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Exploring the behavioral patterns of an online knowledge-sharing discussion activity among teachers with problem-solving strategy

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ABSTRACT

The sharing of teaching-related knowledge may help teachers solve a variety of problems that they face, and the appropriate use of online knowledge-sharing activities is expected to assist teachers' knowledge-sharing. This study proposed an online knowledge-sharing discussion activity, integrated with a problem-solving strategy for teachers. Empirical observations are noted. The participants were 495 teachers, and quantitative content analysis, sequential analysis, and qualitative original protocol analysis were used to explore the content and patterns of teachers' discussion behavior. The study identified influences on and limitations of knowledge-sharing in the activity, from which suggestions were generated to be proposed to teacher educators.

1. Introduction

In recent years, as technologies advance and teaching methods are updated, teachers' classroom activities have become increasingly complicated. The sharing of teaching-related knowledge may help teachers solve a variety of the problems that they face. However, studies have shown that most teachers do not interact in a culture in which teaching-related knowledge is exchanged (Barab et al., 2001; Tyack & Cuban, 1995); they are accustomed to designing teaching activities in isolation (Goodlad, 1984; Rosenholtz, 1991; Tyack & Cuban, 1995), and their teaching-related knowledge is often tacit (Carroll et al., 2003), which, in turn, prevents knowledge externalization and sharing. As a result, teachers are often unable to effectively access relevant experiences or answers from their peers when facing teaching-related difficulties.

Focusing on the aforementioned limitations, many studies have been conducted to address how to utilize "communities of teaching practices" and to learn how teacher interactions can be improved through designed interactive mechanisms or technological interventions (Carroll et al., 2003; Gibson, Neale, Carroll, & VanMetre, 1999; Hsu, 2004; McCotter, 2001; Olson & Craig, 2001; Snow-Gerono, 2005; Stigler & Hiebert, 1999). However, many studies have also demonstrated the limitations of teacher interactions in community activities, including motives, content, and performance (Barab et al., 2001; Carroll et al., 2003; Chancy-Cullen & Duffy, 1999; Fishman & Pinkard, 2001). Therefore, the topic of how to better utilize technologies to facilitate interactions in teacher communities certainly deserves our efforts.

By looking at the aforementioned limitations related to teacher communities, the limitations in teachers' professional development may be correlated with the lack of in-depth interactions/discussions concerning instructional knowledge. Recently, there have been many studies addressing the issues of knowledge-sharing, which focus on the process of knowledge interaction among community members. This includes the exploration of the "internalization" and "externalization" of knowledge (Hendriks, 1999). Organizations or communities can come up with various knowledge-sharing strategies in order to achieve knowledge transition, innovation, and re-use among members (Davenport & Prusak, 1998; Gilbert & Gordey-Hayes, 1996). Many studies of knowledge-sharing have also discussed the factors that motivate members to share knowledge in organizations (Bock, Zmud, Kim, & Lee, 2005; Hsu, Ju, Yen, & Chang, 2007; Kankanhalli, Tan, & Wei, 2005; Wasko & Faraj, 2005). Most of these studies discuss the application of knowledge-sharing in commercial organizations, and the technologies proposed to assist in knowledge-sharing (Li, Montazemi, & Yuan, 2006; Rafaeli, Barak, Dan-gur, & Toch, 2004; Ras, Avram, Waterson, Weibelzahl, 2005; Roda, Angehrn, Nebeth, & Razmerita, 2003; Soller, 2004).

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Since studies related to educational knowledge-sharing are rare, knowledge-sharing behavior may be different between organization types (Bock et al., 2005; Yang, 2007; Yang & Chen, 2007). In order to promote knowledge-sharing within online educational groups (e.g., online teacher/student communities), this study explores the knowledge-sharing activities of online teacher communities.

In the context of e-Learning, knowledge between teachers and students is often shared via online discussion forums. Since the design of online discussion activities has a strong influence over the quality of discussions (Hewitt, 2003; Patricia & Dabbagh, 2005; Swan, Shea, Fredericksen, Pickett, & Pelz, 2000; Vonderwell, 2003; Vrasidas & McIsaac, 1999), this study focused on designing an appropriate online knowledge-sharing discussion activity for teacher communities. We then explored the behavioral patterns and content during the discussions, in order to further explore the influences and limitations of a particular knowledge-sharing discussion activity. There have not been many studies targeting this topic, and this study will be useful in terms of the evaluation and development of online knowledge-sharing discussion strategies for teacher communities in the context of e-Learning.

In our study, we adopted "problem-solving" as the knowledge-sharing strategy. Problem-solving is frequently used in teaching, and its theoretical model has already been widely discussed (Basadur, 1994; Mayer, 1992; Schoenfeld, 1992; D'Zurilla & Goldfried, 1971). This method has also been integrated into online forums and applied to teacher-training (Hsu, 2004).

Therefore, the objectives of this study were as follows:

(1) Design and conduct an online problem-solving knowledge-sharing discussion activity for teacher communities.
(2) Through empirical observations, explore the influences and limitations of the activity in terms of knowledge-sharing, then propose feasible suggestions for teacher educators who want to promote teachers' knowledge-sharing.

2. Theoretical background

2.1. Problem-solving

Problem-solving is an instructional strategy frequently used in collaborative learning (Gagne & Briggs, 1979). There have been many studies on instructional strategies that use online problem-solving methods. Different scholars define "problem-solving" in different ways (Gagne, 1980; Hatch, 1988; Mayer, 1985; Sternberg, 1996). Gagne (1980) treats problem-solving as the process of combining previous knowledge and solving a new problem. Mayer (1985) believes that problem-solving is the process of transforming an initial status to a targeted status. Mayer proposed that problem-solving is a cognitive process, the behavior of an individual seeking a solution, and a process of using previous experience. Hatch (1988) defines problem-solving as the process of finding a suitable solution to a question. Sternberg (1996) believes problem-solving is a process of removing obstacles when finding solutions. Many studies also propose procedures and models of problem-solving (Henna, Potter, & Hagaman, 1995; Isaksen & Parnes, 1985; Sternberg, 1996).

The above scholars' opinions indicate that "problem-solving" focuses on using past experience and knowledge, thinking deeply, and using cognitive skills to solve new problems. This process not only helps solve problems, but can also encourage students to interact/discuss with peers and develop their cognitive skills when applied in "cooperative learning" settings. This is why problem-solving has long been used as a teaching strategy (Gagne & Briggs, 1979; Duch, Groh, & Allen, 2001). This strategy has also been applied to teacher education (Hsu, 2004). By using collaborative problem-solving discussion activities that promote teaching knowledge interactions, teachers' professional development can be improved.

2.2. Online discussions of teacher communities

Many studies discuss the teacher community and attempt to enhance inter-teacher interactions (Carroll et al., 2003; Gibson, Neale, Carroll, & VanMetre, 1999; Hsu, 2004; McCotter, 2001; Olson & Craig, 2001; Snow-Gerono, 2005; Stigler & Hiebert, 1999). Due to the spatial and temporal limitations of face-to-face community interactions, more and more studies have started using online forums to create online teacher communities (Dana & Yendol-Silva, 2003; Hobson & Simolin, 2001; Sing & Khine, 2006), and some communities use online teaching films to promote knowledge-sharing among teachers (Barab et al., 2001). Hsu (2004) applied an online case-discussion activity in a teacher community and used questionnaires and interviews to understand teachers' attitudes. It was discovered that, during the discussion process, the teachers' problem-solving skills improved. They were able to propose different perspectives, develop action plans, acquire knowledge and skills, and receive more peer assistance. Furthermore, they became more confident in their professional development. Certain studies also utilized content analysis to discuss the content of teachers' online discussions (Deryakulu & Olkun, 2007; Sing & Khine, 2006), and these studies showed that online discussions can help us explore teachers' perspectives on certain teaching issues (Deryakulu & Olkun, 2007).

However, many studies have shown limitations in teacher interactions in community activities, including a lack of motivation, interactions, and depth (Barab et al., 2001; Carroll et al., 2003; Chancy-Cullen & Duffy, 1999; Fishman & Pinkard, 2001). In a quantitative content analysis of 11 teachers' online discussions by Sing and Khine (2006), the results showed that, although teachers participated in the discussion activities actively, the level of knowledge construction of the discussions were limited.

Moreover, most of the studies that explore teacher communities' online interactions are often limited to case analyses, interviews, or content analyses, and do not offer enough information about the overall behavioral pattern of teacher communities. Therefore, in this study, we attempted to utilize a problem-solving strategy to design knowledge-sharing online discussion activities for teachers, and we used a large number of samples to conduct an empirical analysis and explore potential limitations and solutions. For the analysis methods, we adopted quantitative content analysis, sequential analysis, and qualitative original protocol analysis to explore the content and behavioral patterns of teachers' discussion behaviors.

3. Online problem-solving knowledge-sharing discussion activity

During a "collaborative problem-solving" process, the need to answer peers' questions and discuss the questions/solutions provides an opportunity for members to internalize/understand the knowledge relevant to the proposed questions. Furthermore, a member can propose solutions to other members in order to externalize his or her knowledge. Through the Internet, more questions and answers can be passed around in an efficient and timely manner via online discussions, resulting in a more efficient sharing of knowledge during the online problem-solving process.

We compiled a literature review regarding problem-solving (Basadur, 1994; Henna, Potter, & Hagaman, 1995; Isaksen & Parnes,1985; Mayer, 1992; Schoenfeld, 1992; Sternberg, 1996;

D'Zurilla & Goldfried, 1971), and summarized the four interaction/discussion behaviors that may emerge during online problem-solving discussion activities as: (1) to propose or clarify questions, (2) to propose solutions or related information, (3) to conduct comparisons and discussions based on existing solutions, and (4) to propose summarizing conclusions. According to these discussion behaviors, this study has integrated the relevant concepts of problem-solving and knowledge-sharing to produce an online knowledge-sharing discussion activity centered on problem-solving. Table 1 lists a description for each discussion behavior of this online activity and its impact on teachers' knowledge internalization and externalization.

As described in Table 1, the content and function of each online discussion behaviors to assist in knowledge internalization (i.e. understand, read and think) and knowledge externalization (i.e. write and demonstrate) differ from each other. This table shows the benefits for knowledge-sharing of using problem-solving online discussion strategies, and can be used as an analytical framework for understanding the content of teachers' online discussions and their problem-solving behavioral patterns. We then conducted empirical observations to explore the pattern of teachers' online problem-solving behaviors, and we discuss the influences and limitations of this activity.

4. Method

In order to explore the actual online discussion patterns more deeply, the method for analyzing the process is important. In this regard, there have been many studies targeted at describing the interactions in asynchronous online discussions (Fahy, Crawford, & Ally, 2001; Gunawardena, Lowe, & Anderson, 1997; Hewitt, 2005; Levin, Kim, & Riel, 1990; Newman, Webb, & Cochrane, 1995; Sudweeks & Simoff, 1999), where case analyses of the discussion content and the quantitative content analyses were often used to explore the interactions. By coding and analyzing the discussion content, we can understand the overall content pattern of the discussions, yet the results of content analyses alone do not allow us to dissect the behavioral patterns and sequential progression of the entire discussion (e.g., What kind of problem-solving discussion behavior often occurred subsequently after a certain kind of discussion behavior?). Understanding these sequential correlations will allow us to infer the overall behavioral sequential patterns, as this will allow better understanding of the actual situations in the overall discussion behaviors and the detection of the possible limitations in interactions.

In this regard, lag sequential analysis (Bakeman & Gottman, 1997) will allow us to more accurately examine whether the sequential relationship between each discussion behavior has reached statistical significance. This method has already been utilized in studies that explore online discussions (England, 1985; Hou, Chang, & Sung, 2007, 2008; Jeong, 2003; King & Roblyer, 1984), which gives us more inferential information that can be used to analyze the sequential correlations among the interactive behavior of knowledge-sharing. Finally, this study also extracted the contents of original discussions, and the contents were processed with original protocol analyses to trace and discuss the derived content/behavior patterns. Discussions, reviews, and comparisons were carried out with the results obtained from qualitative interpretation, quantitative content analysis and sequential analysis.

Table 1
Online knowledge sharing discussion behaviors that integrate problem-solving strategy

Behavior	Description	Benefit on knowledge internalization	Benefit on knowledge externalization
Propose or clarify questions	Post new topics or articles in order to ask questions or to define and clarify a question itself.	Read, understand, and internalize the key points in the questions proposed by other members, and clarify the questions.	Externalize one's questions in words and show them to other members.
Propose solutions or related information	Post articles to answer questions or to provide question-related information.	Read, understand, and internalize the knowledge relevant to the questions proposed by other members, and think of ways to answer the questions.	Externalize the solutions deemed appropriate by oneself in words and show them to other members.
Conduct comparisons and discussions based on existing solutions	Post articles to compare and analyze existing solutions.	Read, understand, and internalize the question content and solutions proposed by other members, and think about the differences and logic.	Externalize one's comments on the analysis and comparison of each solution in words and show them to other members.
Propose summarizing conclusions	Integrate the existing solutions and discussions and propose one's own solutions.	Read, understand, and internalize the question content and discussions by other members, and think about how to draw a conclusion.	Externalize one's summarizing conclusion comments for a question in words and show them to other members.

4.1. Participants

To observe teachers' knowledge-sharing behaviors, we conducted 18 workshops in Taiwan from June to August 2006. The voluntary participants in this study were 495 teachers from locations around Taiwan. Regarding the background of the samples, the individual information of the samples was analyzed. Four hundred and forty one teachers provided their personal information and correctly filled out the forms. Except for one pre-service teacher, all others were in-service teachers; where 209 were males (47.4%), and 232 were females (52.6%); 24.7% were 20–29 years of age, 45.4% were 30–39, 25.2% were 40–49, 2.72% 50–59, and 2.02% were 60–69; 60.8% worked in elementary schools, 24.3% worked in junior high schools, and 15% worked in senior/vocational high schools.

4.2. Instruments

To observe teachers' online discussion behaviors, an online knowledge-sharing environment was provided for the teachers. This environment included online asynchronous forums which served as a tool to record the community members' discussion processes. In this study, we incorporated the "WIDE" platform (Web-based Instructional Design Environment) (Chang, Sung, & Hou, 2006). The current version of WIDE (WIDE-KM, WIDE with Knowledge Management modules) provides interactive functions for teachers' online knowledge-sharing and for conducting online instructions. The functions provided for knowledge-sharing included modules such as teacher community sites, teachers' weblogs, and a problem-solving forum to form an integrated environment for teachers' knowledge-sharing.

We used the problem-solving forum within this system as the tool for our observations. The problem-solving forum of WIDE-KM is an online discussion module that allows teachers to conduct Q&A of teaching-related knowledge, and to propose and discuss questions. Teachers can post new problem topics, and all of the topics are listed in the "topic list page." Teachers can also browse the topics and click on a topic link to enter the "topic page" of a certain question to see the content of the question and its relevant reply messages. They can also click on "reply" to provide a response to the question. Examples of responses include clarifying questions, providing answers, and comparing, discussing, and drawing conclusions. The posted responses were listed based on the temporal order in the "topic page" and were recorded in the database for future analysis.

4.3. Procedure

In order to ensure that each teacher had the basic skills needed to use our forum and to reduce the effect of skill differences, we conducted workshops before the observation period. During the workshops, we introduced the concept and importance of the sharing of teaching knowledge and the functions of the problem discussion module in our knowledge-sharing system WIDE-KM. We also provided an operation guidebook for the WIDE-KM system for the teachers. We explained and demonstrated how to use the online problem-solving discussion forum and gave examples of how to post and respond to questions, helping teachers become familiar with the online knowledge-sharing environment. Moreover, each teacher was given an account in order to access the website and practice how to use the functions during the workshop. Before the workshop concluded, we encouraged the teachers to participate in the problem-solving activity of teaching-related knowledge via the system at their homes or schools. The above research procedures were faithfully replicated in all the workshops. The content of the problem-solving discussions by the teachers who participated from June to September 2006 was analyzed. There was no intervention from teacher educators during the discussion process in order to ensure precise analysis of how teachers conduct online discussions in a free, unsupervised, and unaffected environment. During the period of teachers' online discussion, we had a support team available to help the teachers using this system or to help answer any questions they had regarding this activity.

4.4. Data coding and analysis

Content analysis and sequential analysis requires the coding of each posted message. Based on the problem-solving behaviors defined in Table 1, we constructed a coding scheme for problem-solving discussion content in order to allow follow-up coding and analysis. As shown in Table 2, the study gave each behavior a code, and an example of a discussion is listed in the table.

The coding method in our study is as follows: each topic was treated as a unit (each proposed question is a question-topic), and the messages in each topic were coded based on their temporal order (each topic can have multiple response messages). If a single message had two or more codes, the codes were listed based on the temporal order. For example, the first paragraph of a message is coded as P1, the following two paragraphs are coded as P2, and thus the message's code is P1P2, based on the temporal order.

After all the messages were coded based on the above method, each question-topic had a set of problem-solving coding data. The observations took place from June 9 to September 1, 2006, and 133 question-topics with 622 messages were posted. In order to verify the reliability of the coding content, we randomly chose 61 topics (about half of the total number of topics) for another rater's analysis. The inter-rater reliability of coding – the Kappa reliability, was 0.863 ($p < 0.01$). The coded data then underwent content analysis and sequential analysis.

5. Results

From the content analysis, we gathered a total of 133 topics and 622 posted articles during the activity period. After taking out the non-question-related topics, we conducted a quantitative content analysis. A total of 672 codes were found after all the discussion contents were coded, and the distribution of the coded behaviors is shown in Fig. 1.

Table 2
Coding scheme of problem-solving discussion content

Code	Behavior	Example
P1	Propose or clarify questions	In the class, I need to talk to the students about the life and works of author A. Can you tell me what kind of teaching would be appropriate?
P2	Propose solutions or related information	The data I gathered show: The climate in author A's homeland was so cold that it affected her writing style, making it full of the sense of isolation and helplessness. I often introduce my students to her works through this feature of hers.
P3	Conduct comparisons and discussions based on existing solutions	I do not think that the previous teacher's comment was complete enough since that author's family background was what contributed to her works that were full of the sense of loneliness. The author was born to a single family which tried to survive in a war-torn era, thus she seldom felt any human warmth. This is an important aspect.
P4	Propose summarizing conclusions.	By summarizing other teachers' comments and information, I believe that both climate and family background are capable of affecting how a person expresses his or her feelings. When teaching our students, we can describe both points at the same time or ask the students to look for the author's biographical data, or we can encourage them to try to make connections between the author's life and her works. I think this is a good way to go for.
P5	Other discussions those are irrelevant to the main topic.	One of my friends also lives in the city where author A lived in. He told me the hand-made cookies there are very delicate and delicious…

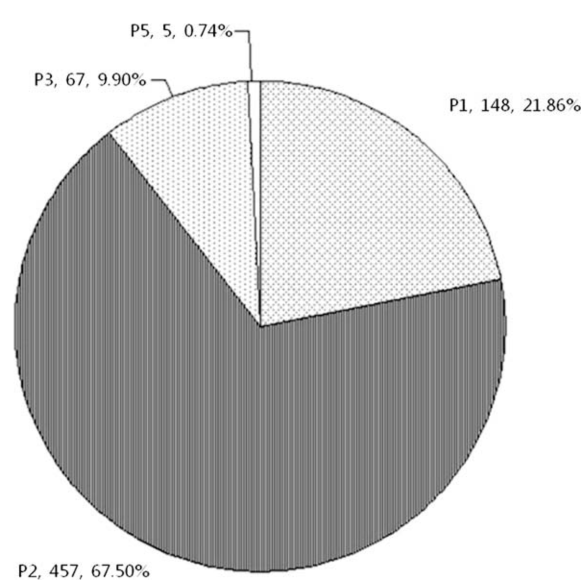

Fig. 1. Percentage of problem-solving online discussion knowledge construction codes.

As shown in Fig. 1, P4 was not found in the coding results; thus it was not included in the figure. Among all the codes, P2 took up the largest proportion (propose solutions or related information) (67.5%), followed by P1 (propose or clarify questions) (21.86%), and P3 (conduct comparisons and discussions based on existing solutions) (9.9%). The proportion of P5 (other discussions that are irrelevant to the main topic) was extremely low (less than 1%).

From the lag sequential analysis, we calculated the frequency of each behavioral category immediately following another behavioral category. The results are shown in Table 3: the columns are the starting behaviors and the rows are the behaviors that occurred after the starting behaviors finished. The numbers represent the total number of times a column behavior occurred immediately after a row behavior ended (e.g., the number "20" in row 2/column 1 means that "P1 occurring immediately after P2" happened 20 times).

Based on the data in Table 3, we then conducted sequential analysis and further determined whether the connection between each sequence reached statistical significance. As shown in Table 4, a Z value that is greater than +1.96 indicates that the continuity of that sequence reached the level of significance ($p < .05$).

Table 4 tells us that the four sequences in this observation that reached the level of significance include: P1 → P2, P2 → P1, P2 → P3, and P5 → P5. This allowed us to infer the behavioral approach in the discussions within the teacher community. We then deduced a behavioral-transfer diagram based on Table 4, as shown in Fig. 2, which presents all sequences in Table 4 that have reached significance.

The values in the figure represent the Z-value of each sequence, the thickness of the arrow represents the level of significance, and each arrow points in the direction of the transfer. This diagram allows us to explore the behavior patterns in the discussion process.

Finally, this study also extracted original discussion contents, and processed them with original protocol analysis to discuss with the derived content/behavior patterns. Discussions, reviews, and comparisons were carried out with the results obtained from qualitative interpretation, quantitative content analysis, and sequential analysis.

In order for us to further discuss the results of the content analyses and sequential analyses mentioned in the above sections, we excerpted the discussion topics proposed by the teachers numbered N1536 and N1504. Based on these cases, we can try to interpret and further understand the processes of teachers' knowledge internalization and externalization during the problem-solving activities and their behavioral patterns that were derived earlier:

Let us look at the case of teacher N1536:

Excerpt of an actual discussion topic (Teacher no.: N1536, Message #7101–#7103)

N1536: The textbook says that the three primary colors of light are red, green, and blue, but I have heard that they are not the three primary colors used on TV. For example, one of the primary colors used on TV is an orange-ish red. Does anyone know more about this? (Message #7101, 2006/7/13 15:57:00)
N1529: The three primary colors of light are red, green, and blue. This was tested on academic assessment exams. (Message #7102, 2006/7/13 16:00:00)

Table 3
Frequency transition table

	P1	P2	P3	P5
P1	5	132	3	0
P2	20	277	57	2
P3	0	47	7	1
P5	0	0	0	2

Table 4
Adjusted residuals table (Z-score)

	P1	P2	P3	P5
P1	−0.71	2.06*	−4.54	−1.51
P2	2.73*	−2.71	5.93*	−1.91
P3	−1.75	0.27	0.14	0.79
P5	−0.30	−1.29	−0.49	14.79*

*$p < 0.05$.

N1531: The colors we commonly see are mostly comprised of two or more colors: The three primary colors are red, green, and blue, and the original colors of the three pigments are magenta, yellow, and cyan. The mixture of the lights of the three primary colors yields white light, and the mixture of the three primary colors yields black. With appropriate proportions, we can use the three primary lights or colors to generate different colors. (Message #7103, 2006/7/13 16:01:00)

During the discussions, after teacher N1536 proposed a question, N1529 provided his/her initial understanding and information (code P2) (see #7102 message), but this analysis lacked depth. The message proposed by N1536 regarding the three primary colors on television was not even answered. Afterwards, teacher N1531 found more information regarding this topic (P2) and conducted a more meaningful exploration and analysis (see the message of #7103 on the analysis and additional information on colors, lights, and pigments). Although this message was not able to completely solve the question of teacher N1536 on the primary colors of television or to form a conclusive answer (P4), it nonetheless helped the participants to move from knowledge-sharing to an in-depth exploration and to externalize the answers. However, a lack of P4 also limited teachers' discussions.

Then let us look at the case of teacher N1504:

Excerpt of an actual discussion topic (Teacher no.: N1504, Message #9401–#9404)

N1504: Is it true that organic vegetables do not need pesticides or net supports to promise a good harvest? (Message #9401, 2006/7/13 16:08:00)
N1209: Air, temperature, moisture, and soil fertility all should be considered. Bugs are also a problem that needs to be solved! (Message #9402, 2006/7/14 14:30:00)
N1507: The concept of "organic" is not just limited to vegetables. Fish and meats can also be "organic" since being organic is a way for us to show that we care about the environment. If you want to know more about organic vegetables, you could join the Teachers' Growth Camp in summer or winter vacation. It's a great "organic" camp, and the participants are required to eat only vegetables – organic ones, too! You also get to learn good concepts about education. I recommend it. (Message #9403, 2006/7/14 16:08:00)
N1630: Do you want to know how to grow organic vegetables or are you questioning how organic vegetables are achieved? I also

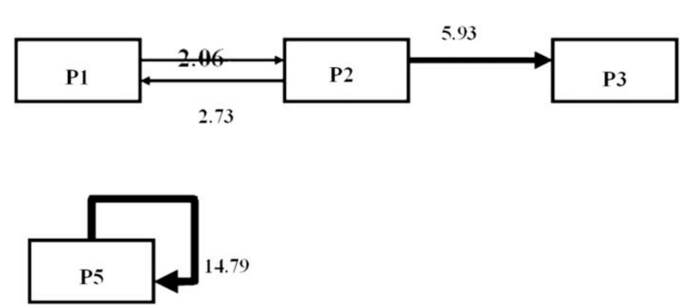

Fig. 2. Sequential behavioral pattern of problem-solving discussion.

want to know how to grow them. (Message #9404, 2006/7/17 16:06:00)

The case of teacher N1504 shows that the question proposed by teacher N1504 was not very clearly externalized (message #9401 did not allow others to understand whether this teacher wanted to know more about how organic vegetables are grown or the effectiveness of the cultivation given certain methods), and this may have prevented the participants from focusing on a certain topic or making a more in-depth analysis of the topic of "organic vegetables". A more complete answer was thus rendered impossible, and this could have possibly led to the fact that teacher N1209 and N1507 were only able to provide related comments and supplementary information (P2) rather than being able to focus and make a deeper analysis of this topic (P3 or P4). Teacher N1630 then asked a question in reply in order to clarify the question (P1) (shown in message #9404, the participant asked a question in order to clarify the core of the original question). This P2 → P1 behavioral pattern was able to bring the discussion back to focus and increase the depth of the discussion. This also shows that during a discussion that involves a complicated internalization process, the teachers were able to detect the loss of focus and blind spots in a discussion, and were also able to specifically explain these issues.

The content and order of the teachers' discussions in the above two cases have, to an extent, explained and confirmed some of our findings in quantitative content analysis and sequential analysis (e.g., the behavioral patterns about P1 → P2, P2 → P1, etc.).

6. Discussion

The results of the quantitative content analyses and sequential analyses show that P1 (propose or clarify questions) and P2 (propose solutions or related information) are closely connected (P1 → P2, P2 → P1), and the total number of P1 and P2 occurrences was 90% of the total behaviors (P1:21.9%, P2:61.5%), whereas P3 (conduct comparisons and discussions based on existing solutions) comprised 9.9%. Irrelevant messages (P5: 0.74%) were extremely rare, meaning that irrelevant discussions or deviations from the topic, which were mentioned in previous study which focuses on learners' discussions (Hou, Chang, & Sung, 2007), were seldom seen in this study. This shows that there is a certain degree of concentration and continued interaction in the problem-solving behaviors among teachers, and that deviated discussions (those that are irrelevant to the discussion topics) were rarely seen in teacher communities. This is significant since knowledge-sharing behavior may be different from one organization type to another (Bock et al., 2005; Yang, 2007; Yang & Chen, 2007). This also shows that although most teachers still have not established the culture in which teaching-related knowledge is exchanged (Barab et al, 2001; Tyack & Cuban, 1995), after applying the problem-solving knowledge-sharing discussion activity, the close interaction between P1 and P2 during the process (P1 → P2, P2 → P1) has certain facilitative benefits on the in-depth discussion, as we found in the sequential pattern and protocol analysis (see the case of teacher N1504, Message #9401–#9404).

On the other hand, the percentage of P2 and P3 is not low (P2 add P3 were about 78%), and the level of significance of P2 → P3 is higher than that of P1 → P2 and P2 → P1, showing that the participating teachers tend to externalize their own solutions or opinions instead of staying in asking questions (P1) or answering questions (P2). A certain percentage of them conducted in-depth discussions or comparisons (P3), showing that knowledge-sharing discussions based on problem-solving helps break through the difficulty of externalizing teaching-related knowledge as proposed by Carroll et al. (2003).

If we take a further look at the phenomena of P1 → P2, P2 → P1, and P2 → P3, we can see that in the teachers' problem-solving process, the teachers often dig more deeply into different solutions (P2 → P3) or return to clarify questions (P2 → P1) after proposing solutions. This suggests that problem-solving discussions have certain "exploration processes" and that the teachers have read and internalized the topics or the solutions proposed by others to a certain extent before they conduct further analyses or clarifications. This shows that the teacher community in this study conducted knowledge internalization to an extent that is sufficient to ensure the depth of the discussions. The above phenomena show us that using the problem-solving discussion activity to a certain extent assists teachers' knowledge internalization/externalization in our findings.

In our study, we have also discovered some limitations in applying this kind of strategy in teacher discussions. First, P4 (propose summarizing conclusions) was not observed, showing that the teachers seldom integrate other's opinions and draw conclusions in the problem-solving process. This shows that teachers' overall discussions lack systematic conclusions or summaries; this may be due to the fact that teaching-related topics are complex, and it is difficult to form standard answers.

What also deserves our attention is that although P5 (other discussions that are irrelevant to the main topic) is less than 1%, the sequence of P5 → P5 shows that it continued despite its low frequency. This shows that once an irrelevant discussion occurs, it will be continued to a certain extent and might even affect the depth or direction of the entire discussion. Moreover, deeper discussions tend to be difficult to achieve. For example, after making analytical comments (P3), the teachers tend to be unable to continue with more analysis or comparisons (P3 → P3), to integrate (P3 → P4), or to find new solutions through analysis and comparison (P3 → P2), and, in turn, arrive at new questions (P3 → P1). These sequences may very well help enhance the quality of discussions and facilitate the internalization and externalization of teaching-related knowledge more deeply. Behavior sequences such as P2 → P4, P4 → P2, P4 → P1, and P4 → P3 also have their facilitative effects on the quality of discussions.

Teacher educators or senior teachers often serve as guides in online teacher communities, and based on our findings, we will now provide some useful suggestions regarding how they can intervene and guide teachers' online problem-solving discussions. The methods include:

(1) Encourage integrated conclusions and avoid deviation: pay special attention to the discussion limitations that were commonly seen in our study (e.g., lacks integrated discussions (P4) and continued deviation from the topic (P5 → P5)), and post messages to guide teachers in a timely fashion. For example, after a teacher has given a certain number of solutions or analyses for a certain question (P2, P3), he or she should be guided to summarize and organize the solutions and discussions and draw a summarizing conclusion (i.e., facilitate the occurrence of P2 → P4, P3 → P4), or he or she should be reminded to return to the topic once they deviate from the original topic in order to ensure the deviation is not continued (P5 → P5).
(2) Promote further analysis/discussion: appropriate strategies can also be formulated to help teachers explore new solutions (P3 → P2, P2 → P2), continue in-depth analysis (P3 → P3), and arrive at new questions (P3 → P1). Teacher educators can post corresponding messages to guide the teachers since the above sequences rarely occur by themselves in the discussion process.
(3) Applying technologies to assist knowledge-sharing: many studies in recent years have used technologies to assist

knowledge-sharing (Li, Montazemi, & Yuan, 2006; Rafaeli et al., 2004; Ras et al., 2005; Roda et al., 2003; Soller, 2004). Among these, an intelligent agent is capable of providing automatic timely guidance to users (Aroyo & Kommers, 1999). This kind of technology detects a user's online operations and actively provides guidance. If we were able to integrate this technology in the existing problem-solving forums, teachers would receive automatic prompts and supplementary information instantly, possibly assisting them in overcoming the bottlenecks in the discussion (e.g., after teacher discussion is halted for a certain length of time, the system would automatically generate messages to encourage the users to continue discussing or would conduct data mining processes in the knowledge database or websites of teaching-related knowledge to provide supplementary information relevant to the discussion in order to encourage the teachers to continue). Beyond automatic guidance, the utilization of such technology would also help generate a report that shows the pattern of teachers' interactions (such as the frequency of teacher discussion, social interaction network, break-off points in discussions, and behavioral patterns). This would provide information to teacher educators to guide teachers and facilitate the internalization and externalization of teaching-related knowledge.

7. Conclusion

In this empirical study which explores problem-solving-based knowledge-sharing discussions, we observe how teachers solve problems online. Through content analysis, sequential analysis, and protocol analysis, we conducted empirical observations and analyzed the behavioral pattern in teachers' discussions. The results allow us to see how knowledge is shared among teachers and the possible limitations. We have also provided related suggestions that assist researchers and teacher educators who use the same strategy to promote teachers' online knowledge-sharing.

One limitation of this study is that we focused on how teachers proposed and solved questions; thus, we talked about a general pattern in the problem-solving behavior in the entire teacher community rather than providing an in-depth analysis of discussions that focus on specific knowledge types (i.e., concept knowledge, principle knowledge, or critical knowledge) of the questions. However, questions based on different knowledge-types may lead to different problem-solving processes (Gijbels, Dochy, Bossche, & Segers, 2005). Future studies that analyze behavioral pattern of discussions focusing on specific knowledge types will help us explore how teachers discuss when facing different types of questions.

Moreover, we also hope to observe how most of the teacher educators help teachers who face bottlenecks in online discussions or conduct empirical evaluations to observe the discussion process in an environment where intelligent agent modules are embedded in the forums. Moreover, in order to facilitate the depth of teacher interaction and motive, appropriately combining physical communities with online communities and designed more hybrid interactive mechanisms which also deserve to be analyzed. These future studies may help us better understand how teachers share knowledge online and determine more effective ways to help them share teaching-related knowledge.

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