of the spatial measures (SV, MRA, and MRS) among the three groups showed a marked difference in terms of spatial visualization only. Arguably, the higher performance of orthographic drawing of the interaction-enabled group was accounted for by this specific spatial measure. This finding concurs with other studies (e.g., Olkun, 2003; Rafi, Khairulanuar, & Azniah, 2006) which conclude that solving a technical drawing or engineering graphics entails learners to engage in mental processing that taps on spatial visualization more than other spatial measures. Premised on this particular finding, there was a transfer of knowledge and/or skill from spatial training to engineering drawing

task afforded by spatial visualization factor. From the cognitive perspective, such a transfer is indicative of similar mental operations invoked by learners during spatial training and problem solving of engineering drawing task.

There are several implications that can be learned from these research findings for educational researchers, instructional designers, and technical graphics teachers. First, SV and MRA measures are amendable to training, but not the speed measure of MR. Apparently, the eight-week training sessions are not sufficient to make the participants quicker in solving spatial tasks. Longer training duration and more practice sessions are needed to make one more efficient in solving spatial tasks. It stands to reason that the more exposure to training the greater the development of the strategy or the process in solving spatial tasks through continuous refinement. This process-based practice effect eliminates redundant, inefficient processing steps allowing better utilization of distinct processes that speed up performance (Wright, Thompson, Ganis, Newcombe, & Kosslyn, 2008). Second, differential training outcomes based on training condition have been found in this study which raises some concerns with regard to selecting appropriate technologies in training. Participants in the interaction-enabled condition were able to navigate in the virtual environment rendering either a close-up or distant viewing of the training objects. Coupled with the ability to twist, pan, and roll the objects in this interactive environment, visual perception of objects in 3D space was enhanced leading to improved visualization. This training condition is effective as close and distant interactive viewing to examine specific and holistic features of objects enhances spatial skills (Smith, 2001) that encourage active processing of information (Brady, 2004). The second most effective training setting was the animation-enhanced condition. Apparently, participants utilizing these features gained better spatial cues leading to improved cognitive processing to solve the spatial tasks. Animations are used to fulfill a cognitive function where in this role they support students' cognitive processes that ultimately improve their understanding (Love, 2004). Animations which represent the physical form and movements of an object can be internalized as mental images allowing learners to mentally manipulate with greater efficiency during problem solving (Klein & Koroghlanian, 2004; Tversky, Morrison, & Betrancourt, 2002). Based on the cognitive load theory, as the spatial tasks get more complicated, the intrinsic load will increase which limits the available resources for extraneous processing. This will render a demanding learning process, but it can be mitigated by having appropriate representations such as animation that facilitate the generation of mental representations when solving tasks (Holzinger, Kickmeier-Rust, & Albert, 2008).

Another major concern linking to the second implication is that boys tend to train differentially based on different conditions but girls seem condition-neutral. There could be several reasons for this finding. Heeter (1994) found that boys were generally more interested in VR learning experiences with interaction where 3D environments were more appealing to them (Ziemek, 2006). The finding that girls did not capitalize much on the interactive nature of the training environment warrants further explanation. Contributing factors for this outcome may be attributed either to experiential (i.e., environmental) elements or to general intelligence. The former seems more probable as Adamo-Villani, Wilbur, and Wasburn (2008) found that girls completed object manipulation tasks slower in desktop VR compared to boys due to differences in mouse and keyboard interaction skills that favored the latter. Thus, the use of desktop VR for training purposes may entail intensive familiarization training for girls to let them become more adept when interacting in the virtual environment before the actual training.

The third implication that can be learned is that greater spatial ability particularly spatial visualization measure leads to better performance in multi-view orthographic drawing task. This finding provides insight that mental processes used in solving the spatial visualization tasks and orthographic drawing task may share similar underlying cognitive processes which enable such a transfer. This has a practical implication as orthographic projection theory forms the core of the curriculum in technical graphics. Students lacking this ability will be at risk in pursuing the course as most topics at the foundational year of learning are closely related to and dependent on this particular unit (Rafi & Khairulanuar, 2007). These researchers found that students perceived some topics — orthographic drawing, isometric drawing, and auxiliary views — at the foundational year difficult compared to others. Successful learning of the subject matter hinges on spatial visualization — a pivotal ability — more than analytical ability as learning materials deal with visuo-spatial contents. The authors strongly recommend that instructors teaching engineering drawing especially involving these topics to be aware of the potential learning problems that may confront their students. Foreseeing such challenges allows instructors to take a more cautionary approach in their teaching by taking students' spatial ability and gender differences into consideration as these have been demonstrated to be significantly correlated with engineering drawing performance. Instructors can utilize visual aids namely animations in teaching difficult topics as students will be able to learn problem solving steps with less cognitive effort thus enhancing the learning process. In most cases, learning engineering drawing entails learners to perform visualization and manipulation of objects in their minds. Some topics (e.g., orthographic drawing and auxiliary views) involve

transformation of mental images from three-dimensional (3D) representation into two-dimensional (2D) representation, while other topics (e.g., isometric drawing) necessitate the reverse transformation. Thus, this constant shift of mental operations between these two representational modes will impose great cognitive demand especially for low spatial ability students. Animations can effectively lessen this cognitive load by shifting the cognitive processes involved from the learners through the externalization of the internal mental operations in the visual and dynamic form.

Research has also shown that class lessons that utilized various instructional aids not only improved instructional delivery, but students were more motivated in learning. In some cases, instructional materials in digital format can be uploaded onto schools' web servers where student can gain access for learning outside the formal hours. Instructors can also plan interventional programs or rehabilitative courses to help low spatial ability students through individualized coaching and/or remedial classes, if such a situation arises. In addition, specific spatial training like the one used in this research can be employed over a certain period to train low ability students in visualization that can partly eliminate some of the learning difficulties associated with visualization. Entry requirement practice of schools may have to be re-examined for improvement through additional criterion namely spatial visualization test to screen candidates such that those that failed to meet a certain level of spatial ability or skill must enter special classes.

As demonstrated in the study, spatial ability is a malleable skill that can be improved through training using appropriate training conditions that can be developed based on affordable technology. Schools involved in the technical graphics instruction can make use of such a training tool for students to improve their ability in visualizing and manipulating objects. Though this finding seems promising in improving students' performance in orthographic drawing through spatial training, it is yet to be seen whether improved spatial visualization is transferable to more complex multi-view orthographic drawings and to the rest of the curriculum. Overall, this study provides evidence to support the notion that spatial ability namely spatial visualization and mental rotation accuracy could be trained and training transfer is achievable in multi-view orthographic task. However, spatial training entails careful selection of training methods that is invariably influenced by trainees' demographic and experiences.

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An e-portfolio Design Supporting Ownership, Social Learning, and Ease of Use

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ABSTRACT

This project attempts to improve electronic portfolio software through the creation of a design model using ownership, ease of use, and social learning variables to predict user adoption. The pilot software attempts to encourage student learning by enhancing peer interaction. The software was used by two groups of students. The first group used it to submit course portfolios as a department-wide assessment program. The second group used it to complete a MBA course. Usage logs shows that students heavily used the social learning features. Survey results validate the design model; ease of use, social learning, and ownership proved to be critical variables in predicting user satisfaction. Interview results triangulate survey results. Future work shows promise in promoting higher standards by showcasing top content, as well as in helping students become intellectually engaged with their peers.

Keywords

Educational technology, Education, Social software, e-learning, e-portfolios

Introduction

One of the most popular and widespread educational technology innovations since the introduction of the course management system has been software supporting the Internet-based creation of portfolios (Lorenzo & Ittelson, 2005a & 2005b). Adoption of educational portfolios has been increasing for some time. They are particularly popular in the United Kingdom, and are part of the government's personal development programs initiatives (Becta, 2007). In the U.S., their popularity is largely driven by assessment requirements, where portfolios can be used to demonstrate higher-order thinking such as synthesis and application (Camp & DeBlois, 2007).

However, as portfolios are increasingly adopted for assessment purposes, their original pedagogical purpose is often subverted (Barrett & Wilkerson, 2004). Instead of using portfolios for learning, and their contents for assessment, portfolio initiatives and software are increasingly focused solely on providing assessment data. The adoption of portfolios for assessment purposes can be a positive development, provided that it is understood that assessment data are a result of the learning process. Unfortunately, faculty and administrators' focus on assessment have skewed portfolio software designs. This research project was intended to refocus the design of electronic portfolio systems back onto learning.

Literature Review

According to Beetham (2005), a portfolio is “a collection of documents relating to a learner’s progress, development, and achievements” (p.2), with the purpose of providing a record of progress, collecting evidence for outcomes assessment, and encouraging reflection on learning. The key feature of a portfolio is that it is owner-centric, as opposed to course-centric (ePortConsortium, 2003).

A portfolio’s support for reflective thinking (Becta, 2007) is its most defining pedagogical feature. Students are typically required to upload artifacts, and then reflect on how the artifact demonstrates a certain competency or learning progression. Most software packages provide specific fields next to uploaded files for students to type their reflections.

One of the key reasons for the original use of portfolios was their ability to enhance students’ meta-cognition (where students know what they know) through reflection. Originally fueled by theory, the use of portfolios was strongly supported by Lee Shulman (8th President of the Carnegie Foundation for the Advancement of Teaching) and other

researchers (Carney, 2004). Today, their pedagogical benefit is well known (Murray, Smith, Pellow, Hennessy, Higgison, 2006), but have some theoretical holes that require further research (Carney, 2004).

As a result of these advantages, portfolios have been extensively adopted in many disciplines, particularly in teacher training programs. A 2002 study found that 89% of the educational program respondents used portfolios in their outcomes assessments (Salzman, Denner & Harris, 2002). Almost all of these units were using locally-developed software. The United Kingdom is also a major supporter of portfolios, and many professional bodies and large employers encourage the maintenance of portfolios (Beetham, 2005).

Zubizarreta (2006) argues that portfolios require three domains of activity: documentation, reflection, and collaboration. That collaboration should include faculty members (classroom teachers or an advisor) and other students. As he says, "... reflection is facilitated best by not leaving students individually to their own devices in thinking about their learning but by utilizing the advantages of collaboration and mentoring in making learning community property."

Research Opportunity

Cohn and Hibbitts (2004) identify the "ossification of the current prefabricated, one-size-fits-most portfolio" (p.2). This is largely a result of an overdeveloped focus upon assessment as the primary outcome of a portfolio. The focus on the assessment of learning at the expense of the development of learning (Barrett, 2005, Barrett & Wilkerson, 2004) has warped the dominant implicit portfolio design model.

This implicit design paradigm typically models a portfolio as a database of artifacts submitted in views for specific audiences. This model is suited for controlling access and providing multiple views onto data, and works well for assessment purposes. However, it makes portfolios relatively complex to construct, and the "private by default" permissions settings discourage sharing and social learning. Unfortunately, this paradigm is so common that almost all major programs use it.

Unfortunately, most portfolio software systems also do not provide robust features for collaboration and sharing. A survey conducted by the UK's Becta (2007) found that only 33% of the surveyed students in the case studies agreed that their system "shows me what my friends are learning" (p.17). Only 46% agreed that the systems helped them give feedback on each other's work.

Students want education software that helps them to connect with each other, lets them express their individuality, and is easy to use (Jafari, McGee & Carmean, 2006a & 2006b). Students are requesting systems more like the social software they use outside of school (Jafari et al., 2006a). As one student says, "social software has been around for a while now and it's a lot more user-friendly" (Becta, 2007, p.16). Similarly, staff and faculty who use portfolios for their own learning are less satisfied with education software than social software. Another person said:

I engage in many e-portfolio-like practices. Those involving dedicated e-portfolio tools have been far less satisfactory than those involving social software tools such as blogs, wikis, social networking sites. (Becta, 2007, p.24)

Conceptual Approach

My research approach is to create an artifact and use it in an educational setting. The combination of usage logs, survey data, and interview results can then be used to evaluate a design model and related software implementation.

This pragmatic approach to research is normally called design science. Building upon Herbert Simon's concept of the "science of the artificial" (Simon, 1996) it follows a "build and evaluate" cycle (Hevner, March, & Park, 2004). This is different from other scientific approaches, such as natural science's "theorize and justify" approach.

Beyond simply creating a new implementation, this project focuses upon the creation and validation of an alternative model (or mindset) for the creation of portfolio software to support higher education. Design science research

precisely includes this kind of theorizing (March & Smith, 1995). The following sections propose a number of conceptual requirements for a portfolio system (following Walls, Widmeyer & El Sawy 1992; 2004).

Ownership

The concept of ownership is central in portfolio systems. As stated earlier, the defining characteristic of a portfolio is that it is owner-centric. Social presence is a theory describing how people can “project themselves socially and emotionally as ‘real’ people” (Cameron & Anderson 2006). Social presence uses 5 dimensions: focus, identity, safety, ownership, and style.

- Focus relates to the ability of students to talk about subjects that interest them. As Cameron and Anderson (2006) put it, “[t]opics of discussion within a computer conference are typically course focused and instructor directed.”
- The concepts of identity and style relate to the ability of students to develop their personal voices. Identity can also be developed through customization and personalization of a site, use of a formal or informal voice, and stylistic decisions.
- Students must have a feeling of safety before they can project themselves online. This can be accomplished by allowing students to close off some of their work to a limited audience through permission settings, or by closing down their account in the future.
- The concept of ownership is also linked to social presence. Most blogging systems allow the users to control their environment and communication. Creating a sense of personal ownership is also thought to be crucial in constructivism, where learners are expected to learn in their own unique way.

Social Learning

Collaborative influences during portfolio construction has a positive effect upon student learning, but has been poorly acknowledged in existing system design. As one of the 3 basic realms of activities proposed by Zubizarreta (2006), collaboration should be reflected in systems’ design as more than an afterthought. Casual exposure to peers’ content should be one of the basic use cases of any portfolio software. Most systems emphasize security and privacy, and, as a result, leave out the casual learning that occurs in a traditional paper classroom portfolio project.

Ease of Use

One of the major complaints about existing systems is that they are difficult to learn and use. The Technology Acceptance Model (Davis, 1989) *ease of use* and *usefulness* constructs accurately model students’ acceptance of portfolio software (Goldsmith, 2007). Because *ease of use* is such a critical variable, system designers should make a great effort to ensure that users have an easy time becoming skillful with a system.

The most common portfolio style uses a collection of pages that are organized for specific snapshots. This assumes that students will create a large amount of re-usable content that is submitted a number of times, and adds unneeded complexity.

Workflow of Collect, Select, Reflect, Assess Cycle

Ultimately, every portfolio system needs to support the basic workflow cycle of collect, select, reflect, and assess. *Collect* refers to the process of saving material used to satisfy course- related requirements. *Select* then refers to the process of choosing from among the saved artifacts to find those illustrating either achievements or learning. After selecting a set of artifacts, students then *reflect* on their learning, using their artifacts and a set of learning objectives as a prompt. Lastly, the teacher (or staff) *assess* the students’ learning and record the results for further use. This cycle then repeats for the next assignment or class, or terminates at the end of the student’s enrollment.

Research Design

The research approach for this project was to create a software package embodying the concepts presented in the previous section. Using a number of products would have yielded a stronger research design. Unfortunately, a review of existing products was unable to locate ones with the conceptual features being tested. As a result, I created a new software program for this project.

I began developing my portfolio software as a wiki plug-in for Elgg (an opensource social networking system) in January 2005. Since then, I have put out 7 major releases and many more incremental beta releases. The tool is broadly used, with some of the largest users being the University of Brighton, Emerald Publishing, and Cambridge University.

Screen Design

Folio provides extensive support for portfolio workflow, from the initial page creation to archiving work for later assessment. Whenever a user either goes to the “Page” tab for the first time, or clicks the link to add a new page, they are shown a list of pre-build templates (Figure 1).

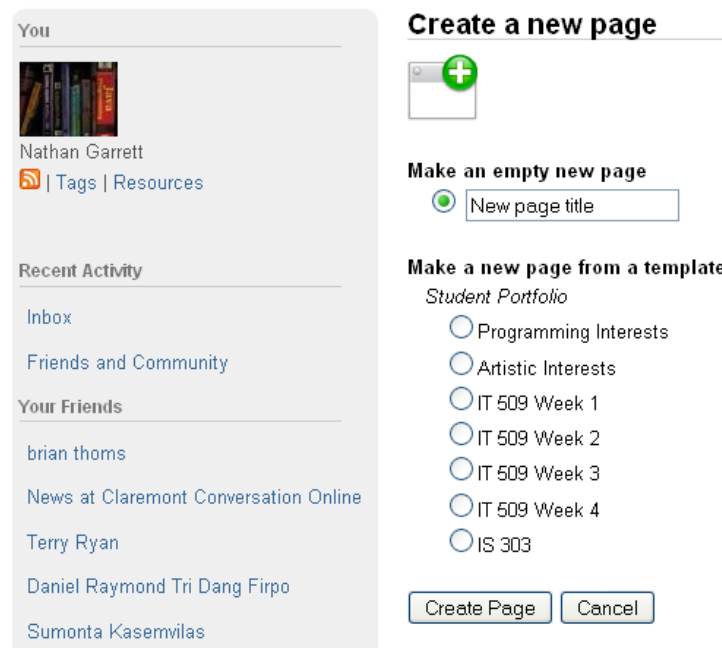


Figure 1. Create New Page

Allowing users to create individual pages from a template has important implications. This means that users can add pages created for a single class after the user started their portfolio.

Pages with similar tags are shown in the left-hand sidebar. Because class pages are created through templates with pre-populated tags, this immediately allows students to view peer work (Figure 2).

Hovering over these pages with the mouse cursor results in them being ‘popped-up’ through the use of a JavaScript window. Users can also click on the link to be taken directly to that user’s page. This hovering behavior is important because it provides an immediate sense of the level of development for each page. Since students may create a template page to see their weekly assignment, not all created pages may have content. This pop-up feature (Figure 3) makes it simple for students to quickly scan for completed work.

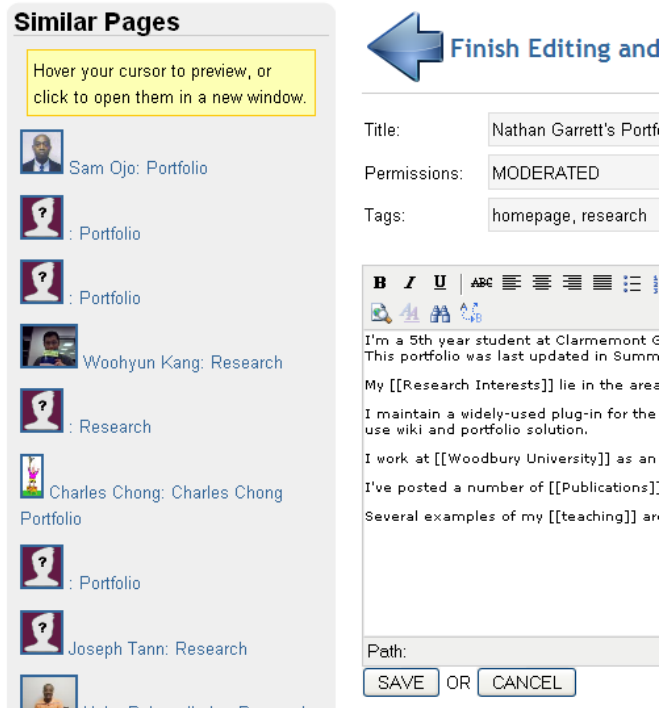


Figure 2. Editing Screen

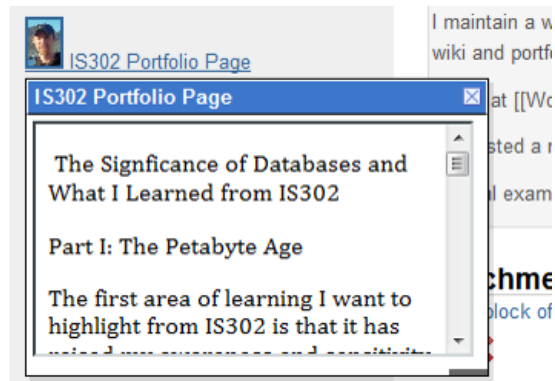


Figure 3. Pop-up Window

Attachments

Add a [block of text](#), [upload a file](#), or [embed html](#)

Upload a file into the page



B *I* U | ABC [List icons] [Link icon] [Image icon]

This is my first actual publication. It is on the Scholar much half of Claremont (Dr. Richlin's [[PFF]] Fellows,

Figure 4. Attachments

The bottom of each page has a section for attachments. Attachments could be a select of text, a file, or embedded html. Each uploaded file comes with a reflection field. Clicking on this field changes it into a RichText editor (Figure 4).

Portfolio structure is displayed through a tree-based side navigation pane; this makes it easy to see all of a user's work. Tags are listed below the page body; clicking on these tags takes the user to a page showing all pages they have permission to see with the given tag. These features are displayed in Figure 5.

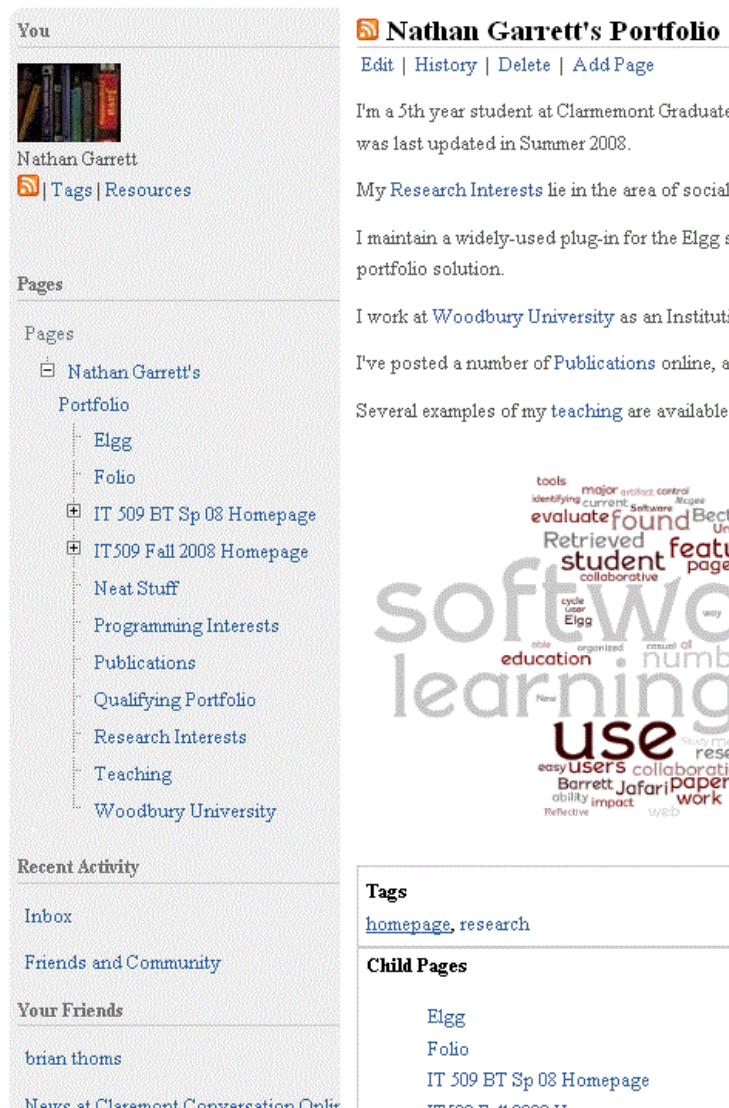


Figure 5. Main Screen View

Each view page also displays a comment box on the bottom. This makes it easy for an instructor to provide public feedback. All comments are automatically e-mailed to the page owner. If desired, an option box is also present that will not keep a copy of the comment posted on the page.

Research Design

My research method was to create an artifact, use it in a live setting, and evaluate the artifact effectiveness through surveys and usage statistics.

First, I recorded detailed usage statistics.

- Pages Viewed: Users' browsing behavior was recorded.
- Page Edits: The system recorded each time a user edited one of their own pages.
- Popups List: Whenever students edited a page, they were shown a list of pages with the same tag. The number of pages listed varied throughout the term, as the first person to create a page would not have any similar pages to see. The total number of popups listed was recorded.
- Popups Viewed: The system recorded each time a student moved their mouse over a page listed in the sidebar (causing a window to popup with the page contents).

Second, my design model hypothesis claims that ownership, social learning, and ease of use are major factors in user satisfaction. These variables were operationalized and measured through a post-test survey.

- Hypothesis: Ownership, social learning, and ease of use predict user satisfaction.

Third, I conducted a number of phone interviews to provide additional triangulation for the survey results and system usage logs. The interview script was created to answer questions raised by the survey analysis. Primarily, these focused on the following questions.

1. I wanted to better understand students' feelings of control and ownership over their portfolio. Why did some feel they had control over the visual style? What factors influenced their feelings of control?
2. How did students use the ability to view peer work? Were they trying to benchmark their work, learn about the content, or build personal relationships? How did the tool help them in each of those areas?

My tool was used in two separate sites.

1. The School of Information Systems and Technology (SISAT) at a research university used the software as an assessment portfolio tool in Fall 2008. All students taking courses were required to submit artifacts demonstrating learning for each class. Of the 11 sections that term, an average of 81% (56 students in total) submitted material into a portfolio.
2. Folio was also used to support 3 sections of a "Management of IT" MBA course at a small liberal arts university called IT509. This course was taught by the author. IT509 is part of the core MBA curriculum, providing a broad sample of MBA students. It is also an accelerated course, with students meeting once a week for 4 hours during the seven-week term. As a result, students are required to do much of their work outside class. Students used the site as their primary course management, submitting material each week before class. A total of 46 students were enrolled in these three courses.

Neither group of students was given incentives or encouragement to use the collaborative features of the tool.

Usage Results

The logging feature enabled me to record usage statics for both SISAT students and for the IT 509 course.

Overall Editing Usage

The SISAT students created a total of 91 pages from templates, an average of 11.4 per class (81% of the course, or 56 students in total). For each page submitted to a class, the author averaged 2.8 visits to the edit screen. In each of these edit screens, an average of 2.7 pages were shown in the sidebar. 53% of the time, people hovered their cursors over the available pages in the sidebar to pop-up their peer pages.

The 46 IT 509 students (in three sections) individually submitted a page for each of the 7 weeks of the course. Each week, the students visited the edit screen an average of 4.2 times. On average, the sidebar showed them 4.2 peer pages. On average, 88% of these peer pages were viewed through the use of a pop-up. Due to a glitch in the software, the second section's Week 1-5 log files were not recorded.

and frequent use of the pop-up feature. Figure 8 is provided to compare usage of the pop-up feature with overall system usage.

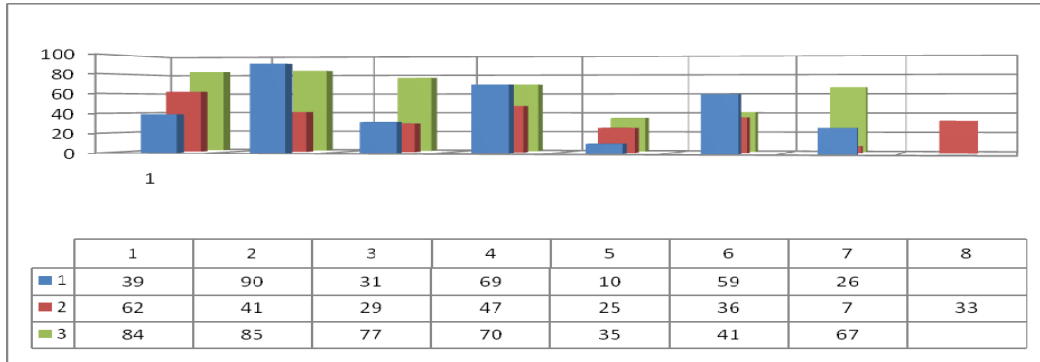
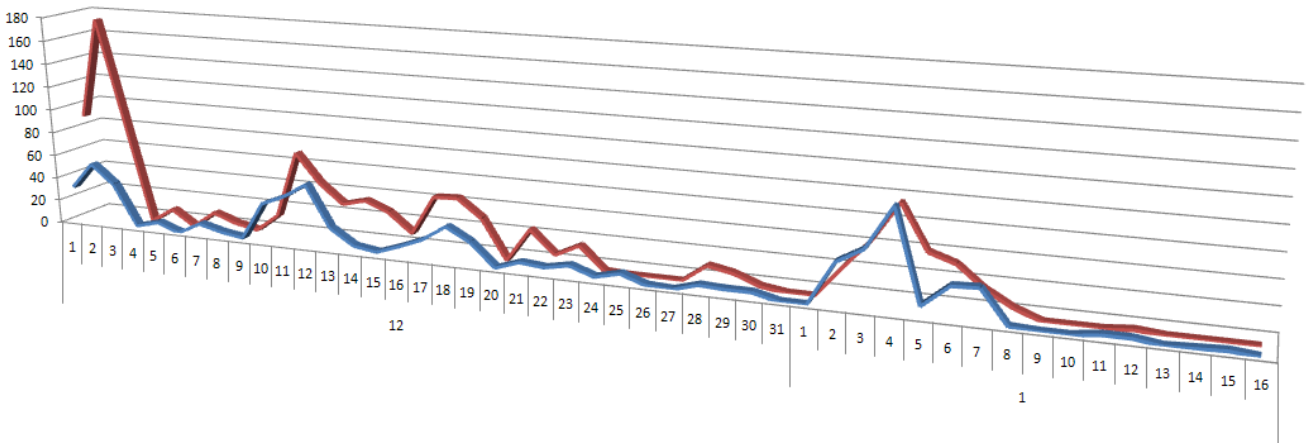


Figure 8. IT 509 Saves

Peer Page Viewing Behavior Over Time

Beyond using the pop-ups to view peer work, students also had the option to click through to view peer pages. The qualitative comments indicate that students frequently used the pop-ups to find when students had submitted work, and then would click through to view peer work in more detail.

The following Figures 9 and 10 show the frequency with which students viewed pop-ups and how often they viewed their peers' pages.



	12																															1																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16			
■ view_other	31	53	37	2	7		10	5	2	34	42	54	19	6	3	10	18	31	20	1	8	6	10	3	8	1		6	5	5			36	48	83	9	27	28	1			3	3	1	2					
■ view_popup	90	176	89	1	13		14	7	3	18	74	50	34	39	31	15	48	49	34	1	29	10	20	1				15	11	3			25	48	80	44	37	20	8											

Figure 9. SISAT Page Pop-up Viewing

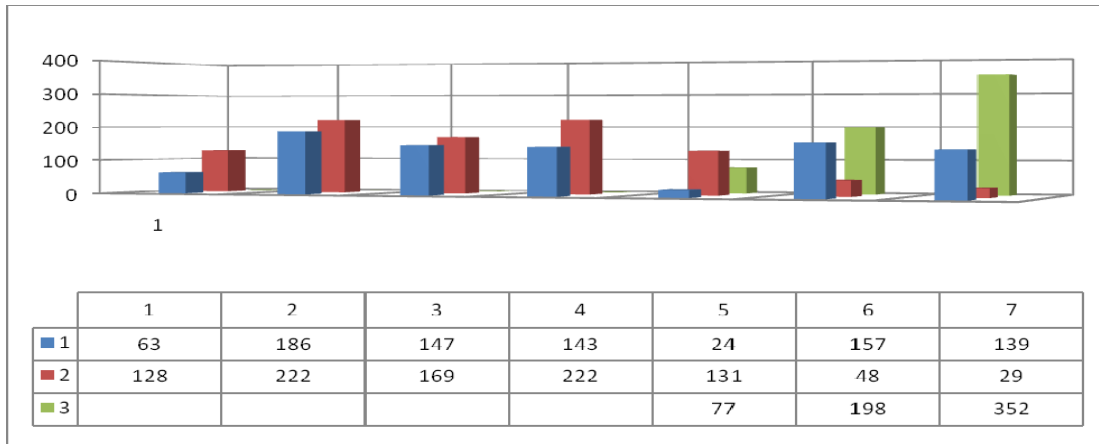


Figure 10. IT 509 Peer Work Viewed

As can be seen in both groups, students frequently looked at each other's pages throughout the term. This is encouraging, as it means that students quickly realized that they could view peer work, and persisted throughout their usage of the system.

Survey Hypothesis Results

Both IT 509 and SISAT students were given surveys to measure their experiences. Most SISAT students submitted their portfolio after the last week of class. Surveys were administered to 5 courses during the first two weeks of the following Spring 2009 term. Since many students were enrolled in multiple classes, they were asked to only fill out a survey one time. A total of 29 usable surveys were returned (a small number of blank surveys were thrown out).

The IT 509 students completed the post-test survey in the final week of the class. To prevent the possibility that students would give biased answers (since the researcher would be giving grades), the surveys were sealed and delivered to a neutral third party. After grades for the class were submitted, the sealed envelope of surveys was returned. A total of 39 surveys were returned.

Both groups of surveys were combined, giving a total of 68 surveys available for analysis.

Design Theory Variables

The survey measured a number of variables related to the design model. These included measures of students' feelings of control over their portfolio, perceptions of social learning, ease of use, and reported user satisfaction. Questions were in a 5-level Likert format.

Control

Both the IT509 and the SISAT students reported that they felt like they controlled the content (90%) and organization (77%) of their portfolio. However, only 52% felt like they controlled the visual template. The latter is not surprising, as the software template was not easily customized. However, the combination or custom avatar (user picture), formatting, and fonts appears to have led at least half of the students to feel that they had control over their work's visual presentation.

A high number of students (83%) reported that their portfolio belonged to them. This is an important validation of the design feeling student-centric instead of institution-centric.

Social Learning

Students reported that the social learning aspects of the tool helped them in a number of ways. The most positive result was that the social learning helping them to learn the material (79%). 58% of students also reported that seeing each other's work helped them to get to know each other. 54% of students reported that they were motivated by knowing their work was public, and that their work quality was improved by being able to see peer work.

Ease of Use

Most students (79%) reported that the site was easy to use. Almost all of the students reported that they had an easy time editing their portfolio and adding content. Several reported that they had difficulty uploading large PowerPoint files, but otherwise that it was easy to use.

User Satisfaction

80% of users reported that using the site was a positive experience. Users were most satisfied with how the system helped them view classmate's work (71%), but also thought it helped them do better in class (64%) and get to know their classmates (50%).

Variable Reliability

My portfolio design predicts that ownership, social learning, and ease of use will predict users' satisfaction with the software.

The *Ownership* construct includes the following variables, and had a Cronbach's Alpha of .806. Social Science research generally considers an alpha above .7 as acceptable (Nunnally 1978). Questions were in a Likert format.

- I had control over my portfolio's organization
- I had control over my portfolio's content
- I had control over my portfolio's visual template
- My portfolio belonged to me
- I have the ability to continue using my portfolio in the future

The *Social Learning* construct included the following questions, and had a Cronbach's Alpha of .887. Questions were in a Likert format.

- Being able to see other students' work:
 - Helped me learn the material
 - Improved the quality of my work
 - Helped me to get to know other people
- It was motivating to know that other people would see my portfolio.

The *Ease of Use* construct was constructed from the following 5 TAM questions. These had a Cronbach's Alpha of .924. The <sitename> text shown below was replaced with the url of the site.

- Learning to operate <sitename> was easy for me.
- I found it easy to get <sitename> to do what I want it to do.
- My interaction with <sitename> was clear and understandable.
- I found <sitename> to be flexible to interact with.
- It was easy for me to become skillful at using <sitename>

The *User Satisfaction* variable had a Cronbach's Alpha of .881.

- Overall, using <sitename> was a positive experience.
- Using <sitename> helped me to do better in my class
- Using <sitename> helped me to have a better sense of my classmates' work

- Using <sitename> helped me to get to know my classmates

Regression Model Result

My hypothesis was that the ownership, social learning, and ease of use predict user satisfaction.

The resulting model has an adjusted R^2 of 0.545, and an F score of 28.148 (Figure 11, 12, 13). As a result, I can be highly confident that the regression model is the result of random variation in my data.

R	R Square	Adjusted R Square	Std. Error of the Estimate
.752 ^a	.565	.545	.535

Figure 11. Model Summary

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	24.202	3	8.067	28.148	.000 ^a
Residual	18.630	65	.287		
Total	42.832	68			

a. Predictors: (Constant), Ease of Use, Social Learning, Control

b. Dependent Variable: User Satisfaction

Figure 12. ANOVA

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	.225	.245		.919	.362
Control	.230	.132	.178	1.749	.085
Social Learning	.371	.086	.428	4.318	.000
Ease of Use	.287	.102	.296	2.819	.006

a. Dependent Variable: User Satisfaction

Figure 13. Coefficients

I also created a regression model that used IT509 membership as a 1/0 variable to test the significance of the difference between the SISAT users' experience and the IT 509 users' experience. This was not significant, with a t value of 1.371 (a 0.175 chance of random chance), and did not have a significant effect upon either the overall model predictive value or the predictor's coefficients.

Interviews

After analyzing an early copy of the dataset, I conducted a number of interviews to clarify issues raised and to triangulate the overall results.

Participants were gathered from both the SISAT students who submitted Fall 2008 program portfolios as well as students from the 2nd session of the IT 509 course. I interviewed 5 SISAT students and 4 from an IT 509 section.

The interviews averaged 8 minutes in length. I added questions as needed to clarify student responses, and provided explanation if a question was not understood. The questions focused on 4 central issues: site purpose, control, ownership, and social learning.

Site Purpose

One theme that came up several times in the interviews was the importance of the way in which the site was presented to students. Several of the SISAT students said that the site was introduced to them as a purely course-related requirement, and not as a site for their own personal portfolio.

It was not told to us as you can use the portfolio in any way you want... Professors said it's a requirement, you need to do this....There needs to be more encouragement from the professors themselves.

One mentioned that the "institutional" feel of the site prevented him from realizing that it could be used like Facebook or MySpace. Referring to the feeling of MySpace or Facebook, another said that it does "not have as much as that; it had an institutional feel."

Control

Most of the interviewed students said that they felt like they had control over their portfolio and the portfolio content. Several of them equated control with the potential for other people to insert things into their space, or on their own ability to put whatever they wanted into the site. One student said she had control "because I'm allowed to do certain things with the ePortfolio even if I don't use it." Another said that he had control, even though it was "tricky" to figure out where to place things. Another student said that he had "complete control, it was pretty much a blank slate for me to put in whatever I wanted."

Most of the interviewed students did not feel that they had control over the visual style of the portfolio. When asked to explain, most said that they had either not tried to use that feature, or that they did not know how to change the template. Some students seemed to think that they could not change the template, or that the institutional branding of the site meant that they did not have control over it.

A small minority disagreed, saying that they felt like they did have visual control. When asked to explain, they said that they had the ability to move things around the page, or that they had seen another student's page with a custom template. However, this group was definitely in the minority.

Ownership

While most students reported that they had control over their portfolio, a significant number said that they did not feel like they fully owned their site. Some of the ownership issues related to the institutional branding of the site; one student said, "It didn't look like Facebook or MySpace so we didn't realize that was what it was for." Faculty also presented the site as a course requirement, and not as a way for students to create a personal site. One student said:

We use the portfolio only as a course requirement. You don't have a sense you want to go into it all the while... It was how it was introduced to us.

Lastly, one student explicitly compared setting up a portfolio to using a social networking site. As he said, "I didn't feel like it was genuinely mine, like if I went and created a page somewhere... I didn't feel it was ownership, I felt like it was part of the system a little bit."

The students who did report a sense of ownership mentioned the ability to add pages and control content as the source of that feeling.

Social Learning

Some of the most useful data gathered was in determining why students used the social learning features of the site.

First, the most common reason given for viewing peer work was to get ideas on how peers were approaching the assignment. Many students said something similar to how this tool let them "see how they're approaching the

problem,” or “what idea[s] they have that are different from my own.” Some reported being surprised at what their peers wrote, with one saying:

Some of the classmates answered very differently than mine... [O]thers describe more. This is good; I didn't see it from this perspective before.

One student highlighted the usefulness of the feature for classes where the assignments were unclear, or more complicated (such as Finance or Accounting):

[This feature would] be useful for when I didn't have an understanding of the assignment, then I can look at other peoples' work and can see how they interpreted it....[It would] be good in a class where the assignments were tricky.

Second, many students reported that the tool acted as a benchmark. One student said that “I tried to always be better than someone else.” Another student said:

There was one time where I really wasn't sure of the approach to take... I read someone else's, and ooh I wasn't going to write that much and prompted me to write more.

However, a strong minority of students reported that they did not use the tool in this way. Some said that they only looked at peer work after doing their own, or that there was not any peer work posted until after they completed the assignment.

Third, most students reported that the social learning feature did not help them to get to know the material better. As one said, “...as far as learning the material, that's more of a personal thing.” Most students reported using the social learning aspects of the site after studying on their own. This is in contrast to the survey results, where most students indicated that the site helped them to get to know the material.

Fourth, students had different reactions to the question asking if they got to know fellow students better through the social learning feature. Because the IT 509 course was only 7 weeks long, most of the MBA students said that the class was too short and intense to allow much peer bonding. As an example, one student stated:

Not really, but... that's the compressed time format of the class itself... It goes by so quickly; it's all you can do to keep up with your assignments.

Some students did say that they got to know their peers better. Those tended to talk about how it helped them understand peer perspectives, views, and writing ability. As another student wrote:

Yah it did a bit, you can see their grammar style and how they interpret the questions... Can tell you a lot about how they think and where they're coming from.

Lastly, students seemed to have a strong desire to minimize their usage of the social learning features. The word “copying” or phrase “copying and pasting” in the formatting question frequently caused the tone of the interview to change. Students went from talking freely to single word “yes” or “no” answers. This impulse seemed particularly strong in PhD and international students. Student seemed to feel a need to justify their capability to accomplish the work without needing peer assistance.

Discussion

The survey, interview, and usage results strongly support my predictions drawn from the background literature.

Design Model Validation

My portfolio design theory predicted that ownership, social learning, and ease of use are central variables in explaining students' portfolio adoption. Results of my hypothesis clearly indicate that these three variables can predict satisfaction with a high degree of accuracy (with an adjusted $R^2 = .574$).

Social learning proved to be an important variable. Students clearly felt that the social learning aspects of the site improved their learning and peer relationships. Students felt that seeing the way in which peers approached the assignments helped them see the material from a different point of view.

Students' usage of the social aspects of the site was high, and the pop-ups proved to be an important way to help students see peer work. Placing similar work in the edit screen is a novel concept that has been proved to increase students' peer exposure. While students may feel a need to minimize the extent to which their work is based off of peers, their heavy usage indicates it was a useful feature.

Ease of use was a significant predictor of overall satisfaction in my regression model.

Design Implications

The major implication of this work is that portfolio software should be redesigned to be more open, social, and easy to use. Jettisoning the current database-driven view of portfolios, which emphasize re-use instead of ease of use, is the first step designers should take in redefining the portfolio.

Next, portfolio designers and pedagogical or program leads should reconsider the emphasis on social aspects of portfolios. Students clearly are motivated by social portfolios, learn the material better, and better know their peers.

Limitations

This research project has a number of limitations.

1. While two groups used the site, usable survey data were only gathered from 68 students. While this is a small sample, survey results were almost evenly split between the MBA and IT (MSIS/PhD) students, and were similar enough that a dummy variable in the regression was not statistically significant.
2. The SISAT students' experience of the portfolio features of the site may have been contaminated by their use of the blogging and file sharing features in other courses. This threat was mitigated by the instructions on the survey form, which asked students to answer questions based on their experiences with the portfolio tool. Interviews with students also indicated that their responses were based on portfolio usage.

Conclusion

The project demonstrates the validity of a new style of social ePortfolios.

1. Usage results indicate that students quickly learned how to view peer work, and consistently did so during their editing and submission process.
2. Survey results indicate that the design model is sound. The ownership, ease of use, and social learning constructs passed Cronbach's Alpha test, and were able to predict user adoption with an adjusted R^2 of 55%.
3. Interview results triangulated the survey results, and provided additional information on the reasons why students used the social learning features.

Students enjoyed learning from peer work, and did it even when not required. Many reported being surprised at the way that different people approached an assignment or topic, and said that looking at peer work caused them to reexamine their approach.

This project provides consistent support for a new style of eportfolio. Easy to use software that encourages students to learn from each other, and provides a sense of ownership, will lead to improved adoption and learning. Instead of emphasizing assessment rigor, ePortfolio software should be designed to help students learn from each other.

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Conceptual Model Learning Objects and Design Recommendations for Small Screens

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ABSTRACT

This article presents recommendations for the design of conceptual models for applications via handheld devices such as personal digital assistants and some mobile phones. The recommendations were developed over a number of years through experience that involves design of conceptual models, and applications of these multimedia representations with students in schools and higher education. Three sets of design recommendations are discussed: design presentation of conceptual models, small screen design, and design in relation to specific learning uses. These recommendations should prove useful to designers of multimedia resources and professionals engaged in instructional uses of these representations. The article calls for researchers to pay more attention to the design of conceptual models and other forms of multimedia resources and their instructional uses.

Keywords

Design, Conceptual models, Learning objects, Multimedia learning, Handhelds, M-learning

Introduction

A conceptual model is a particular kind of a learning object (see Churchill, 2007). It is an interactive and visual representation designed to depict a concept or a number of connected concepts, and support conceptual learning through multimedia and processes of manipulation and interrogation of represented properties and relationships. Emerging handheld technologies (portable digital assistants and some mobile phones) are equipped with multimedia capabilities that enable delivery of conceptual models. If appropriately designed for the context of use, conceptual models can be effectively delivered to a variety of learning environments via this technology.

This article presents recommendations on three aspects of conceptual model design for applications via handheld technology: presentation of conceptual models, small screen design, and design in relation to specific learning uses. These recommendations were developed over a number of years of experience designing conceptual models and applications of these multimedia representations with students in schools and higher education. The paper lists and expands on these recommendations, and provides brief background information on how these were explicated. The paper also attempts to substantiate the presented arguments through reference to an example of a conceptual model. However, readers should not expect detailed descriptions of data collection and analysis in this paper. Detailed reports on a study of various sets of recommendations have been presented elsewhere (e.g., Churchill & Hedberg, 2008b). Overall, the paper provides information that could be useful to designers of multimedia resources and professionals engaged in instructional uses of these representations, and calls for researchers to pay more attention to design as it relates to instructional uses of conceptual models.

A simple example of a conceptual model is presented in Figure 1. This conceptual model displays a concept of a triangle and its associated properties and relationships. It allows students to manipulate the base and height of the triangle by dragging corresponding sliders. Manipulating either of the two parameters of the triangle (base or height) by dragging the sliders will result in an immediate update of the display: the triangle will be redrawn in a corresponding size, and the numerical information regarding associated parameters (such as the value of the hypotenuse) will be updated. This conceptual model can be reused for different purposes and with different groups of students. For example, lower grade students could use it to explore the properties of a right-angled triangle, while more senior students might explore properties such as Pythagorean theorems and basic trigonometric functions (sine and cosine).

The current literature lacks specific recommendations for the design of conceptual models for applications via small screens of handheld technology. This paper introduces a set of recommendations for such design. These recommendations integrate three sets of independently developed guidelines: (a) design for presentation, (b) design for small screen and (c) design for learning uses. The recommendations reported in the article will contribute to the

literature, and are useful to designers of educational multimedia, teachers involved in uses of conceptual models in instruction, and researchers interested in the effect of design possibilities on multimedia learning.

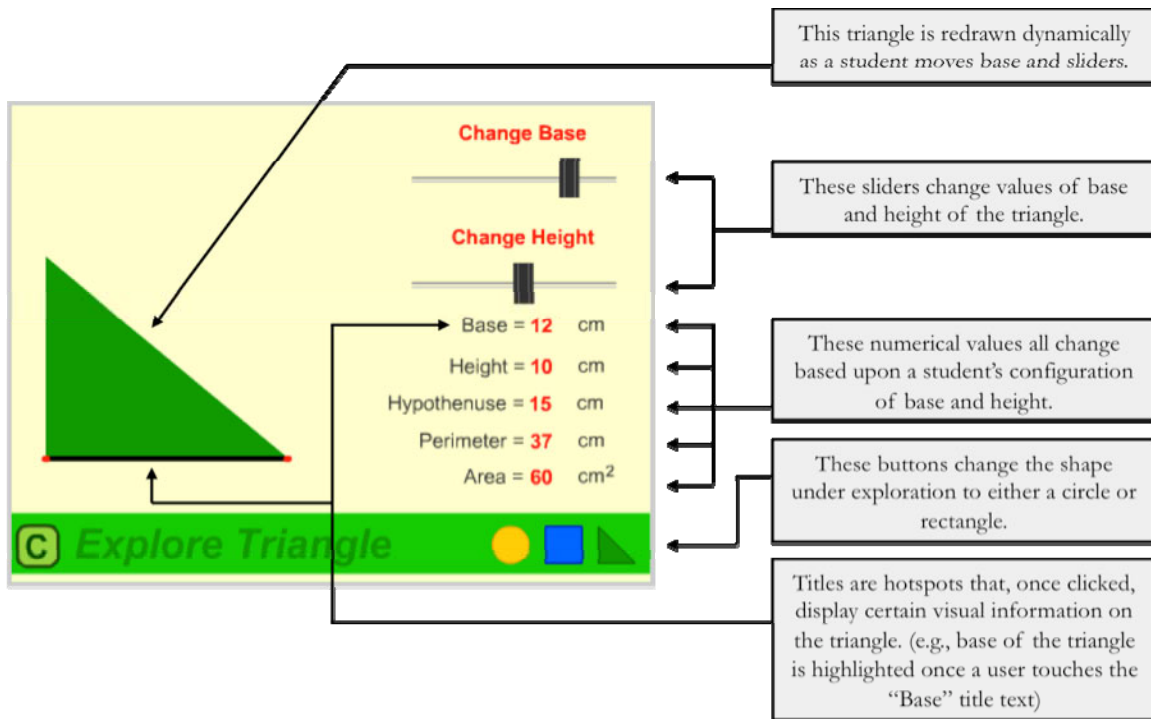


Figure 1: “Explore Triangle” conceptual model learning object (from Churchill & Hedberg, 2008b)

The rest of the article is organized into three main sections. The first provides theoretical background relevant to idea of a conceptual model and its application. The next section presents various design recommendations. Finally, there is discussion of a conceptual model designed in line with these recommendations.

Key Concepts and Issues

The idea of *concept* has been the subject of a philosophical debate and has influenced the work of well-known figures such as Kant, Vygotsky, Piaget, and others interested in understanding forms of knowledge and how these develop in individuals (see Berger, 2005, Hartnack, 1968, Turner, 1975). Concepts in a school curriculum can be understood as components of knowledge that learners need to construct in order to engage with specific disciplinary issues, solve problems and further learn. Anderson and Krathwohl (2001) propose a model for curriculum planning that divides content knowledge into four categories: factual, conceptual, procedural and metacognitive. Similarly, in the instructional design community, Merrill (1983) introduces Component Display Theory (CDT) and classifies knowledge into concepts, facts, procedures and principles. Overall, learning should not simply include remembering of facts but also development of *conceptual knowledge*. Conceptual models, when appropriately designed, might serve as useful tools to support *conceptual learning* (Bruner, Goodnow, & Austin, 1967). The key idea behind the conceptual model as presented in this article is that concepts from curriculum content can be represented through digital representations specifically designed to support conceptual learning.

Models have been described as powerful tools for learning, and their educational use has been described as model-centered learning and instruction (e.g., Seel, 2003, Gibbons, 2008). Lesh and Doerr (2003) define a model as a conceptual system “consisting of elements, relations, operations, and rules governing interactions” that are used to “construct, describe, or explain the behavior of other system(s)” (p. 10). For Dawson (2004), a model is “an artifact that can be mapped onto a phenomenon” and that is “easier to understand than the phenomenon being modeled” (p. 6). Johnson and Lesh (2003) more specifically discuss technology-based representational models and suggest that these models can be used for communicating, modeling, describing, or experimenting with other system(s). For

Johnson and Lesh (2003), key characteristics of technology-based models are that they are interactive and involve the use of more than one type of representational media. Norman (1983) uses the term ‘conceptual model’ and refers to it as a representation of a target system designed to serve as a tool for understanding or teaching. Mayer (1989) also describes a conceptual model as a representation designed for teaching and learning purposes, and writes that such a representation “highlights the major objects and actions in a system as well as the causal relations among them” (p.43).

Today’s technology enables design of conceptual models in multimedia form. This form is predominantly interactive (e.g. sliders, buttons, hot-spots, text-entry and other interactive features of a screen) and visual (e.g., diagrams, illustrations, pictures, videos, effects and animations). It can also contain other modalities such as text and audio. This idea of a conceptual model as visual and interactive multimedia representation is influenced by theoretical work such as: external multimedia representations (Schnotz & Lowe, 2003), dynamic visualization (Ploetzner & Lowe, 2004), information visualization (Bederson & Shneiderman, 2003), visual explanations and envisioning information (Tufte, 1990; Tufte, 1997; Tufte, 2001), visual and multimedia displays and conceptual models (Mayer, 1989; Mayer 2003), conceptual models (Norman, 1983), multiple representations (van Someren, 1998), modality and multimodality (De Jong et al. 1998; van Someren et al. 1998) and pedagogical models (Fraser, 1999). Overall, the literature suggests that technology creates opportunity for design and application of conceptual models and other forms of multimedia representations that can effectively support teaching and learning (e.g., De Jong et al., 1998; Fraser, 1999; Norman, 1983; Johnson & Lesh, 2003; van Someren, 1998). It is also suggested that learning with these representations is supported through activation of certain cognitive processes such as mind modeling and linking between internal representations (e.g., Churchill, 2008a; Seel, 2003; Mayer, 1989; Mayer, 2003).

The Cognitive Theory of Multimedia Learning (Mayer, 2001; Mayer, 2005) provides some useful ideas for the design of conceptual models and other forms of representations for educational purposes. In terms of this theory, learning is a sense-making activity in which a student actively builds a coherent mental representation from presented pictures and words, and the teacher is a guide who assists the student’s sense-making process. Visuals and words are processed through different channels, passing into the working memory through sensory memory. Through processing of the material in the working memory, and by drawing upon their prior knowledge, students develop verbal and pictorial models (mental models) that are further integrated into coherent knowledge (cognitive schema) in long-term memory. Multimedia supports students to pay attention to relevant information, selecting words and pictures, organizing these in mental models and integrating them with prior knowledge into coherent knowledge constructed in long-term memory. Mayer and his collaborators provide a number of principles as guides for the design of representations for multimedia learning (Ayers & Sweller, 2004; Fletcher, & Tobias, 2005; Low & Sweller, 2005; Mayer, 2001; Mayer, 2005; Sweller, 2005):

- *Multimedia principle* (a representation for multimedia learning should integrate visual and verbal information, not verbal alone);
- *Principles for managing essential processing*: segmenting (multimedia messages should be presented in student-paced segments), pre-training (names and characteristics of main concepts should be familiar to students) and modality (words should be spoken rather than written);
- *Principles for reducing extraneous processing*: coherence (extraneous material should be excluded), signaling (cues should be used to highlight the organization of the essential material), redundancy (the same information should not be presented in more than one format), spatial contiguity (words and pictures should be physically integrated), and temporal contiguity (words and pictures should be temporally integrated); and
- *Principles for multimedia learning based on social cues*: personalization (words should be presented in conversational style), voice (narration should be in a standard-accented human voice) and image (it is not necessary to include a speaker’s image on the screen).

Although these multimedia learning principles suggest some useful ideas for conceptual model design, a more specific set of recommendations is required, not only for design purposes, but also to inform teachers regarding the effective instructional uses of these representations. Attention needs to be given to learning as a cognitive activity in which a student builds a coherent mental representation from the presented material. Further, a learning task should trigger these cognitive processes through conceptually demanding acts where learners use multimedia material as a means to achieving an outcome.

A conceptual model should be used in context of a learning task (see Churchill & Hedberg 2008a). For Foo, Ho and Hedberg (2005), learning task design should be the central task for a teacher when planning lessons. Such tasks

might take the task-form of troubleshooting, strategic performance analysis, case study, design challenge or resolving a dilemma (for more detailed classification of problem types, see Jonassen, 2000). Mayer, Dow and Mayer (2003) suggest that a task should present students with a conceptually demanding question that requires deep processing of the presented material and the development of self-explanations. Alternatively, a conceptual model can be used as an aid to a teacher's presentation or to engage students in discussion about the presented properties and relationships. Post learning, a conceptual model can be provided for students to support their homework, assignments, preparation for tests and independent learning activities. When developing computer-based instructional material, instructional designers might use a conceptual model as a media object to be integrated in their overall design product: e.g., a conceptual model can be used as supportive or just-in-time information in learning designs based on the 4C/ID-Model (see van Merriënboer, Clark, & de Croock, 2002).

Emerging handheld technology (e.g., portable digital assistants and mobile phones) opens a spectrum of opportunities for the support of teaching and learning. Attewell (2005) claimed that as the number of such devices increases globally, this technology is becoming part of "digital life" for many individuals. These tools may assist learners "to access Internet resources and run experiments in the field, capture, store and manage everyday events as images and sounds, and communicate and share the material with colleagues and experts throughout the world" (Sharples, Corlett & Westmancott, 2002, p. 222). For Luchini, Quintana and Soloway (2004), the key benefit of handheld technology is as a powerful personal device that "provides access to tools and information within the context of learning activities" (p. 135). Studies reported a variety of situations for the use of handheld devices in teaching and learning: during classes, enabling teachers and students to share files (Ray, 2002) and allowing students to ask anonymous questions, answer polls and give teachers feedback (Ratto et al., 2003); for delivery of courseware and quizzes and as an intelligent tutoring system (Kazi, 2005); for dissemination of information and collection of data during field trips (So, 2004); as a tool that supports students' inquiries (Sharples et al., 2002; Clyde, 2004); in computer-supported collaborative learning (Roschelle & Pea, 2002; Zurita & Nussbaum, 2004); as personal technology for lifelong learning (Sharples, 2000); as support for more flexible modes of assessment (Vogel, Kennedy & Kwok, 2007); and to assist disadvantaged young adults to improve literacy and numeracy skills (Attewell, 2005).

One important affordance of this technology is as a 'multimedia-access tool' (see Churchill & Churchill, 2008b). A variety of multimedia resources can be delivered using this technology (e.g., e-books, web pages, presentations, interactive resources, audio files and video segments). These resources can be accessed any time, anywhere, by connecting to the Internet using 3G mobile telephony network or WiFi, from the memory of the device or storage card if the resources were previously downloaded, or through synchronization of a handheld device with a computer. However, merely moving resources from a computer to a handheld device might not lead to effective learning. Resources for use via handheld devices must be designed with certain design principles in mind.

Conceptual models might be effective resources for handheld technology, as these can be made available to students in a variety of situations, anytime and anywhere via such technologies (Churchill, 2008b; Churchill, Kennedy, Flint & Cotton, 2010). Designing and implementing conceptual models via handheld technology might open possibilities for its more effective use in teaching and learning. However, this requires an understanding of effective design for presentation via the small screens of handhelds, and the ways in which a conceptual model might support learning when delivered via this technology in learning contexts such as educational fieldwork.

Design Recommendations

This section of the paper discusses recommendations for conceptual model design for small screens. These recommendations were developed over a number of years through experience that involves reviews and design of conceptual models, and applications of these with students in schools and higher education.

Design for Presentation

The first set of recommendations informs the design of content, screen and interface elements of a conceptual model. These recommendations were developed through a review of a number of conceptual models (some of these conceptual models are available at <http://www.learnactivity.com/lo/> or through a repository at <http://risal.cite.hku.hk>). Two experienced instructional designers assisted the author in the review. Each of the three

reviewers described features and characteristics of the reviewed conceptual models through reference to the criteria based on the relevant issues from the Cognitive Theory of Multimedia Learning, as follows:

- *Multimedia principle* -- What is the predominant mode of representation for the essential content of this conceptual model (e.g., visual, textual, animation, auditory)?
- *Principles for managing essential processing (navigation)* -- Describe characteristic structure and navigation (e.g., single or multiple screen, user-paced or automatic, hierarchical or linear navigation, physically and temporally integration of modes).
- *Principles for managing extraneous processing (interactivity)* -- Describe interactive features used to manipulate the represented concept (e.g., slides, buttons, clickable hot-spots).
- *Principles for reducing extraneous processing* -- How was the extraneous content used (e.g., use of cues to highlight the organization of the essential content)?

Data collected was unitized and sorted by the reviewers into a number of emerging categories, from which the following design recommendations were generated in relation to the presentation of conceptual models:

- *Present information visually* -- In a conceptual model information should be presented predominantly through use of visual elements (e.g., photographs, illustrations, diagrams, graphs, colors, icons and symbols). Sometimes, the same information can be presented in a number of modes simultaneously (e.g., as text, visually and via audio). However, visuals are the central mode of representation and using redundant information should be carefully managed (see redundancy principle [Mayer, 2001]).
- *Design for interaction* -- Relationships should be displayed in interactive ways to allow the user of a conceptual model to manipulate parameters and observe outcomes (e.g. by manipulating sliders, clicking on buttons, or inputting text/numbers). Outcomes of the manipulation can be presented in a single mode or in several modes at the same time (e.g., as a number or a graph).
- *Design a holistic scenario* -- Design elements should be arranged in ways that integrate bits of content into a holistic presentational scenario depicting the concept that is represented. In other words, all areas of the screen need to integrate into a holistic scenario that supports multimedia representation of a concept.
- *Design for a single screen* -- A conceptual model should be most often presented in a single screen, since this allows a student to have a holistic focus on all elements of the required conceptual knowledge. Further, a single screen enables a student to manipulate relationships and properties, and to access outcomes of this manipulation all in one place. At the same time, a single interactive screen can be easily meshed with other media into structures such as web pages.
- *Design for small space* -- The design of a conceptual model should utilize only the screen space necessary to present all the required information, properties, relationships and interactive elements. From the experience of the author, most conceptual models can be designed in a screen space that does not exceed 640 by 480 pixels. This recommendation has two important implications. Firstly, the student concentrates visual attention on a smaller screen area. Secondly, a conceptual model designed for a small screen might later serve as a media object that can be embedded into larger structures such as blog posts, instructional products and PowerPoint slides.
- *Use audio and video only if it they are the only option* -- Audio should only be used if it is effective for a representational purpose or to enhance realism when required (e.g., a specific sound indicating a faulty machine), or to offload cognitive processing from the visual channel (see modality principle [Mayer, 2001]). Similarly, video should only be used when, for example, manipulation of relationships requires different segments from a video to be presented based on the configuration of parameters. Often, content from a video might be presented as several images of the key frames, with short blocks of text explaining each of the frames (which might support temporal contiguity principle [Mayer, 2001]).
- *Use color in moderation* -- In order to clearly present the content, color should be used in moderation. Often, color can be used to connect related information (e.g., connecting a positive numerical value displayed in red with a red bar on a bar graph). Different shades of color can be effectively used, but use of sharply contrasting colors must be avoided. The focus should be on simplicity and clarity of presentation and support for learning, rather than in pursuit of gratuitous artistic beautification of the display.
- *Avoid unnecessary decorative elements* -- Unnecessary decorative elements can add complexity to the representation and result in increased extraneous cognitive load (Mayer, 2001). These should be used in moderation, or not at all. All elements of the display should serve the purpose of representing a concept (or should facilitate this representation) and allow a student to manipulate its properties and explore relationships. In addition, cartoon-like characters should be avoided unless they serve some representational purpose. Many

designers assume that cartoon-like characters will motivate students by making learning fun; however, such graphics are less than productive for learning. For Collins (1996), designers should not assume that fun is a desirable component of presentation, because there is a risk that students might not take such learning seriously; thus, a 'fun' presentation might impede learning! Motivation lies in a learning task engaging a student in the use of a conceptual model, rather than in the model itself. A conceptual model is a strategy for effective representation of educationally useful concepts, and unless its display elements support this representation, they should not be included.

- *Design with a single font* -- In order to keep the presentation simple, a single font style should be used (e.g., Arial font in different sizes, shades and styles). The same color fonts can be used to relate pieces of information. Using multiple font types might increase extraneous cognitive load and have a negative effect on learning.
- *Use frames to logically divide the screen area* -- Frames can be useful in dividing the presentation screen into functional and logical areas and groupings. For example, interactive elements such as sliders and buttons can be grouped together in one area of the display, while another area can be used to display output information. Such areas might support visual attention (as a student focuses attention on one framed area at a time) and positively affect the utility of the essential cognitive load required to process information (Mayer, 2001).

While these presentation recommendations should prove useful, other aspects of design must be considered when presentation is via devices whose screen size and interactions are limited as compared to computers. Furthermore, these recommendations do not provide ideas regarding instructional uses of a conceptual model and therefore, although useful to designers, are of little use to teachers. Applying these recommendations alone will result in a conceptual model design that is not necessarily optimized for instructional use. Further inquiries were conducted in order to develop more comprehensive recommendations which incorporate specific features of design for small screen and learning uses.

Design for Small Screens

If appropriately designed for the context, conceptual models can be effectively delivered via technologies including small screen handheld devices (PDAs and some multimedia-enabled mobile phones). The key challenge for the effective delivery of conceptual models is the limited screen sizes of these devices. The current typical dimension of the screen area of a handheld device is about 3.5" (9cm), with a resolution of 320 by 240 pixels. Recent studies have pointed to potential limitations of such screen sizes for effective presentation of information (see Albers & Kim, 2001; Bradley, Haynes & Boyle, 2006; Jones et al., 1999; Jones, Buchanan & Thimbleby, 2003; Kim & Albers, 2001; Lee & Bahn, 2005). Albers and Kim (2001) identify three specific issues that affect user access to information via handheld devices: (a) reading of text on a handheld computer screen is more difficult than on paper, (b) presenting graphical information is limited as regards the size and complexity of image, and (c) interactivity may be compromised due to the lack of keyboard and mouse, while the screen size limits display space for interactive elements. Elsewhere, Kim and Albers (2001) suggest that information design for handhelds must be informed by a new understanding of small screen usability, and the "limited real estate." Rettig (2002) proposed that designers should storyboard their prototypes on pieces of paper with dimensions that resemble the physical size of the screen of a handheld device. When designing learning objects for use by students on handheld devices, Bradley, Haynes, and Boyle (2006) suggest that although user interactivity does not appear to be affected, screen size continues to present design challenges. These authors report that text legibility and the nature of interactions represented limitations on design possibilities. They suggest that learning objects should be designed for full screen presentation rather than for presentation in a browser window, and recommend greater use of audio over text to compensate for the limited design space.

The author previously engaged in an inquiry to develop a set of design recommendations for small screen presentation (see Churchill & Hedberg, 2008b). In the earlier stage of the study, participants (including a number of school teachers) were engaged in interaction with a number of learning objects via handheld devices (HP iPAQ rw6828 Multimedia Messenger). These learning objects were selected to permit demonstration of various modalities (e.g., text, visuals, audio) and different kinds of interaction (e.g., buttons, hot-spots, sliders, text-entry boxes) in order to facilitate discussion leading to an understanding of possibilities for dealing with the challenges of a small display area. Following the interviews, a few learning objects were progressively (re)designed in consultation with the participating teachers for implementation with students. Students' use of learning objects was observed and interviews were conducted in an attempt to identify any further issues that should be considered in the effective design of the learning objects. From this inquiry, the author explicated the following recommendations:

- *Design for full-screen presentation* -- Full-screen presentation of a conceptual model increases amount of available space and this appears to create an improved user experience.
- *Design for landscape presentation* – Typically, the screen of a handheld device is presented in portrait layout. The landscape presentation offers more flexibility for design.
- *Minimize scrolling* -- Scrolling should be avoided, or at least minimized.
- *Design for short contacts and task centeredness* -- A conceptual model should be designed such that it enables learning through task-centered information.
- *Design for one-step interaction* -- The design goal for a learning object should be to provide through visualization and interactivity all necessary information with a single display that fits in the screen of the handheld device. Single interactions, such as changing the position of a slider, should result in immediate updates on the screen presented in a way that is perceptually and immediately noticeable by a student in response to an action.
- *Provide zooming facility* -- The display should be enlarged beyond the physical limits of the screen when appropriate. The user should be able to zoom and drag the entire screen in any direction to access hidden areas of the display beyond the physical limits of the screen.
- *Design movable, collapsible, overlapping, semi-transparent interactive panels* -- Utilize floating panels in order to maximize amount of information presented on a display.

Although the two sets of recommendations (design for small screen and design for presentation) address important aspects of design, the critical issue for use of any technology in education is how it can be designed to effectively support learning. The presented design recommendations might be further examined for their impact on learning through methodologies used by the Cognitive Theory of Multimedia Learning researchers. However, this article emphasizes that understanding effective design of conceptual models must also incorporate understanding of how such models are used to support learning tasks. Although the Cognitive Theory of Multimedia Learning provides useful ideas regarding learning from multimedia resources, this article suggests that this theory is incomplete without consideration of learning tasks that require uses of conceptual models and other forms of multimedia representations.

Design for Learning Uses

The author's further inquiry developed a third set of recommendations that more specifically address the issue of application of conceptual models via handheld technology in learning contexts. This final set of guidelines complements the design recommendations for presentation and small screens, resulting in a more comprehensive set of guidelines for the design of conceptual models for application via the small screens of handheld technology. On a number of occasions the author engaged with teachers who used conceptual models in instruction and students. Classroom and fieldwork observations, interviews, and review of collected work of students provided data and an informed understanding of the learning uses of conceptual models via handheld devices. These learning uses were classified in emerging categories that became specific recommendations for design (see Table 1 for a list of recommendations and corresponding learning uses).

Table 1. Design for learning uses

Design for learning uses recommendations	Learning uses of conceptual models identified
Design for observation	<ul style="list-style-type: none"> • Aid to observations • Tool for linking of theory to the world outside the classroom • Tool for inquiry
Design for analytical use	<ul style="list-style-type: none"> • Analytical tool
Design for experimentation	<ul style="list-style-type: none"> • Experimentation environment • Tool for generalizing
Design for thinking	<ul style="list-style-type: none"> • Environment for articulation of components of knowledge • External cognitive supplement • Decision-making tool
Design for reuse	<ul style="list-style-type: none"> • Preparation tool • Collaboration tool • Reflective tool

The following elaborates on each of these recommendations:

- *Design for observation* -- A conceptual model should be designed such that learners are supported in making links between the real world and the represented properties of a concept. It should be designed such that learners can recognize properties from a real environment in the interface of a conceptual model, as well as the converse. These representations of properties are not simply copies of the real world. Rather, designers should represent reality through illustrations, diagrammatical representations, analogies, metaphors, signs, cues, symbols and icons.
- *Design for analytical use* -- A conceptual model should contain design features that allow learners to input data from the real environment for analytical processing (e.g., a special purpose calculator). Designers should use interactive features (e.g., sliders, dialers, hot spot areas and text input boxes) to enable input of parameters. Outcomes of interactions can be displayed in a variety of formats such as numbers, graphs, audio, verbal/written statements, pictorial representations and animation.
- *Design for experimentation* -- A conceptual model should enable learners to manipulate parameters and properties, and observe changes that result from such manipulations. Also, it might be useful to allow the manipulation of outcomes of analytical use to enable learners to examine how these changes affect related parameters. The changes should be highlighted to provide cues and encourage generalizing. A conceptual model's design features should allow emergent generalizations to be tested in some way.
- *Design for thinking* -- Designers should incorporate in a conceptual model features that initiate and support thinking. This can be achieved by integrating triggers (e.g., signals and cues) to capture attention and initiate curiosity. Some design ideas from the Cognitive Theories of Multimedia Learning (Mayer, 2001) could be useful as a conceptual guide. For example, a conceptual model design should support the cognitive activities of linking mental models (verbal and visual) developed through interaction with that conceptual model.
- *Design for reuse* -- The design of conceptual models for handheld devices should allow reuse in different environments and activities. For example, reuse might include a classroom presentation, or use by multiple learners as they collaborate. Other applications might require delivery via devices other than handheld, such as a computer, a projector or an interactive white board. The design of a conceptual model needs to consider at least two issues for flexibility of reuse: (a) interactivity should be supported by a variety of devices, and (b) presentation of a conceptual model on a large screen should not cause split attention problems (see Mayer, 2001). In certain cases, it might be useful to provide features that allow data from a conceptual model to be saved in an external file for reuse, or for exchange between collaborating users (e.g., through the Internet or via handheld device connectivity).

These design recommendations and corresponding possibilities for learning uses provide guides for teachers engaged in the planning of instructional uses of a conceptual model. They present possibilities for learning-task-related uses, while at the same time informing designers on ways to ensure that conceptual models effectively support these uses. In the next section of the paper, a case of a conceptual model designed to reflect the three sets of recommendations is discussed. Overall, the intention is to demonstrate the usefulness of the recommendations, and prompt readers to examine if and how these might apply in their own practices.

A Case of a Conceptual Model Design Based on the Recommendations

In February 2008, the author traveled to Northern Thailand with a group of 72 secondary school students and two of their Geography teachers from Hong Kong. During the trip, the students were required to conduct a study of a river - one of the key topics in the students' Geography curriculum. This topic includes issues such as how a river changes downstream; how farming and various human settlements influence its changes; obtaining key measurements such as a river's width, depth, velocity and gradient; and calculating values of other parameters such as discharge and hydraulic radius. During the field trip, the students were equipped with handheld devices - namely, the HP iPAQ rw6828 Multimedia Messenger. This handheld device uses the Windows Mobile operating system. As well as recording collected data and images, the handheld devices were used to access a conceptual model that was designed specifically for use in the context of the students' field work. This conceptual model is presented in Figure 2.

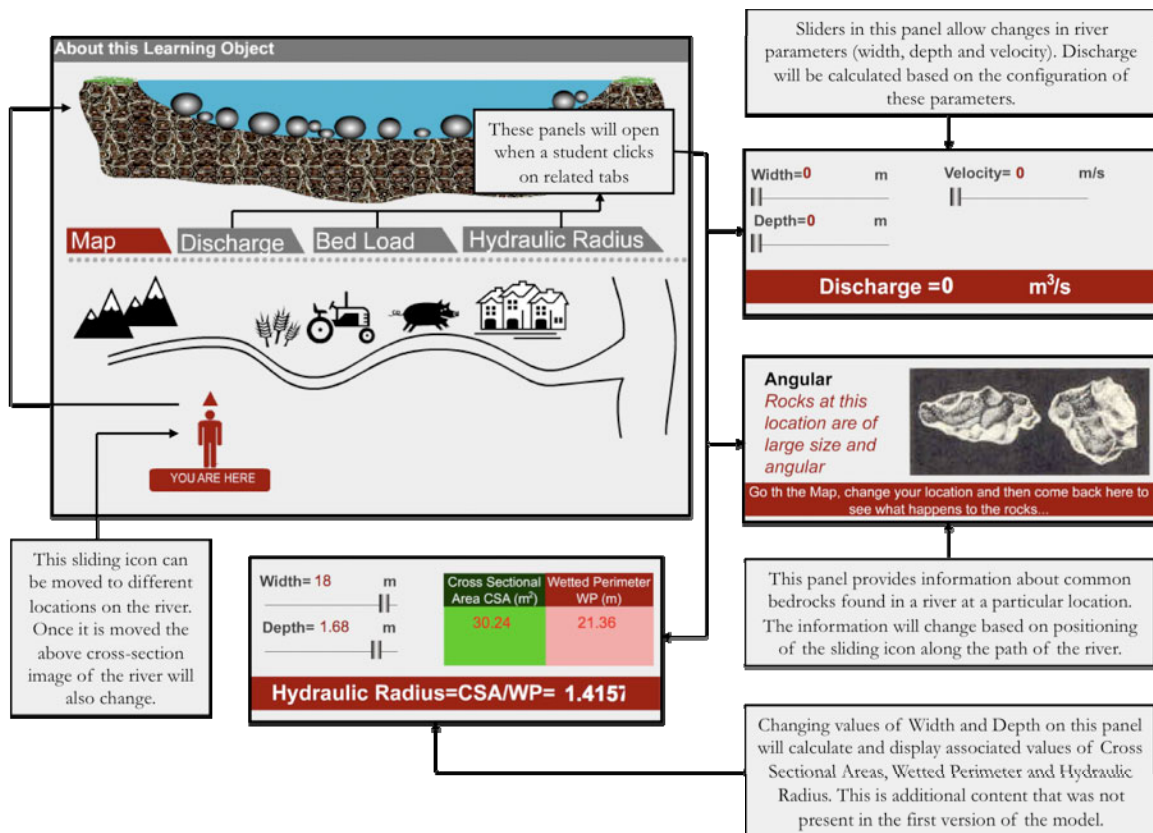


Figure 2. The “River” conceptual model

The conceptual model contains information about a number of river parameters, enables calculations of river discharge, presents the impact on flow rates caused by the shape of a riverbed, and allows identification of common bedrocks at different locations along the river. Various items of information are presented based on a student’s interaction with the conceptual model. A student can explore issues affecting the river through interaction and manipulation of specific parameters (e.g., how the cross-section of the river changes as its course progresses downstream), and by systematic exploration of specific information (e.g., how the river discharge is calculated based on values of width, depth and velocity).

Prior to the field trip, the teachers displayed the conceptual model via a projector and used it as a visual aid when explaining the key concepts of a river (e.g., depth, velocity, discharge). Once outdoors, the students used the model to support their river study learning task in any way they perceived as useful. After the fieldwork, the conceptual model was useful as a tool that facilitated reflections and writing up of a river case study report in digital form. The students were provided with a PowerPoint template, which they populated with their data, evidence and media from the field, then presented conclusions. During the fieldwork, students used handhelds to store measurements, collect images and capture video, made audio-recorded notes etc, and this information was used as data, evidence and media for the report. The template was also embedded with the conceptual model, along with relevant conceptually challenging questions requiring students to refer to the model when developing their arguments.

Design features of the “River” conceptual model illustrate the usefulness of the recommendations discussed in this article. This is elaborated in Table 2, which links each of the recommendations to some specific feature of the conceptual model. The conceptual model reflects most of the recommendations. It is the author’s intention to further revise the conceptual model in order to improve its design in a way that is fully consistent with all of the recommendations. In particular, revision is required to more closely match recommendations for small screen design. Overall, the author intends to provide sufficient description of recommendations in order to allow readers to examine whether these are useful in their own practices.

Table 2. Design features from the “River” conceptual model (cm)

	<i>Recommendations</i>	<i>Design features from the “River” conceptual model (cm)</i>
Design for presentation	<ul style="list-style-type: none"> • Present information visually • Design for interaction 	<ul style="list-style-type: none"> • Information in the cm is presented mostly visually (e.g., cross-section of the river and downstream changes). Text is used for buttons, labels, values and instruction. • The cm allows a learner to manipulate parameters through sliders (e.g., position on the river). Outcomes of manipulations are presented visually and numerically (e.g., river cross-section and value of discharge).
	<ul style="list-style-type: none"> • Design a holistic scenario 	<ul style="list-style-type: none"> • Elements such as cross-section of the river and the river path are arranged in a way that integrates them into a single scenario.
	<ul style="list-style-type: none"> • Design for a single screen 	<ul style="list-style-type: none"> • Content of the cm is presented in a single screen.
	<ul style="list-style-type: none"> • Design for small space 	<ul style="list-style-type: none"> • The cm is designed for effective presentation in a 320x240 pixel screen area.
	<ul style="list-style-type: none"> • Use audio and video only if it is the only option 	<ul style="list-style-type: none"> • No audio or video content is present in the cm. Although audio could add some realism (e.g., water flow), its presence was not necessary.
	<ul style="list-style-type: none"> • Use color in moderation 	<ul style="list-style-type: none"> • Color use was limited in the design. Colors include blue, white, black, brown, maroon and green.
	<ul style="list-style-type: none"> • Avoid unnecessary decorative elements 	<ul style="list-style-type: none"> • No decorative elements were used in the cm. All elements are related to essential content.
	<ul style="list-style-type: none"> • Design with a single font 	<ul style="list-style-type: none"> • Only Arial font was used in the cm.
	<ul style="list-style-type: none"> • Use frames to logically divide the screen area 	<ul style="list-style-type: none"> • The screen was divided into functional areas. Top part of the screen presented cross section of the river and its changes. Bottom part of the screen presented related content and interactive elements.
	Design for small screen	<ul style="list-style-type: none"> • Design for full-screen presentation
<ul style="list-style-type: none"> • Design for landscape presentation 		<ul style="list-style-type: none"> • The cm is displayed in landscape mode.
<ul style="list-style-type: none"> • Minimize scrolling 		<ul style="list-style-type: none"> • Content is designed in such a way that scrolling is not required.
<ul style="list-style-type: none"> • Design for short contacts and task-centeredness 		<ul style="list-style-type: none"> • Content is presented visually to maximize amount of information that can be viewed in shortest time. The content displayed, such as numerical values, can support tasks like analyzing real river parameters (e.g., parameters can be configured based on requirements pertaining to the real environment).
<ul style="list-style-type: none"> • Design for one-step interaction 		<ul style="list-style-type: none"> • Any single interaction will result in immediate display on the screen of related information. Outcome of any interaction is immediately noticeable.
<ul style="list-style-type: none"> • Provide zooming facility 		<ul style="list-style-type: none"> • Zooming has not been utilized in the cm. A redesigned version of the cm should contain this facility.
Design for learning uses	<ul style="list-style-type: none"> • Design movable, collapsible, overlapping, semi-transparent interactive panels 	<ul style="list-style-type: none"> • Content is distributed in four panels, each containing content information and interactive features. Cross-section of the river remains displayed at all stages. The redesigned version of the cm will build further upon this recommendation by including features such as semi-transparent panels.
	<ul style="list-style-type: none"> • Design for observation 	<ul style="list-style-type: none"> • Visual elements (e.g., illustrations) are designed in ways that are easily related to reality (e.g., rocks in the river bed or color of water). Also, elements of reality (e.g., farm land) are easily related to visuals in the cm.
	<ul style="list-style-type: none"> • Design for analytical use 	<ul style="list-style-type: none"> • Interactive features allow manipulation of parameters and calculation of associated outputs (e.g., changes in the river’s width, depth and velocity will calculate and output value of discharge).
	<ul style="list-style-type: none"> • Design for experimentation 	<ul style="list-style-type: none"> • The cm allows a learner to manipulate parameters and experiment with outputs (e.g., how hydraulic radius varies based on changes of the width and the height of the river).
	<ul style="list-style-type: none"> • Design for thinking 	<ul style="list-style-type: none"> • Prominent color and objects were used to highlight information such as how velocity is averaged across the river, or to highlight certain manifests in order to lead a learner to query and generalize.
	<ul style="list-style-type: none"> • Design for reuse 	<ul style="list-style-type: none"> • The cm is designed with Adobe Flash. It is flexible and easily rescaled to fit larger screens and be displayed via computers and projectors. Interaction used (sliders and clickable spots) is supported across different devices. As a Flash Object, the cm can be embedded in other digital media environments such as PowerPoint slides or blogs.

Conclusion

Contemporary research on technology in teaching and learning pays insufficient attention to the design of educationally useful multimedia representations and their roles in learning experiences. Even existing discussions about learning objects are over concerned with defining what a learning object is, rather than examining effective models for design and their uses. Work reported in this article attempts to contribute in this direction and emphasize the importance of multimedia resources as tools for conceptual learning. The article builds on previous work that defined learning objects and their specific forms (see Churchill, 2007) and expands to detail aspects of design that are perceived as important.

Basically, a conceptual model is a strategy for the design of educationally useful digital material that supports conceptual learning. Effectively designed conceptual models can be provided to teachers to integrate them in their teaching, to students for uses in their independent learning activities, or to instructional designers to use as media objects for integration in larger structures such as computer-based instructional packages. This article more specifically describes aspects of designs of conceptual models for learning applications via handheld technology. Three sets of design recommendations are discussed and it is proposed that these be integrated into a framework for the design of conceptual models. The recommendations cover design for presentation, small screens, and learning uses. An attempt is made to demonstrate their usefulness through presenting a case of a conceptual model designed according to the recommendations. The three sets of recommendations should be considered when designing conceptual models for application via small screens of handheld devices and might also inform planning of their instructional uses. The three sets of recommendations are diagrammatically represented in Figure 3.

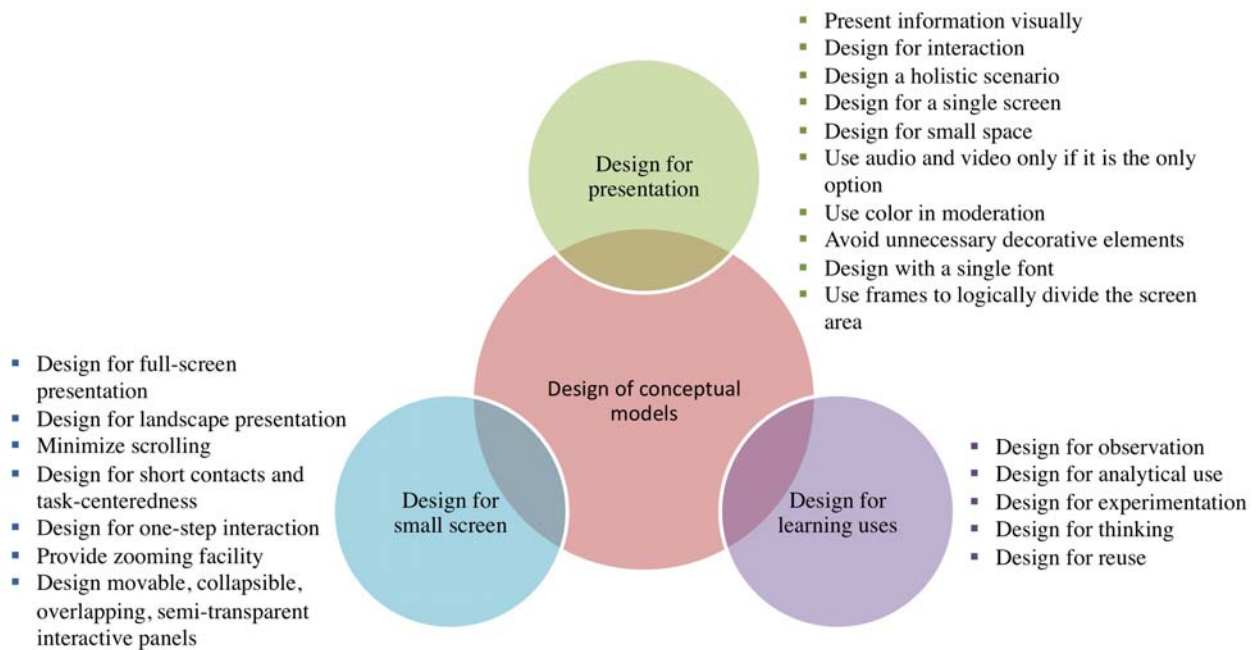


Figure 3. Recommendations for design of conceptual models for small screens

It is the contention of this article that it is important to recognize two processes related to conceptual models: the process of designing conceptual models, and that of designing learning tasks with the intention of them being used and reused by students. The recommendations are applicable in both processes, and thus could prove useful to designers who develop conceptual models, and to teachers who plan to use conceptual models in their instruction.

Multimedia designers, teachers and instructional designers are invited to consider the application of the recommendations in their practices. In addition, researchers should examine the effects of the design recommendations on learning outcomes in disciplines where conceptual models might be useful (e.g., science, engineering or mathematics). The author is currently engaged in further study to investigate forms of cognitive residues and associated mind processes when these residues are used. It is hoped that such investigation will lead to

further refining of conceptual model design recommendations and provide outcomes that challenge, revise or further extend theoretical works such as Cognitive Theory of Multimedia Learning (Mayer, 2001) and Cognitive Load Theory (Sweller, 1994).

Acknowledgements

This work was partially supported by grant No200707176064 from The University of Hong Kong.

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Exploring Adult Digital Literacy Using Learners' and Educators' Perceptions and Experiences: The Case of the Second Chance Schools in Greece

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ABSTRACT

The research reported in this paper aspires to shed light into adult digital literacy using learners' and educators' experiences and perceptions at Second Chance Schools, a project in Greece aiming at combating social exclusion through education. In exploring the above, this investigation uses a case-study approach within a qualitative paradigm and draws upon a heuristic that brings together a set of ideas on adult program development to guide research techniques and analysis procedures. The latter focuses on five key elements of program development for adults: needs identification, planning, design, climate, and evaluation. The findings identify the importance placed by the participants on digital literacy and indicate some tentative points and practices that, when suitably adapted, could pave the way for effective preparation and delivery of digital literacy courses for adults.

Keywords

Digital literacy, Teaching and learning practices, Adult and lifelong learning

Introduction

Information and Communications Technologies (ICT) play a central and pervasive role in our modern age, permeating every aspect of our social life, such as workplace, education, public services, economy, administration, healthcare, entertainment, and culture. The tremendous growth of new technological environments is considered a driving force that transforms our world into a global, universal society. ICT affects our lives and everyday relationships as well, from accessing a wide range of information and interacting with public services to working from home, from collaborating with colleagues to communicating with friends, and from receiving education from distance to political participation.

In the framework above, computer literacy is recognized as an important skill for the 21st century work force and the learning society (European Commission [EC], 2000a; EC, 2001). Educational policy directives and initiatives in most developed countries have articulated clear and unambiguous statements about integrating ICT in everyday education practice in order to inform citizens about the knowledge and skills needed to participate in the 21st century's knowledge society. ICT is also considered the driving force for widening adults' participation in learning and lifelong learning initiatives (Gorard, Selwyn, & Madden, 2003; Mason, 2006), facilitating flexible learning in terms of time and distance, and thereby establishing opportunities and conditions for a "learning society" for all (EC, 2000b; 2001; 2003).

Improving adult digital literacy levels is fundamental in the sense that it bridges the digital divide and confronts the issues of exclusion and marginalisation that accompany the increasing importance of ICT-mediated activities in modern social life. According to Selwyn, Gorrard, & Furlong (2006, p. 1), "mapping how ICTs and ICT-based learning fit with the everyday lives of adults is a vital task for the research community." During the past decade, a great number of studies have investigated various groups of people regarding their attitudes and beliefs toward computers, such as students, teachers, adults, etc. (for example, see Knezek & Christensen, 2002; Sugar, Crawley, & Fine 2004; Jimoyiannis & Komis, 2006, 2007). Most of the investigations have revealed four correlated dimensions (Jimoyiannis, 2008): anxiety, fear or caution regarding computer use; self-efficacy and confidence in the ability to use ICT; liking use of computers and ICT tools; and perceptions about the value and the usefulness of ICT use in personal life.

It seems that the development of students' ICT expertise has a basis in strong internal motivation and in intensive use of ICT, both at school and at home (Ilomaki & Rantanen, 2007). Undoubtedly, young people who have grown up with computers, mobile phones, and the Internet are not fearful of technology and they are willing and open to experimentation with new ICT applications and facilities. In contrast, adults' learning habits, their notional barriers

about new computing systems, their technical difficulties in using ICT, and, finally, their attitudes toward ICT seem to be different from those of high-school or university students (Chua, Chen, & Wong, 1999; Wilfong, 2006).

However, while research worldwide has proved that adults need digital skills (Selwyn, 2004a; 2004b), limited empirical evidence has been directed to digital literacy teaching approaches and the associated pedagogy (Kambouri, Mellar, & Logan, 2006; Jimoyiannis & Gravani, 2010). As Probert (2009) suggests, school teachers' understanding of information literacy and the associated classroom practices constitutes an open research subject. In addition, adult educators are faced with many peculiarities and complicated situations that describe the digital literacy framework, namely learners' pre-existing knowledge and learning habits, their lack of time and personal computer, and their attitudes and social representations about ICT as well.

Understanding more about adult digital literacy constitutes the fundamental purpose of this study, which seeks to shed light on the educational reality at the Second Chance School (SCS) program in Greece. The investigation presented is justified, given the importance placed on ICT by both the EU Commission and the Greek government, the fact that adult digital literacy is an under-researched field, and the central role of digital literacy in the curriculum of adults education in SCSs. It aspires to extract from the findings those practices that, when suitably adapted, could pave the way for effective preparation and delivery of digital literacy courses for adults. The ultimate purpose of this paper is to contribute to the discussion regarding the design of adult digital literacy courses and programs.

Second Chance Schools and digital literacy

The SCS project was funded by the EU and the Greek State in light of the Commission's 1995 white paper, *Teaching and learning: Towards the learning society* (EC, 1997), aiming to propose actions that combat social exclusion. In addition to Greece, the SCS pilot projects have been initiated in eleven more EU countries (Jimoyiannis & Gravani, 2010). In particular, the projects have been initiated in cities that have both concentrations of detrimental socio-economic factors and a strong potential for mobilizing the local players. A network linking all these projects has been set up, enabling an exchange of experience and best practice between different pilot sites and participants.

In Greece, the SCS project constitutes a flexible and innovative educational program (Jimoyiannis & Gravani, 2010), which provides lower secondary education to adults aged 18 and over who have not completed the nine-year compulsory education. It aims at combating the social exclusion of individuals who lack the qualifications and skills necessary to meet the contemporary needs of the labour market. The program lasts 18 months, divided into two stages of nine months each (two academic years). The weekly schedule covers 21 teaching hours, taking place during the afternoons. Forty-eight schools have been established and operate all over the country, while three SCS operate within prisons.

SCSs are characterized by an open and flexible curriculum that is significantly differentiated from the one followed in formal schools, in terms of principles, content, teaching methods, students' learning activities, and assessment. Multiliteracy is the key concept that forms the basis for the development of the program of studies, while adults' interests and the wider social environment are the critical factors determining the written and the oral word (General Secretariat for Adult Education [GSAE], 2003). The core of the learning subjects is mainly developed around three interrelated literacies, namely, language literacy, numeracy, and digital literacy. In particular, the curriculum of SCS is determined by three main objectives (Jimoyiannis & Gravani, 2010):

- to develop adults' skills in language, mathematics, and communication, with special emphasis on foreign languages and ICT. (The basic subjects are Greek, mathematics, digital literacy, English, social education, environmental education, aesthetic education, technology, and the physical sciences)
- to offer basic training and preparation for their professional life in cooperation with the local authorities
- to develop adults' skills in the domain of their personal interests, such as, for example, sports, music, theatre, etc.

In SCSs, teaching and learning activities are seen as a communication act rather than an effort to achieve pre-determined goals. According to this, the learning activities are not drawn up in advance; rather they draw upon the basis of students' individual needs. Therefore, learning is not seen as a process of knowledge transmission. The teaching and learning practices should promote personalized teaching, experiential learning, self-motivation, students' active involvement and decision making, critical thinking, and more. Educators and students have the

opportunity to communicate and collaborate in the synthesis of what each community knows about important learning and teaching processes (Gravani, 2007).

The role of digital literacy in the curriculum of SCS is vital, since it aims at helping adult learners to achieve the following:

- acquire the necessary technical knowledge and skills to use ICTs effectively
- be competent in using ICTs to solve problems of everyday life
- understand the social dimensions and the impact of ICTs in our modern society
- cultivate positive attitudes regarding ICTs and face the demands of modern age.

In the framework above, digital literacy is considered in a broader view than computer use and familiarization with various ICT environments (hardware devices, software tools and applications, digital content, etc.). In other words, it refers not only to the knowledge and skills of using a wide range of ICT environments but also to those skills related to accessing, processing, analyzing, evaluating, applying, and communicating information (content) so that adults will be able to participate as active members in the so-called knowledge society (EC, 2000a).

Methodology

This study is based on the experiences and perceptions of the participants to unveil the processes of adult digital literacy teaching and learning in the context of the SCS. A qualitative case-study approach within the phenomenological mode to the selection and analysis of the data was adopted (Bogdan & Biklen, 1982). Four broad case studies were used for the purpose of this research. These were the four oldest SCS programmes run in Greece (Acharnes, Peristeri, Agioi Anargyroi, and Ioannina). The replication logic (Yin, 1984) was followed in the selection of the cases explored. According to this, each case is selected so that it either a) predicts similar results or b) produces contrary results but for predictable reasons.

However, selecting the setting and context of research is not the only decision required. In case studies, decisions involve internal sampling as well, which involves decisions about with “whom to talk.” With regard to choosing participants for the study, it was decided to take an opportunistic sample. According to Miles & Huberman (1994), an opportunistic approach to sampling involves every individual in the population to have an equal chance of being selected. For this study, 24 adult learners and 8 educators were selected. The learners ranged in age from 23 to 57 and varied in their adult life stages. There were 21 women (the majority of the learners attending SCS are women) and 4 men, with varying employment status. The educators, one woman and seven men, were all permanent secondary-school teachers in ICT and varied in their profile. They ranged in their teaching experience in schools from 2 to 15 years. Their prior experience in adult teaching in SCS or/and elsewhere also varied from zero to hundreds of hours.

The tools employed for the collection of the data include in-depth, audio-recorded, semi-structured interviews carried out over a two-month period. The researchers carefully designed the interview process. They were well trained, and guarded against personal biases by recording detailed field notes, which include reflections on subjectivity, to ensure validity of responses. In particular, the semi-structured approach has the advantage of retaining its main objective of eliciting equivalent information from a number of informants, thus allowing a comparative analysis of responses between different groups of subjects. Moreover, it provides a more flexible style that can be adapted to the personality and circumstances of the persons being interviewed and permits the researcher to probe and expand the informants’ responses (Hitchcock & Hughes, 1989).

Interview schedules were prepared for learners and educators. Examples from the agenda included questions related to the factors that influenced the adult teaching and learning of ICT in this particular context, such as the social and education context of the program, the feelings and emotions triggered, the “conceptual inputs” that participants brought into the courses. Participants were interviewed separately in a setting, and at a time that was convenient and comfortable for them. Most of the interviews took place in classrooms. Each interview lasted between 45 minutes to an hour. Prior to the interview, the researchers had contact with the respondents and explained the aims, nature, utility, and contribution of the research in order to establish a rapport with and gain the trust and respect of the respondents. For the purposes of clarity, adult learners and educators in the study are referred as learner 1, learner 2, etc. (through to learner 22) and tutor 1, tutor 2, etc. (through to tutor 8).

The data analysis was completed in the spirit of hermeneutics and involved the deployment of the constant comparative method, whereby categories and their properties emerged from a detailed sententious analysis of the data. For the purposes of illustration a heuristic was used to structure the early stages of data analysis. This draws upon a set of ideas that cohere under the rubric program development developed by Gravani and John (2005). The heuristic is represented in Figure 1.

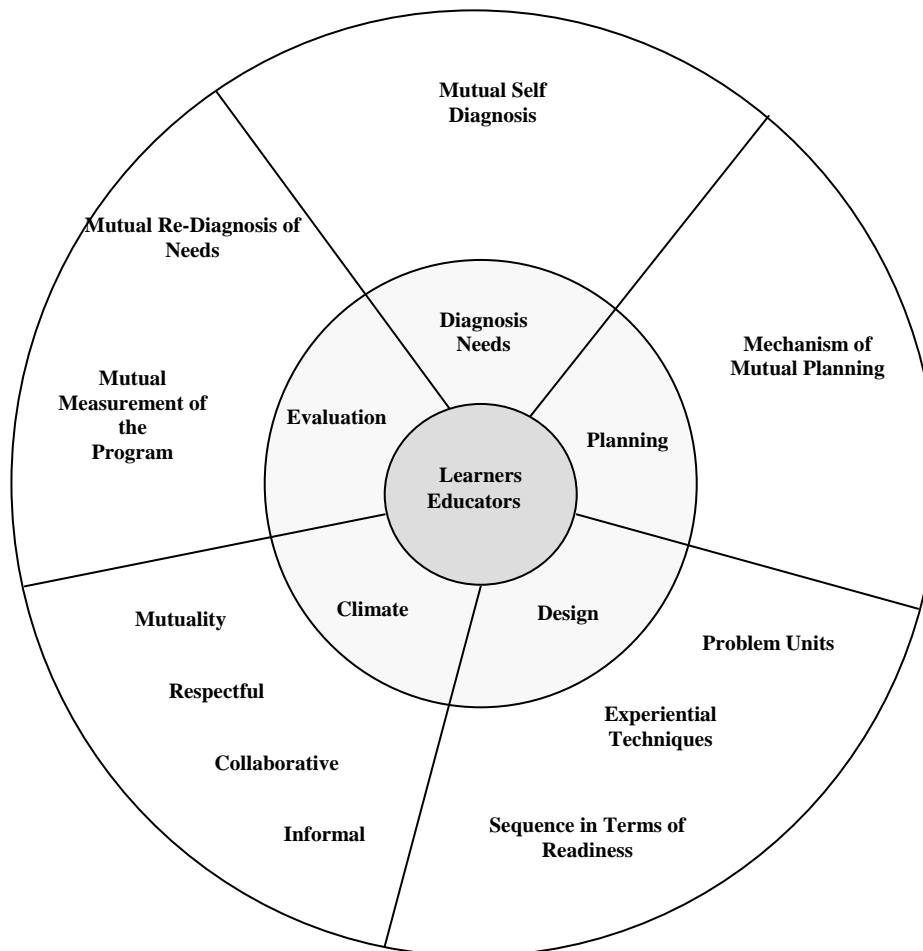


Figure 1. Representation map of the heuristic

The inner circle represents the key unit of analysis: adult educators and learners. The second circle and its parts suggest the program elements that guided the collection and analysis of data. There were five major themes, namely, needs identification, planning, design, climate, and evaluation, linked to the elements of the guiding heuristic. The outer circle and its segments show some traits that orient the organization and analysis of data. Data were indexed, and various themes that seemed to be related to the five organizing concepts outlined in the guiding heuristic were identified. Themes that emerged along with the relevant quotes were then sited under the five concepts. This was the process of coding (sorting) data into categories, according to the commonalities that they share. The emergent categories were then turned into a series of codes that were applied to the corpus. These were derived from an iterative reading of the data and guided the validity of the wider emerging themes. This process comprised three sub-components: naming, comparing, and memoing. The themes were then contextualised by placing them in correspondence to the literature through the process of theoretical memoing (Locke, 2001). The final accounts were illustrated by using the most telling pieces of data, which evoked the original words of the participants.

As criteria upon which the soundness of this research is judged, we used four constructs that reflect the assumptions of the qualitative paradigm:

- *Credibility*. The study transcripts were returned to the participants to ensure that the transcriptions made were as close to the original as possible.
- *Transferability*. The findings of the study often have an influence on practice through the “phenomenological exchange,” whereby learners and educators engage in a mutual recognition of similar instances.
- *Dependability*. The researchers have fully explained in the analysis new ideas and further lines of questioning that emerged in the course of the investigation.
- *Conformability*. The findings were constantly discussed with the heads of the SCSs explored and presented at conferences.

Analysis and interpretation

Needs identification

Identifying the needs for learning involves deciding which procedures will help learners responsibly and realistically determine what they need to learn. The results of this study show that the educators placed great importance on putting into practice a mechanism for mutual needs identification. All of them, with one exception, argued that they tried to find out their learners’ experiences, perceptions, preferences, and needs of the ICT course in the first class meeting. Half of the educators’ also mentioned that, prior to the meeting, they were informed about their learners’ profile through the head and other colleagues. This was a requirement since each student had to be seen as an individual, according to the SCS regulations, which argue for educators to develop curricula derived from the exploration of students’ needs.

Indicative is the following quote from the interview with an educator with two years of experience in the SCS and a limited experience with adults. He argued the following:

In the SCS the curriculum for the ICT course is developed during the academic year in the light of the preferences, needs and prompts given by our students...I discuss the course content with them and I try to ensure a climate of mutual trust and profound communication (Educator 5).

The majority of the learners in the study (19 out of 24) confirmed that their educators were keen on negotiating with them the ICT course content. However, educators pointed out that the adult learners could only help them to a certain extent since they did not have any knowledge in the use of ICT. A few of the learners (7 out of 24) had some experience in ICT and only two had their own computers at home before entering the course. The majority of the students (20 out of 24) also admitted that they were even scared of personal computers, due to their age and fear of technology, and were reserved at the beginning of the course. Characteristic is the following quote from the interview with a 34-year-old woman who joined the SCS aspiring to get the certificate, which would help her to get a better job. She commented as follows:

Educators wanted to find out what we wanted out of the course, but unfortunately we couldn’t say much, given our small experience in technology. It was my first time with a computer and I wasn’t feeling very comfortable. I had doubts whether I could make it (Learner 11).

Planning

Planning is concerned with the setting up of the framework of the program. A cardinal principle of andragogy is that a mechanism must be provided for the involvement of all the parties in the planning of any educational enterprise (Brookfield, 1986).

From this starting point, adult learners’ and educators’ experiences regarding the planning of the ICT course were explored. The analysis reveals that, in all four schools, sessions were planned in light of learners’ expectations and identified needs within the context of the principles underlining the digital literacy course, as stated in the Program of Studies, namely, ICT knowledge and technical skills, using ICT in problem solving, and the societal aspects of ICT. Findings also show that there was flexibility in the choice of topics and that learners’ profiles were taken into account when planning the sessions.

Regarding learners' performance at each of the three areas, data show that the majority (18 out of 24) of the learners faced serious difficulties in comprehending the technical knowledge concerning various ICT components (e.g., hardware concepts like memory, processor, etc., or software concepts like information coding, files and folders, data files, and program files). On the other hand, they performed better in technical skills, such as using word processing, spreadsheets, and Internet services (e.g., Web, email etc.). They also exhibited a great interest in getting to know about the numerous ICT applications and uses in everyday life and the impact of ICT in modern society.

Interesting are the planned means used by educators to adjust the course aims to individual learners' profiles and needs. Educators achieved this by using examples from everyday life and even from learners' professional lives. For instance, an educator (7) stated that, in his attempt to teach spreadsheets (Excel), he used the example of a female student who runs a kebab shop:

I told my students that a very good exercise for using spreadsheets is the following: in a kebab shop I buy meat, bread, pitas etc., then I can estimate using Excel how much I buy, sell, and earn (Educator 7).

Design

Designing a comprehensive program in the andragogical model involves selecting the combination of learning units, that is, problem areas that have been identified by the learners through self-diagnostic procedures and learning formats, such as individual, group, and mass activities for learning, that most effectively accomplish the objectives of the program and arrange them into a pattern.

In the present study, data reveal that educators, to a greater or smaller extent, designed the ICT courses on the basis of problem areas and activities identified by their learners so that they could make good use of their experience and keep them motivated. As both learners and educators underlined, there was an open and flexible plan for the sessions which was under change and adjustment according to the learners' profiles. Findings identify that ICT courses varied in all four schools, and not all the educators designed sessions of the same content and by using the same activities, paradigms, and examples.

In general terms, the findings of this study identified four different teaching and learning formats followed in digital literacy courses in the SCS: ICT competence activities, cross-thematic approaches, ICT-based projects, and individualized teaching.

ICT competence activities

The activities focused on students' development of ICT technical skills and competence in using computers and general-purpose software. They addressed both first- and second-year students and were operated in the computer lab. Course sessions were between two to three hours per week. The students were working individually or collaboratively in pairs. In the four schools studied, the ICT competence laboratory activities took different forms. In two schools it took the form of *frontistirio*, a class aimed at preparing students to pass their exams for the ICT certification. In the other two schools, digital literacy was taught in conjunction with some other literacy, such as mathematics, English, or Greek. Characteristic is the following transcript from the female educator with extensive experience in teaching adults:

This year in the lab we taught ICT with Greek language. I collaborated with the language teacher and asked students to practice writing Greek with the use of the computer. Students were trained simultaneously in Word and in Greek (spelling, grammar etc.) (Educator 1).

Cross-thematic teaching

This approach involved teaching of two literacies at the same time, aiming at studying the two different subjects jointly. In the case of the ICT courses examined, data point out that cross-thematic teaching was implemented to a small extent. As 17 out of the 24 learners stated, only a few times they were taught ICT along with another subject. Learners were not in the position to explain why this happened. The majority of them even hardly understood the

significance and the value of cross-thematic teaching. Three of the eight educators argued that it was very difficult for them to develop the cross-thematic teaching practice due to various reasons, including the following:

- lack of in-service training that could help educators to implement cross-thematic practices
- lack of motivation and willingness on behalf of educators to try something new and unknown
- difficulties with colleagues
- former experiences and practices from the typical secondary school.

ICT-based projects

ICT-based projects target digital skills that go beyond ICT operational skills, namely, skills to search, select, and evaluate information, critical and analytical thinking, and strategic and problem-solving skills. Assignments focus on various subjects (theatre, gardening, and written essays on important everyday life topics such as environmental pollution, feeding, and health issues) that students of both stages were involved in from the beginning of the academic year. The main idea behind this learning approach is that students who participate in the cross-thematic projects are able to gradually acquire knowledge concerning various fields and transfer this knowledge to real problems and everyday life issues. For the completion of the majority of the projects, tutors encourage and support their students, first, to work collaboratively in teams, and second, to use ICT to access information from the Internet and also to practise the knowledge and skills acquired in order to produce their report or presentation of the subject under study.

A problem regarding project work, identified by both educators and learners in the study, is the lack of collaborative skills and spirit among the learners, presumably originating from their lack of previous supportive experiences. The majority (20 of 24) of adult learners argued that they preferred to work alone rather than to collaborate with others. A 56-year-old learner commented that:

We are all adults with our own pace in learning. I preferred to practice on the computer alone rather than to collaborate with somebody else. You don't learn otherwise. Moreover, there is nothing to learn from a colleague who knows the same or less than I do; it would be different if colleagues were more experienced. I was asking my teacher for help and he was always there for me (Learner 17).

Individualized teaching

Individual lessons were implemented in three of the SCS explored in the study. Each SCS had its own computer lab. The labs were designed for those students who exhibited serious problems and inabilities in using computers. Most of these students had difficulties participating in ICT-based projects and even in attending the ICT-competence courses (3 hours per week).

Climate

Climate conducive to learning is widely articulated to be a necessary prerequisite to effective adult learning (Bickel & Hatrup, 1995; Gravani & John, 2005). Knowles (1990) talks about physical and psychological environments. The former refers to the typical classroom set-up, material infrastructure, timetable of a course, the extent to which the set-up fits individual participants, and students' reward for participating in the program. The latter involves mutual respect, collaboration, mutual trust, supportiveness, and openness.

With regard to physical climate, findings reveal that not all classrooms used in the program were fully equipped with computers and audio-visual media suitable for adult learning. In the above context, participants felt that learning was prohibited and that the lack of appropriate infrastructure was to be blamed for some organizational problems that appeared in the program, such as the absence of the cross-thematic teaching or the few hours spent on individualized teaching.

Regarding the distribution of educational material, data indicate that no books were given in the course of the ICT sessions. This is justified on the basis of the philosophy underlying the SCS program, according to which sessions have to be adjusted to the learners' needs. Tutors tried to meet adults' individual needs and believed that notes,

photocopies, and other material could meet learners' needs more effectively. The majority of the participants in the study, with four exceptions, seemed to agree with this practice. Books were not necessary since individual needs varied in all four schools and even in the same classroom. Hence, no one book could meet all identified needs. On the contrary, a number of books could be proposed or be available in the school library, in accordance to the open philosophy of the program of studies that is at the heart of the SCS.

Psychological climate was investigated in terms of the relationship between adult learners and educators and the relationships among learners. Regarding the former, data reveal that an atmosphere of mutual trust, support, openness, and cooperation was prevalent in most schools. The majority of both learners and tutors said that they felt valued and respected in the ICT sessions, which had a positive impact in the learning process. It was only at the beginning that the atmosphere was a bit cold. This was due to the negative attitudes, insecurity, or fear that some of the older students exhibited about computers and ICT. Educator 1 commented on that:

At the beginning some of them were negative to learn . . . they were saying that computers are devil's machines and they refused to touch them . . . A female student over 50 thought that it was impossible for her to learn due to her age . . . Some others had negative impressions of the school due to their experiences of the typical school they had attended . . . In all the above cases, we're trying to be encouraging, waiting for their (students') disposition to change.

As far as the relationship among learners is concerned, respondents' answers varied. Twenty out of the 25 learners claimed that relations with each other were amicable and good; the rest experienced diversity in relationships and justified this by explaining that the same relationship could not have been developed with everyone, since adults have different personalities that do not always match. A female learner (Learner 24) who was overall negative with the ICT course stressed that collaboration with her colleagues was impossible since they had no knowledge of ICT; therefore, she preferred to work alone.

Evaluation

Evaluation was explored in the present study in terms of reaction evaluation, that is, participants' positive and negative feelings about the program, and learning evaluation, which links to the learning outcomes of the program (Kirkpatrick, 1998).

Learning evaluation focuses on the learning that participants engaged in during the digital literacy sessions and the perceived outcomes on the growth of their knowledge. The majority of the respondents argued that they had gained "new knowledge," which took the form of either subject knowledge or philosophical knowledge.

As 23 of the learners stated during the course of the ICT sessions, they got to know about computers and their use and impact in everyday life. Only a small number of the adults in the sample (five) were interested in technical knowledge (for example, understanding and using computer terminology, and understanding technical specifications and internal operations of the PC, such as processor, RAM memory, hard disk, etc.). On the other hand, almost everyone wanted to obtain the necessary skills for using general-purpose software and the Internet. By the end of the sessions, learners were able to use word-processing programs, the Internet, email, and, in some cases, presentation and spreadsheet software (the extent to which they mastered these skills depended on their level of study and interest as well as on the school and tutor). All tutors stated that adults had serious difficulties developing effective representations about computing systems and concepts. However, both educators and learners agreed that philosophical knowledge was the most valuable and constructive knowledge gained from the sessions. Philosophical knowledge is interpreted as knowledge of the world, people, and behaviors. In particular, educators stated that they had learned from their learners lived experience. They claimed that they had learned to be patient and supportive with their students and to respect individual needs. They had also experienced the power of willingness, and had felt supported by their learners when needed.

Learners also gained philosophical knowledge. They talked about having learned to be persistent, patient, open, and receptive, and that it is never too late to learn and do new things provided that there is desire to do so. A 55-year-old woman stated:

In the course of the ICT sessions, I have learned to be patient and persistent. I had to ask several questions and practise hard because I was forgetting things. My memory does not help in this age.

Besides, at the beginning, I was scared of the machine . . . but if you really want something a lot, then things and life will lead you to this (Learner, 13).

Reaction evaluation involved participants' likes and dislikes about the program. Findings revealed that individuals in the study liked almost every aspect of the program: educators, because they successfully completed their task and managed to persuade the majority of learners about the importance of ICT; and learners, because they worked out their doubts and fears and successfully finished the program. The weakest aspects of the sessions, which both educators and learners would have preferred to have been different, were first, the poor material infrastructure (lack of computers and high-speed Internet connection) in schools that did not have their own building; and second, the limited teaching hours devoted to digital literacy. The majority of the learners (20) argued that the ICT course should have been offered more than three teaching hours per week since it was a difficult, new, and useful subject that was not easy for them to comprehend.

Concluding remarks

The analysis pointed out some interesting issues regarding ICT teaching approaches and adult learning habits during the digital literacy sessions in the context of the four case studies that SCS explored. One of the eminent points raised relates to learners' individuality. As indicated, adult learners' needs, interests, learning styles, and experiences were seriously considered by the majority of the educators when planning, designing, and delivering the ICT sessions. The latter were adapted to individuals' profiles, respected their special characteristics, and were aligned with the adult learning principle, which argues that adults' programs and courses need to be organized on the basis of learners' expectations, profile, and needs (Knowles, 1990; Jarvis, 2006; Gravani, 2008). The above conforms to the SCS' Program of Studies (GSAE, 2003) and is in accordance to the initial plan and aim of the project. As Vecris and Hodolidou (2003) stated, since students at SCS are not a homogenous team, heads and teachers should not create an absolutely common education program for all students, but look for activities that allow each learner to get involved, try, develop, and reform and that extend individuals' cognitive patterns and strategies.

In the light of the above, no single coursebook about digital literacy was distributed in all SCS schools, while educators adjusted the course material to the adult learners' needs. They chose open-ended social-life material that was under adjustment and transformation according to the learners' needs and desires. By doing so, they respected the individuality of their students, who came to the SCS with different lived experiences, and they connected innovation to the social conditions within which it is produced, helping students articulate their creativity, needs, and desires.

Another major theme that came out of the analysis is that ICT sessions aimed mainly at developing adult learners' technical and social skills in ICT while exhibiting some elements of interdisciplinarity. However, this study showed that educators had difficulties implementing interdisciplinary tasks to the extent aspired to in the SCS curriculum. In addition to the above, findings pointed out some factors that enhance or hinder learning in ICT sessions in SCS, namely the learners' age, lack of appropriate organization and material infrastructure, old habits that educators carried with them from the typical secondary school, and learners' difficulties in collaboration and team-work. Similarly, Selwyn (2004a) lists fear of exposure, fear of technology, and even fear of failure as barriers to adult's ICT development. Findings reveal that the friendly climate of mutual respect, trust, openness, and supportiveness developed in digital literacy classrooms had a critical impact on enhancing adult learning. Tett and MacLachlan (2008) emphasized that in learning communities where power and meaning are mutually negotiated, learners begin to recognize their personal worth and power and its impact in the wider world. It seems that learners developed digital competencies more effectively when educators use learning activities that draw upon and match learners' interests.

According to educators, a passive way of learning and working with ICT has been experienced by the learners in some cases. They consider learners' negative view of ICT and their lack of basic skills in literacy and numeracy as critical barriers in adopting ICT as a valuable tool and in developing their ICT knowledge and skills. However, in the course of the ICT sessions, learning to a greater extent has been active for both educators and adult learners on different levels: they both developed philosophical and pedagogical knowledge, while learners further obtained technical knowledge and skills and knowledge on the use of ICTs in everyday life. ICT educators, in turn, gained

useful knowledge from their students' life experiences. Additionally, they learned to be persistent, resilient, flexible, and supportive.

In summary, the results of this study emphasized that adult learners comprise a population with special characteristics and traits regarding digital literacy and related learning activities. The findings can be helpful when designing, organizing, and implementing ICT courses for adults in the context of the SCS and elsewhere. It seems that many of the principles elucidated by Knowles (1990) as features of adult learners remain relevant to adult ICT learning and skills development. These include a) self-directed learning as the preferred model, b) adults' prior experience and interests, as a rich resource for the ICT course, c) a task-based rather than ICT-centred approach, and d) the importance of the wider social context in ICT cultivation and ICT learning. There are still a lot of parameters to be identified regarding the way adult learners perceive digital literacy, their practices or difficulties when using computers, and appropriate ways for educators to support and encourage adults when learning about and with ICT. Further research is necessary to address the issues above in order to redirect future policies and strategies for adult digital literacy and ICT integration in the SCS.

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Science Student Teachers and Educational Technology: Experience, Intentions, and Value

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ABSTRACT

The primary purpose of this study is to examine science student teachers' experience with educational technology, their intentions for their own use, their intentions for their students' use, and their beliefs in the value of educational technology in science instruction. Four-hundred-forty-eight science student teachers of different disciplines and levels participated in the study. A questionnaire was used as the data collection instrument. The data were analysed using correlations (Pearson), t-tests, and one-way ANOVA. Findings revealed differences amongst science student teachers from different subjects. Correlations were also found amongst science student teachers based on their educational technology experience, their intention to use educational technology, their intention to have their students use educational technology, and their belief in the value of educational technology for learning science. Science student teachers who were more experienced with educational technology had greater intentions of using the technology, were more likely to have their students use it, and believed more in its value.

Keywords

Improving classroom teaching, Teaching secondary education, Teaching learning strategies, Pedagogical issues

Introduction

The use of technology in education has become an increasingly important area of research during the past several decades. During this time, technology has been used as a medium to encourage inquiry, enhance communication, construct teaching materials, and assist students' self-expression (Beak et al., 2008). The importance of technology for science in schools is impossible to ignore, as its use has the potential to contribute to science teaching and learning by expediting and enhancing work production, supporting exploration and experimentation, supporting collective knowledge-building, improving motivation and engagement, offering learners more responsibility and control through individual exploration and experimentation, and helping students to visualise processes more clearly (Hennessy, 2006). Generally, technology in classroom-related activities refers to computers and videos and the associated hardware, networks, and software that enable them to function (Mehlinger and Powers, 2002).

Educational technology has an effective role in moving from teacher-centred learning activities to student-centred learning activities. However, the role of a teacher remains crucial to the effective use of educational technologies (Zhao et al., 2001). Therefore, having teachers who are competent in using and managing educational technology is important. One way of solving this problem is by training student teachers in educational technology during their initial teacher education (Smarkola, 2008). Another important factor for focusing on educational technology during initial teacher education is the fact that student teachers or newly qualified teachers are more willing to learn and use educational technology in their classroom practises. Research reports that experienced teachers seem reluctant to incorporate educational technology in schools, while student teachers and newly qualified teachers are more confident users of educational technology (Galanouli and McNair, 2001; Madden et al. 2005; Sime and Priestley, 2005; Andersson, 2006). A study by Smarkola (2008) that included 160 student teachers and 158 experienced teachers found that both groups of teachers strongly believed in the need for additional computer-integrated training. Willis and Montes (2002) reported that pre-service teachers viewed computer technology as a useful tool for personal and professional development. Sime and Priestley (2005) argued that although many initial teacher education programmes provide appropriate support for students to develop their skills, it is important that the development of educational technology pedagogies are underpinned by a reasonable level of generic skills. Being technologically competent allows teachers to use computers as a part of the curriculum and as tools for authentic student engagement and learning (Smarkola, 2008).

Despite the widely advocated usefulness of implementing technology-based teaching/learning activities, there are obstacles preventing teachers from using technology in their classrooms (Beak et al., 2008). According to Pelgrum

(2001), the obstacles for using technology are complex and consist of a mixture of issues, such as an insufficient number of computers. Non-material concerns, such as the lack of sufficient knowledge and skills regarding Information and Communication Technology, are also problematic.

Research has shown that a teacher's attitude toward computers is a major predictor of future computer use (Myers and Halpin, 2002). The successful use of educational technology depends largely on the attitudes of teachers and their willingness to embrace new technology (Teo et al., 2007). A positive attitude towards educational technology will develop an intention or determination to use educational technology in her/his classroom. The value of or teachers' perceptions of the usefulness of new technologies are also critical (Ma et al., 2005). It is reported that teachers generally believe in the usefulness of educational technology in the classroom (Plumm, 2008). If a teacher believes in the usefulness of educational technology, it will be easier for her/him to implement educational technology in the classroom and acquire related the necessary skills. Since teachers are the keys to the effective use of computers in the educational system (Zhao et al., 2001), it is important to understand their attitudes toward computers. To develop student teachers' interest in achieving educational standards, the institutional support offered during their university studies should focus on developing positive attitudes toward computers (Kadijevich and Haapasalo, 2008).

Gender differences in terms of teacher beliefs, teacher self efficacy and teacher attitude towards educational technology is an important research field (Sang et al., 2010). Studies of gender differences in educational technologies have revealed conflicting results. For many years, computers were seen as a male domain, and the earlier studies supported that view (Sutton, 1991; Comber et al., 1997; Shashaani, 1997). But more recent studies have reported that differences between the two genders in regard to educational technology has faded (Yuen and Ma, 2002; Hong and Koh, 2002; Shapka and Ferrari, 2003; Sang et al., 2010). When interaction between a varieties of variables were taken into account this differences were less apparent (Gencer and Cakiroglu, 2007).

There are not many studies focusing grade level of students and educational technology. Studies have usually focused on different level of studies such as primary, secondary and higher education. Based on the level of study the intention of using and educational technology materials available show differences. In lower lever of studies finding suitable material for learning is less available and students use educational technology for entertainment rather than as learning tool (Schofield, 1995). In secondary level there are more educational technology materials available and student can benefit from educational technology tools for learning purposes (Gimbert and Cristol, 2004). Ozdamli et al., (2009) investigated differences among student teachers attitude towards educational technology across disciplines that included computer education and instructional technology, physical education, English language teaching, Turkish language teaching. The study did not report any statistically important difference across disciplines.

This study investigated science student teachers' attitudes toward educational technology by analysing their experience with educational technology, their intention to use educational technology when they embark on teaching, their intention to provide opportunities for their students to use educational technology, and their belief in the value of educational technology in science instruction. Experience, in this study, refers to science student teachers' existing knowledge and previous use of educational technology. In the study the following research questions were investigated:

1. Are there any differences in science student teachers' experience with educational technology when disciplines are considered?
2. Are there any differences in science student teachers' intensions to use educational technology in their teaching when disciplines are considered?
3. Are there any differences in science student teachers' intensions to provide opportunities for students to use educational technology during science classes when disciplines are considered?
4. Are there any differences in science student teachers' beliefs in the value of educational technology in science instruction when disciplines are considered?
5. Are there any differences when genders are considered?

Method

Participants

Participants were 448 (248 male, 200 female) science student teachers of all years who were enrolled in a teacher education course in the education faculty at Dicle University in Turkey. The study was carried out during 2007-2008 academic year. At the time of the study, 126 of the student teachers were studying biology education, 99 were studying physics education, 103 were studying chemistry education, and 120 were studying primary science education. Table 1 shows means and Standard Deviation of the participants' age.

Table 1. Ms and SDs of the participants' age

Sinif	Mean	N	Std. Deviation
1	21,28	109	1,203
2	21,83	77	,818
3	22,62	105	,488
4	23,89	131	1,257
5	24,77	26	1,142
Total	22,65	448	1,526

Instrument

The "Science Student Teachers' Educational Technology Questionnaire" consisted of 48 items with a five-point Likert-type scale. Some of the items on the questionnaire were taken from the Technology Needs Assessment Survey (U.S. Department of Education, 1998). The rest of the items were generated by a written assignment asking science student teachers to discuss the importance of educational technology in science education.

The examination of the factor structure for the questionnaire was carried out using various statistical analyses. The Kaiser-Meyer-Olkin (KMO) value was .912, and the Bartlett's Test of Sphericity value was 10395.957 (DF: 1128, $p < 0.000$). Nine factors produced Eigenvalues greater than 1.00, and four interpretable factors emerged from the analysis of ratings. These factors accounted for 24.74%, 10.91%, 6.92%, and 4.11% of the variance of the data, for a total of 46.73%. This value is higher than the value computed by Tabachnick and Fidell (1998) and Kline (1994) in which they stated that the acceptable variance value of a scale should explain more than 41% of the whole variance. The interpretable factors were labelled as *student teachers' technology background*, *student teachers' intention to use educational technology in their teaching*, *student teachers' intention to provide opportunities for their students to use technology in the classroom*, and *the value of educational technology for learning science*. The reliability of the questionnaire was measured through Cronbach' alpha. Cronbach's alpha was .930 for the whole scale. Cronbach's alphas were .912, .874, .858, and .880 for the first, second, third, and fourth variables, respectively.

Analysis

The five-point Likert-type scale invited science student teachers to respond to the items either as "never", "very rare", "sometimes", "often", "always" or "none", "very little", "little", "high", or "very high", according to the nature of the item.

The data were analysed using correlations (Pearson), t-tests, and one-way ANOVA. Pearson correlation was used to determine whether there was any correlation amongst the four factors. T-tests were used to examine the relationship between each gender's responses to the items on the scale. One-way ANOVA was used to determine the differences amongst disciplines and study years in relation to their responses to the items.

Results and discussion

Relationships amongst science student teachers' experience, intentions, and value of educational technology

Table 2 includes the correlation values for science student teachers' experience with technology, their intention to use educational technology in their teaching, their intention to provide opportunities for their students to use technology in the classroom, and the value of educational technology for learning science.

Table 2. The correlation amongst science student teachers' experience, intention and value of educational technology

		Experience	Intention to use technology	Intention to provide students with opportunities to use technology	Value of educational technology for learning
Experience	<i>Pearson Correlation</i>	1	.327	.234	.202
	<i>Sig. (2-tailed)</i>	.	.000	.000	.000
	<i>N</i>	448	448	448	448
Intention to use technology	<i>Pearson Correlation</i>	.327	1	.672	.435
	<i>Sig. (2-tailed)</i>	.000	.	.000	.000
	<i>N</i>	448	448	448	448
Intention to provide students with opportunities to use technology	<i>Pearson Correlation</i>	.234	.672	1	.549
	<i>Sig. (2-tailed)</i>	.000	.000	.	.000
	<i>N</i>	448	448	448	448
Value of educational technology for learning	<i>Pearson Correlation</i>	.202	.435	.549	1
	<i>Sig. (2-tailed)</i>	.000	.000	.000	.
	<i>N=448</i>				

A positive correlation was found among all four factors ($p < 0.01$). This indicates that a science student teacher with previous experience is more likely to (1) use technology in his/her science classes; (2) ask his/her students to use educational technology; and (3) have a high opinion of the importance of educational technology for learning science. The highest correlation was between science teachers' intention to use technology and their intention to provide their students with opportunities to learn science through educational technology (.672). A science student teacher thinking of using educational technology is also more likely to ask his/her students to use educational technology. For example, if a science student teacher is considering using PowerPoint in his/her classes for presentations, he/she is more likely to provide opportunities for students to use PowerPoint as well.

Science student teachers' experience with educational technology

Of the participating science student teachers, physics and biology student teachers had the most experience with educational technology (Table 3). The difference among the student teachers of different subjects was statistically significant ($p < 0.05$). Chemistry student teachers who took part in the study had the least experience with any of the educational technology components presented on the scale.

Table 3. Science student teacher' educational technology experience in relation to their disciplines

	N	Mean	Std. Deviation	ANOVA results
Biology	126	2.8618	.99058	
Physics	99	2.8939	.99765	F: 3.601
Chemistry	103	2.5461	.78371	Sig: 0.014
Primary science	120	2.6514	.86089	$P < 0.05$
Total	448	2.7400	.92210	

When multiple comparison are made by Post hoc analysis through Scheffe test it is clear the statistically significant difference ($p < 0.05$) appeared through ANOVA is not seen significant (Table 4).

Table 4. Post hoc analysis (Scheffe) for Science student teacher' educational technology experience in relation to their disciplines

(I) Discipline	(J) Discipline	Mean Difference (I-J)	Std. Error	Sig.
Biology	Physics	-.03217	.12277	.995
	Chemistry	.31566	.12143	.082
	Primary science	.21038	.11660	.355
Physics	Biology	.03217	.12277	.995
	Chemistry	.34782	.12866	.064
	Primary science	.24255	.12412	.283
Chemistry	Biology	-.31566	.12143	.082
	Physics	-.34782	.12866	.064
	Primary science	-.10527	.12279	.865
Primary science	Biology	-.21038	.11660	.355
	Physics	-.24255	.12412	.283
	Chemistry	.10527	.12279	.865

Although there are not many studies evaluating teachers use and effectiveness with technology tools, in general, they possess a positive view of using educational technology in their classrooms (Ng and Gunstone, 2003). According to Plumm (2008) the main reason that limits teachers' use of technology is their uneasiness with and not feeling competent enough for some types of educational technologies. The time student teachers spend for teacher training might be used to overcome these negative feelings towards using educational technology in the classrooms. As educational systems are pushing for a more technology based curriculum, providing student teacher with opportunities to develop skill that can help the implementation of the curriculum appropriately. Kadjevich and Haapasalo (2008) found that student teachers experience with educational technology is so important that it can help to improve student interest in and intention to use educational technology in their classes. According to Marcinkiewicz (1993) if we want to achieve integration of technology into educational system, we have to achieve teacher reconciliation with educational technology which means teachers should be familiar with educational theory before being able to use them in their classrooms.

When students were grouped according to their year of study, a significant difference was observed among the different levels ($p < 0.01$). Year 4 and 5 science student teachers had far more experience with educational technology (Table 5). This is not surprising, as these two groups were attached to partner primary and secondary schools for experience and teaching practise. During their placements, science student teachers had opportunities to observe the ways in which educational technology was used by science teachers. When they practised teaching, they were able to use educational technology in their classes as well. Year 1, 2, and 3 science student teachers' experience was limited to what they observed and were taught during lectures at the university. Any experience these participants had with educational technology took place in their lives outside of the education faculty. Actual classroom technology experience was a critical component that contributed to student teachers' future computer usage. Studies have shown that pre-service teachers' placement with a cooperating teacher was a crucial part of their educational technology preparation (Brent et al., 2002; Doering et al., 2003). A Study carried out by Ozdamli et al., (2009) investigated differences among student teachers attitude towards educational technology across disciplines that included computer education and instructional technology, physical education, English language teaching, Turkish language teaching. The study did not find any statistically important difference across disciplines.

Table 5. Science student teachers' educational technology experience in relation to their year of study

Year	N	Mean	Std. Deviation	ANOVA results
1	109	2.3769	.81505	F: 13.557 Sig: .000 $P < 0.01$
2	77	2.4978	.86613	
3	105	2.7405	.88292	
4	131	3.0744	.91289	
5	26	3.2917	.90439	
Total	448	2.7400	.92210	

Scheffe test for Post hoc analysis (Table 6) shows statistically significant differences between the fourth and fifth year student educational technology experience and the first and second year science student teachers' educational

technology experience. As students study through their teacher education course, their experience with educational technologies increases as well.

Table 6. Post-hoc analysis (Scheffe) for Science student teachers' educational technology experience in relation to their year of study

(I) grade	(J) grade	Mean Difference (I-J)	Std. Error	Sig.
1	2	-.12092	.13015	.930
	3	-.36356	.11955	.057
	4	-.69752	.11335	.000
	5	-.91476	.19082	.000
2	1	.12092	.13015	.930
	3	-.24264	.13117	.491
	4	-.57659	.12555	.000
	5	-.79383	.19831	.003
3	1	.36356	.11955	.057
	2	.24264	.13117	.491
	4	-.33395	.11452	.077
	5	-.55119	.19152	.084
4	1	.69752	.11335	.000
	2	.57659	.12555	.000
	3	.33395	.11452	.077
	5	-.21724	.18771	.854
5	1	.91476	.19082	.000
	2	.79383	.19831	.003
	3	.55119	.19152	.084
	4	.21724	.18771	.854

Year 4 and 5 students also had more opportunities to experience different learning styles. With the popularity of student-centred learning activities, these student teachers were given more space to use educational technology to foster active learning (Susman, 1998; Jonassen, 1999).

Table 7. Science student teachers' educational technology experience in relation to their gender

Experience	Gender	N	Mean	Std. Deviation	Result
Experience	Male	248	2,7876	,94981	t: 1.219
	Female	200	2,6808	,88532	Sig:0.223

The analysis of the data suggests that there is no significant difference in science student teachers' experience with educational technology in relation to their gender ($p > 0.05$). Both male and female science student teachers gave similar responses to the educational technology items related to experience (Table 7). This result is interesting as the evidence from the literature lead us to expect a heavier usage of educational technology by male student teachers as female student teachers are thought be more reluctant and less interest particularly in using computers (Ozdamli, et al. 2009; Comber et al., 1997; Levin and Barry, 1997; Durndell and Thomson, 1997). The findings of the present study support the findings of the study by Shapka and Ferrari (2003) that gender differences in experiencing educational technology. Also, a similar study by Yuen and Ma (2002) that was carried out with participation of 186 student teachers in Hong Kong did not find any significant difference in undergraduate trainee teachers' attitude toward computers. A more recent study by Sang et al. (2010) did not find any differences in terms of gender when a variety of variables including constructivist teaching beliefs, teaching self efficacy, computer self efficacy and computer attitudes were studied. This probably shows the speed of development in educational technology and its growing role in instruction and the importance attached to it by student teachers of both genders. The reflection of this importance of being competent enough to use educational technology should be a vital element of a teacher education programme. According to Plumm (2008) apart from limited elective courses, many teacher education programmes do not take courses that discuss the topic of gender or technology and these two elements are not discussed together.

Science student teachers' intentions to use educational technology in their classes

Science student teachers of all subjects intended to use educational technology in their science classes when beginning their teaching careers. When all five subjects were compared, physics and primary science student teachers' intentions were stronger than those of chemistry student teachers (Table 8). This difference was statistically significant ($p < 0.05$). A student teachers' intention for using educational technology is important as research reports that a teacher's attitude toward computers is a major predictor of future computer use (Myers and Halpin, 2002). The successful use of educational technology depends largely on the attitudes of teachers and their willingness to embrace new technology (Teo et al., 2007).

Table 8. Science student teachers' intentions to use educational technology in their classes in relation to their disciplines

	N	Mean	Std. Deviation	ANOVA results
Biology	126	3.9821	.57422	
Physics	99	4.0875	.61265	F: 3.055
Chemistry	103	3.8487	.72571	Sig:0.028
Primary Science	120	4.0667	.62758	$P < 0.05$
Total	448	3.9974	.63857	

Mean scores suggest that student in all groups have high intention of using educational technology in their classes. As future science teachers, science student teacher think educational technology makes important contributions to the teaching/learning process in science classrooms. This might be related to the perception of the strong bond between science and technology and the way technology enables a science teacher to show process (e.g. through simulations, animations) that are not easy to observe in labs. For example, a student can observe how oxygen, food and water are allowed in through cell membrane and how waste products are allowed to leave and harmful substances are kept out. Studies suggest that well designed educational technology tools have positive effects on student learning, creativity, decision making, communication, thinking power and initiatives (Sadler, et al., 1999; Steiff, 2003; Garcia- Lugue et al., 2004).

Post-hoc analysis through scheffe test (Table 9) shows that groups are compared according to their disciplines the differences between them in terms of science student teachers' intentions to use educational technology in their classes is not statistically significant.

Table 9. Post-hoc analysis (Scheffe) for Science student teachers' intentions to use educational technology in their classes in relation to their disciplines

(I) Discipline	(J) Discipline	Mean Difference (I-J)	Std. Error	Sig.
Biology	Physics	-.10540	.08518	.675
	Chemistry	.13344	.08425	.474
	Primary science	-.08452	.08090	.779
Physics	Biology	.10540	.08518	.675
	Chemistry	.23884	.08926	.068
	Primary science	.02088	.08611	.996
Chemistry	Biology	-.13344	.08425	.474
	Physics	-.23884	.08926	.068
	Primary science	-.21796	.08519	.089
Primary science	Biology	.08452	.08090	.779
	Physics	-.02088	.08611	.996
	Chemistry	.21796	.08519	.089

It is interesting to note that science student teachers with more experience with educational technology were more likely to intend on using it in their classes. Physics, biology, and primary science student teachers had more experience with educational technology, and when compared with chemistry student teachers, they were more inclined to make use of educational technology in their classes. Mean scores shows that all students have high intentions of using educational technology in their classrooms. This is also supported by the previous studies in the area that suggest teachers are willing to use educational technology in their classes but as they do not feel competent

enough for using educational technology, this intention is prevented from being implemented into practice in the classroom (Ng and Gunstone, 2003; Plumm, 2008).

Table 10. Science student teachers' intentions to use educational technology in their classes in relation to their year of study

	N	Mean	Std. Deviation	ANOVA results
1	109	3.9488	.60134	
2	77	3.9264	.76160	
3	105	4.0167	.64253	F: 0.752
4	131	4.0445	.62132	Sig: 0.557
5	26	4.0962	.43760	p>0.05
Total	448	3.9974	.63857	

When science student teachers' responses in relation to their intentions to use educational technology according to their year of study were analysed, no statistically significant differences were found ($p>0.05$). Based on this finding, it can be said that science student teachers of all years strongly intended to use educational technology when teaching science (Table 10).

Table 11. Science student teachers' intentions to use educational technology in their classes in relation to gender

	Gender	N	Mean	Std. Deviation	Results
Intention to use technology	Male	248	3.9714	.61885	t: -0.958
	Female	200	4.0296	.66236	sig: 0.339

No statistically significant difference was observed in relation to gender and intention to use educational technology ($p>0.05$). Both male and female science student teachers had strong intentions to use educational technology (Table 11). This result and the result related to student teachers' experience with educational technology suggest that both male and female student teachers are both experiencing similar rate of using educational technology and they have similar intentions for using educational technology in their classrooms. Russell (2004) suggests that female student are less interested or less skilled in technology- related career field, but social barriers prevent them from becoming successful those fields. In terms of educational technology these social barriers are not any longer that strong as it obvious from conferences and academic journals in the field that accommodate female researchers or teachers as many as man counterparts.

Science student teachers' intentions to provide opportunities for students to use educational technology during science classes

The analysis of the data revealed statistically significant differences between the science student teachers' responses to items related to their intentions to provide opportunities for their students to use educational technology ($p<0.01$). Physics and primary science student teachers had the greatest intentions of having their students use educational technology in their classes (Table 12).

Table 12. Science student teachers' intentions to provide opportunities for students to use educational technology in relation to their disciplines

	N	Mean	Std. Deviation	ANOVA results
Biology	126	3.5231	.65005	
Physics	99	3.7916	.61208	F:9.007
Chemistry	103	3.3751	.80859	Sig:0.000
Primary Science	120	3.7591	.64966	$P<0.01$
Total	448	3.6116	.69998	

Mean scores suggest that science student teachers in all groups have the intentions to provide opportunities for their student to use educational technology. This result is supportive of the results obtained in the previous section that science student teacher have intentions to use educational technology in their classes. It, also, is in indicative for science student teachers' believe in student centred learning as they have intentions to involve their student in teaching/learning process through getting them involve in using educational technology. One of the main

contributions of educational technology in science classes is that it contributes to a learner centred approach (Plumm, 2003). These results are supported by previous research suggesting that student teachers believe it is imperative for children to use technology (Doering et al., 2003). It is also interesting to note that science student teachers who intended to use educational technology in their science classes were more likely to intend on providing opportunities for their students to use educational technology as well. Findings also suggest that science student teachers with more extensive educational technology backgrounds intended to both use educational technology themselves and to have their students use it (Sutherland et al., 2004).

Table 13. Post-hoc analysis (Scheffe) for Science student teachers' intentions to provide opportunities for students to use educational technology in relation to their disciplines

(I) Discipline	(J) Discipline	Mean Difference (I-J)	Std. Error	Sig.
Biology	Physics	-.26846	.09158	.036
	Chemistry	.14798	.09058	.446
	Primary science	-.23600	.08698	.063
Physics	Biology	.26846	.09158	.036
	Chemistry	.41644	.09597	.000
	Primary science	.03246	.09258	.989
Chemistry	Biology	-.14798	.09058	.446
	Physics	-.41644	.09597	.000
	Primary science	-.38398	.09159	.001
Primary science	Biology	.23600	.08698	.063
	Physics	-.03246	.09258	.989
	Chemistry	.38398	.09159	.001

Post-hoc analysis (Table 13) with Scheffe test reveals significant differences between groups in terms of their disciplines. Differences between biology and physics, physics and chemistry, chemistry and primary science student teachers are statistically important.

Table 14. Science student teachers' intentions to provide opportunities for students to use educational technology in relation to their year of study

Year	N	Mean	Std. Deviation	ANOVA results
1	109	3.5596	.63518	F: 0.891 Sig: 0.469 $p > 0.05$
2	77	3.5266	.80429	
3	105	3.6649	.63315	
4	131	3.6738	.73040	
5	26	3.5524	.73447	
Total	448	3,6116	.69998	

The findings do not show any significant differences based on year of study ($p > 0.05$). Student teachers of all years intended to have their students use educational technology in their science classes (Table 14). Differences across disciplines do not appear across years which means student teachers in the same discipline group might have similar opinions but this is might not be true for student teachers in the grade groups.

Table 15. Science student teachers' intentions to provide opportunities for students to use educational technology during science classes in relation to their gender

	Gender	N	Mean	Std. Deviation	Results
Intention to provide students with opportunity to use technology	Male	248	3.5968	.70672	t: -0.499
	Female	200	3.6300	.69285	sig: 0.618

The results did not reveal any significant difference between the two genders in relation to their intention to have students use educational technology in their science classes ($p > 0.05$). Both male and female science student teachers had high intentions of providing their students with opportunities to use educational technology (Table 15). This result supports the results in the previous section and the results reported by different studies that both genders consider the use of educational technology in the classroom as important (Plumm, 2008; Ng and Gunstone, 2003).

Science student teachers' responses to the value of educational technology for learning science

There were statistically significant differences based on science student teachers' responses to the value of educational technology for learning science ($p < 0.01$). Although science student teachers from all four disciplines believed in the value of using educational technology to enhance learning, physics and primary science student teachers had higher opinions of the value of educational technology for learning science (Table 16).

Table 16. Science student teachers' responses to the value of educational technology for learning science according to their disciplines

Subject	N	Mean	Std. Deviation	ANOVA results
Biology	126	3.8578	.52920	
Physics	99	3.9192	.61020	F: 4.415
Chemistry	103	3.6833	.63068	Sig: 0.004
Primary Science	120	3.9474	.56324	$P < 0.01$
Total	448	3.8553	.58751	

Believing in the value of educational technology is important as it is most likely to lead to employment of teaching/learning strategies that incorporate educational technologies (Tondeur et al., 2008). Different studies have reported a positive correlation between teachers' attitude to educational technology and future use of educational technology in their classrooms (Clark, 2001; Fisher, 2000). The findings are also supportive of the findings in the previous sections that student teachers indicated that they have intentions to use educational technology in their classroom. The correlation between the variables as indicated in the section 3.1 is evident through these results.

Table 17. Post-hoc analysis (Scheffe) for Science student teachers' responses to the value of educational technology for learning science according to their disciplines

(I) Discipline	(J) Discipline	Mean Difference (I-J)	Std. Error	Sig.
Biology	Physics	-.06144	.07802	.892
	Chemistry	.17441	.07716	.166
	Primary science	-.08968	.07409	.691
Physics	Biology	.06144	.07802	.892
	Chemistry	.23585	.08176	.041
	Primary science	-.02824	.07887	.988
Chemistry	Biology	-.17441	.07716	.166
	Physics	-.23585	.08176	.041
	Primary science	-.26409	.07803	.010
Primary science	Biology	.08968	.07409	.691
	Physics	.02824	.07887	.988
	Chemistry	.26409	.07803	.010

It is also interesting to note that the science student teachers who were more experienced with educational technology, had greater intentions of using educational technology in their teaching, and were more inclined to have their students use educational technology also believed more in the value of educational technology for learning science. According to Bransford et al., (2000) using technology in the learning process can be effective in five different ways. These are (1) bringing real-world experiences into the classroom; (2) providing scaffolding that allows students to participate in complex cognitive tasks; (3) increasing opportunities to receive sophisticated and individualised feedback; (4) building communities of interaction between teachers, students, parents, and other interested groups; and (5) expanding opportunities for teacher development.

Table 18. Science student teachers' responses to the value of educational technology for learning science according to their year of study

Year	N	Mean	Std. Deviation	ANOVA results
1	109	3.7283	.63420	
2	77	3.8521	.58233	F: 2.076
3	105	3.8659	.56265	Sig: 0.83
4	131	3.9383	.57202	$p > 0.05$
5	26	3.9349	.52067	
Total	448	3.8553	.58751	

When science student teachers were compared with one another according to their year of study, no statistically significant differences were found in terms of value placed on educational technology (Table 18). Science student teachers from all years thought it was valuable to use educational technology when teaching science.

Table 19. Science student teachers' responses to the value of educational technology for learning science according to gender

	Gender	N	Mean	Std. Deviation	Results
Value of educational technology for learning	Male	248	3,8520	,58311	t: -0.129
	Female	200	3,8592	,59435	sig: 0.898

Table 19 shows that there were no statistically significant difference between male and female science student teachers in terms of their views on the value of educational technology for learning science ($p > 0.05$). Both sexes believed in the value of educational technology for science instruction. This is view of student teachers is supported by the literature that most teachers have a positive view of using educational technology in their classrooms (Ng and Gunstone, 2003).

Conclusions

This study investigated science student teachers attitudes toward educational technology by examining student teachers' experience with educational technology, their intention to use it in their teaching, their intention to provide opportunities for their students to use it, and their belief in its value for learning science. The study revealed differences amongst science student teachers from different subjects. It also identified correlations between science student teachers educational technology experience, their intention to use educational technology, their intention to have their students use educational technology, and their belief in the value of educational technology for learning science. Science student teachers with more experience with educational technology had greater intentions to use educational technology, were more inclined to have their students use it, and believed more in its value.

Considering the research findings, it is important to adequately train student teachers to use educational technology since their experiences increase their chances of using educational technology in the classroom. When a student teacher's confidence in using educational technology elevates, his/her belief in the value of educational technology also increases. As a result, the student teacher becomes more likely to see importance of using educational technology in classroom activities.

The previous research reports that it is more difficult for experienced teachers to adapt to the use of educational technology in their classroom activities. Therefore, it is very important to incorporate educational technology into science student teachers' training. Technology and science are two rapidly developing areas. It is very easy for a teacher to fall out of touch with technology, which will then result in that teacher falling behind on current trends. Thus, teacher training is very important in the development of future teachers' knowledge and skills regarding educational technology.

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ISSN: 1436-4522 (online)
ISSN: 1176-3647 (print)

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