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Educational magic toys developed with augmented reality technology for early childhood education

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ABSTRACT

Shaping children's experience, enhancing their imagination and affecting their behaviors, toys have great importance. Recently, toys have gained a digital characteristic and many children have tended to use them. For this reason, educational magic toys (EMT) were developed with augmented reality technology in this study. It is called as EMT because virtual objects such as story animations, 3D objects and flash animations appear on the toys. EMT has included puzzles, flash cards and match cards to teach animals, fruits, vegetables, vehicles, objects, professions, colors, numbers and shapes for average 5–6 age children in Early Childhood Education. The aim of this study is to reveal teachers' and children's opinions on EMT, to determine children's behavioral patterns and their cognitive attainment, and the relationship between them while playing EMT. Mix method was used and the sample consisted of 30 teachers and 33 children aged 5–6 in early childhood education. As data collection tools, a survey, an observation and interview form were used. This study revealed that teachers and children liked EMT activity. In addition, children interactively played with these toys but not had high cognitive attainment. From this point, we can say that these toys can be effectively used in early childhood education. However, collaborative and interactive learning with these toys should be provided. Moreover, this study will provide an important contribution, present a new educational AR application, and fill the gap in the educational technology field.

1. Introduction

Playing is an essential part in children's development (Hinske, Langheinrich, & Lampe, 2008) and it always been considered to be of primary importance for children's learning. Therefore, early childhood curriculums provide opportunities for children to play and interact with toys (Yelland, 1999). The relationship between play and learning is proved by researchers, practitioners and parents. Especially integrating new technologies to learning environments bring some benefits for children (Plowman & Stephen, 2005). For example, it enhances the educational value of children's play (Hinske et al., 2008) and enables physical objects to be seamlessly connected to virtual content (Yelland, 1999). Combining physical and virtual worlds such as traditional games and interactive computer games is very beneficial for children (Hinske et al., 2008). So, the nature of the concept of "toy" has changed considerably over the last decades (Yelland, 1999).

Recently, many children have tended to use computer-mediated toys (Kara, Aydin, & Cagiltay, 2012b) and spent a great deal of time playing with them (Johnson & Christie, 2009). Shaping children's experience, enhancing their imagination and affecting their behaviors, toys have great importance for them (Kara, Aydin, & Cagiltay, 2012a; Kara et al., 2012b; Klemenović, 2014). Equipped with computers, digital materials and other smart technologies, toys called as "smart toys" have gained a digital characteristic. Smart toys have some advantages as they integrate multimedia materials in traditional toys (Kara, Aydin, & Cagiltay, 2013). Enriching their play with providing them a more creative environment is one of their advantages. Another one is to increase fantasy play and to enhance interaction (Lampe & Hinske, 2007; Kara et al., 2013). Combining physical and virtual realities, they also provide mixed reality (Kara et al., 2013; Lampe & Hinske, 2007; Stapleton, Hughes, & Moshell, 2002). Besides these advantages, toys can be used for educational aims. In particular, early childhood educators should be aware these educational potential, context for learning and social aspects of play (Yelland, 1999). A toy-based learning environment can provide physical interaction between

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toy and children. According to Lampe and Hinske (2007), the ideal learning experience comes from the combination of physical experience, virtual content and the imagination of the child. In addition, learners can use the toy's abilities according to educational aims (Kara et al., 2012b). Some researches on educational toys have been conducted in the literature. For example, Demir and Sahin (2014) studied the scientific toys used to teach physics, chemistry and biology concepts. They evaluated the toys according to scientific creativity. Kara et al. (2012a; 2013) developed smart toy for storytelling activity and examined storytelling skills, creativity and narrative activities. Both of studies showed positive effects of toys on their depended variables. However, there are few studies on how children play with these toys (Johnson & Christie, 2009). These smart toys facilitate child's social skills (Hinske et al., 2008). Moreover, limited researches on integrating multimedia and new technologies on traditional toys have been conducted. Some researchers developed augmented toys for children integrating multimedia tools on traditional toys, but not using AR technology (Hinske et al., 2008; Marco, Cerezo, & Baldassarri, 2010). In this study, we integrated 3D models, animations and videos on traditional toys by means of augmented reality (AR) technology. Therefore, this study will provide an important contribution, present a new educational AR application, and fill the gap in the educational technology field.

AR can be defined as taking its' three properties into consideration: combining the real world with virtual worlds, providing interaction, and presenting three dimensional (3D) objects (Azuma, 1997). AR provides both virtual and real world simultaneously to users. Although virtual worlds have several advantages like 3D avatar, rich communication channels and rich interaction (Zhang, Ordóñez de Pablos, & Zhu, 2012; Yilmaz, Baydas, Karakus, & Goktas, 2015), real world experiences give valuable opportunities. Especially, appearing of 3D objects in real world creates a magical feeling causing a high degree of surprise and curiosity (Bujak et al., 2013). In addition, texts, images, videos and animations as well as 3D models can be used for educational AR applications. These characteristics of AR make it affective (Wang, Kim, Love, & Kang, 2013). Several AR researches have been done in various education fields (See in Fig. 1). AR technology also provides numerous educational benefits (See in Table 1). Bacca, Baldiris, Fabregat, Graf and Kinshuk (2014) reviewed educational AR applications. According to their results, most of the studies on AR in education were performed in higher education settings. Moreover, the target group such as children in early childhood education should be explored for the uses of AR in future. Besides, no study on educational toys developed with AR has been encountered in the literature. Also, while the potential of learning when playing computer games has already been extensively explored, learning in mixed reality environments such as AR has not been investigated yet (Hinske et al., 2008). Therefore, we focus on children in early childhood education and their play with educational magic toys (EMT) developed with AR in this study.

1.1. *Significance and rationale of the study*

New technologies make valuable contributions to educational technology field and researchers have been explored their effects on students' effective learning and they have focused on "How can modern software technologies support ubiquitous effective knowledge and learning management solutions?" (Lytras & Ordóñez de Pablos, 2011). Therefore, designers have developed some online educational contents. However, they have not captured the users' attentions for a long time because they are ordinary and boring. Besides, Wood and Bennett (1997) stated that if playing provides valuable contribution to learning environments, it should also add valuable contributions for teaching. From this point of view, EMT providing opportunities for teaching has been developed for children so that they interactively learn and have fun. Interacting with toys is important in child development (Butterworth & Harris, 1994 cited in Kara et al., 2012b). If rich and proper interactions are not realized between children and toys, these technologies may make children passive. As we know, AR enables children to interact and provides rich interaction (Azuma, 2004; Bujak et al., 2013; Ivanova & Ivanov, 2011; Kerawalla, Luckin, Selijefot, & Woolard, 2006; Wojciechowski & Cellary, 2013; Wu, Lee, Chang, & Liang, 2013). However, determining how children interact with toys and which behavioral act is important relates to deeper examination in interactions with AR. Especially, children's behaviors with digital toys are important because they provide self-motivation and lead them to learn about the world (Johnson & Christie, 2009). For this, behavior pattern analyses for AR applications have been performed in the literature (Chang et al., 2014; Cheng & Tsai, 2014a, 2014b; Lin, Duh, Li, Wang, & Tsai, 2013). Behavioral patterns enable us to understand the interactions in depth and lead educators to conduct environments (Hou & Wu, 2011). Furthermore, they allow us to understand how instructional strategies can be embedded in our environments (Hou, 2012). Therefore, we examine children's behavioral patterns while playing EMT. On the other hand, interaction with toys supports children's cognitive processes. Lin et al. (2013) suggested that further studies for understanding the user's experience and knowledge construction processes in AR application should be carried out (Bacca et al., 2014). From this viewpoint, we also determine children's cognitive attainment while playing EMT. Especially, Cheng and Tsai (2014b) study was grounded on determining the variables of behavioral pattern and cognitive attainment for different educational AR applications.

Lastly, we determine teachers' opinions about using EMT in education. According to the literature, teachers should know how to maintain a balance between traditional and new digital toys and should become more sophisticated about digital toys (Johnson & Christie, 2009). In addition, the choice of using a technology for education depends on teachers' access and acceptance of the technology. Therefore, we care their opinions in terms of technology acceptance model (TAM). Therefore, this study will examine the following research questions:

- What are early childhood education teachers' opinions about EMT in terms of TAM?
- What are children's opinions on EMT activity?
- How do children behave and interact with each other during EMT activity?
- What is the cognitive attainment of children when engaging in EMT activity?
- What are the relationships between their behaviors and cognitive attainment?

2. Method

2.1. *Research design*

In this study, triangulation method, one of the mix method, was used. While teachers' opinions about EMT and children's behavioral patterns were examined by quantitative methods, children's cognitive attainment and opinions were revealed by qualitative methods.

2.2. *Sample*

Sample consisted of all female teachers (N = 30) and children (N = 33) aged 5–6 including 15 boys and 18 girls in Early Childhood

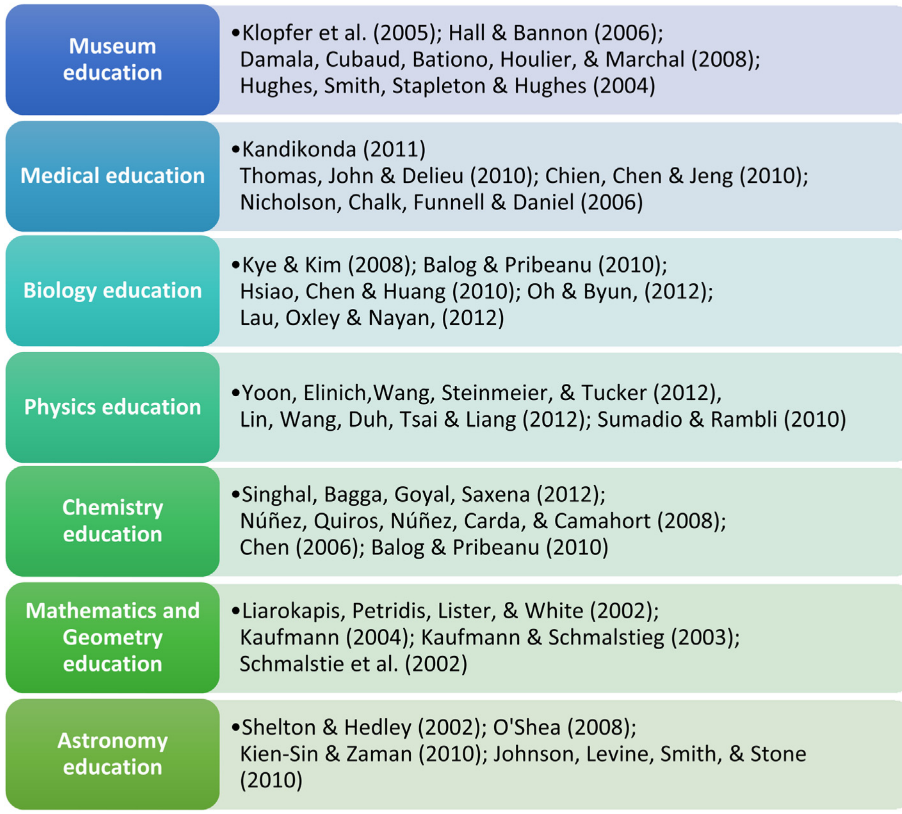

Fig. 1. Ar researches in some educational fields.

Table 1
Educational Benefits of AR applications.

Educational benefits	References
Enhancing attention	O'Brien and Toms (2005); Sumadio and Rambli (2010)
Providing attractive and effective learning	Dünser and Hornecker (2007); Lester et al. (1997); Oh and Woo (2008); Wojciechowski and Cellary (2013); Zhou, Cheok and Pan (2004)
Enhancing motivation	O'Brien and Toms (2005); Sumadio and Rambli (2010); Serio, Ibáñez and Kloos (2013)
Enriching interaction	Azuma (2004); Bujak et al. (2013); Kerawalla et al. (2006); Ivanova and Ivanov (2011); Wojciechowski and Cellary (2013); Wu et al. (2013)
Facilitating learning	Ivanova and Ivanov (2011); Núñez, Quiros, Núñez, Carda, and Camahort (2008)
Enhancing engagement	Bujak et al. (2013); Ivanova and Ivanov (2011)
Providing cooperation	Yuen, Yaoyuneyong, and Johnson (2011)
Triggering creativity	Klopfer and Yoon (2004); Yuen et al. (2011); Zhou et al. (2004)
Developing imagination	Klopfer and Yoon (2004); Yuen et al. (2011)
Enhancing spatial ability	Bujak et al. (2013); Cheng and Tsai (2012); Wojciechowski and Cellary (2013)

Education in Turkey. Convenience sampling method was used for this study because we selected accessible and voluntary teachers and their students.

2.3. Educational magic toys

EMT has included puzzles, flash cards and match cards to teach animals, fruits, vegetables, vehicles, objects, professions, colors, numbers and shapes for average 5–6 age children in Early Childhood Education. EMT's differences from other toys are to integrate multimedia materials on toys and to provide magical sense by means of AR technology. Aim of using the flash cards is to teach a concept in these categories and to see its 3D views. Aim of using the match cards is to teach matching two concept like an animal and its color or an object and its shape. Lastly, aim of using the puzzle is permanent learning providing a story about picture of what will be taught on puzzle. It is called as EMT because virtual objects such as story animations, 3D objects and flash animations appear on toys with AR technology. In the designing process, firstly printed versions of toys were designed. Then, according to the printed designs, story animation for puzzle, 3D objects for flashcards and flash animations for match cards were developed. Lastly, AR technology was integrated in these toys by Metaio Creator Program. Playing with printed toys and then using AR technology with tablets or computers were the major aims of these toys. Some printed materials were presented and a video about the samples of the implementation was added in QR code in Fig. 2.

2.4. Research process

Before implementation, researchers firstly explained to children how to use EMT. Then each child played with toys freely and then

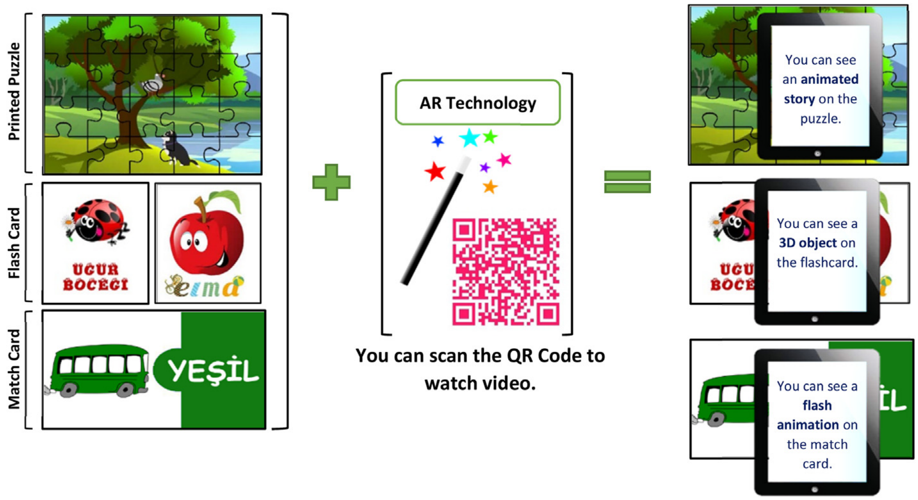

Fig. 2. Samples of EMT.

watched the multimedia materials on the toys by using computer or tablet with their own teacher (See Fig. 3). Children could ask teachers some questions. Similarly, teacher could direct them. The mean of playing time was approximately 25 min ($\mathbf{M}_{\mathbf{flashcard}}$ = 5 min, $\mathbf{M}_{\mathbf{match\ cards}}$ = 7 min, $\mathbf{M}_{\mathbf{puzzle}}$ = 13 min). All playing process was videotaped for behavioral pattern analysis. After implementation, each child was interviewed to reveal their cognitive attainment and opinions on the toys. Because children could not write, structured interview method was preferred. In addition, all teachers were interviewed to determine their opinions about EMT.

2.5. Data collection tools

In this study, three data collection tools were used. For teachers, 5 Likert type survey including their opinions about EMT according to the TAM was conducted. Four factors selected from Teo (2009) survey according to research aim as perceived usefulness, perceived ease of use, behavioral intention and attitudes toward using EMT and 11 items were used. Reliability analyses were determined and Cronbach's Alpha value was .81 for this study. For children, an observation form and an interview form were used. The observation form was prepared according to Cheng and Tsai (2014b) study to understand their behavioral patterns. Their form had parents' narrating, children's reading behaviors and interactions with books and AR elements. For this study, related major behaviors were selected as children's behaviors of operating EMT and children's interaction-oriented behaviors regarding the AR elements. All observations were made on video records captured children play with EMT. Cronbach's Alpha value was .83 for this study. The interview form had four questions to examine their opinions and cognitive attainment of playing EMT. Detailed information about all data collection tools is stated in Table 2.

2.6. Data analyses

Teachers' and children's opinions were analyzed by descriptive method (frequencies, mean and standard deviation). Children's behavioral patterns were observed via observation form. In observation process, researcher firstly observed all children behaviors and then checked out again and corrected all data to provide reliable results. Each observed behavior was noted in the form and was counted from video records. Their counts, percentages and standard deviations were analyzed descriptively. The moment when they engaged with toys, children's cognitive attainments were determined via two interview questions. Each question was analyzed within two categories as appearance description and extensive description. If a child simply described what he had seen, it was evaluated in appearance description. For example a children's statement as "*I saw a car. Its color was blue.*" was coded as two frequency counts in the appearance description category. If a child stated own thoughts, imagination and comments, it was counted for extensive description. For instance, a child said "*I think, police man on flashcard is very strong like my father.*" was counted as

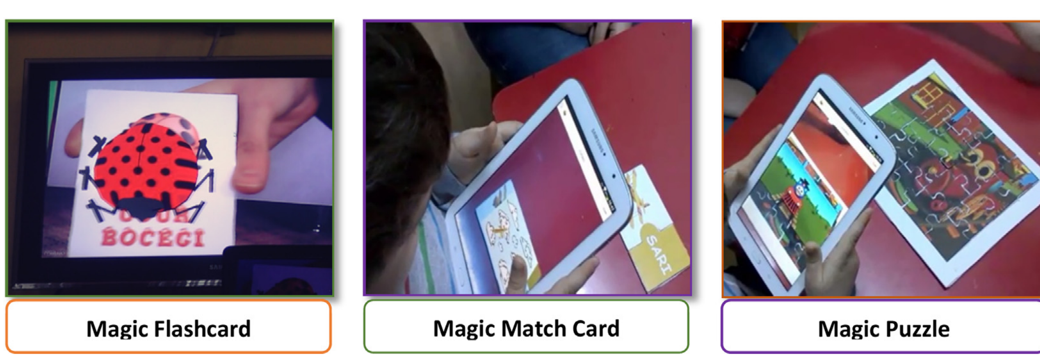

Fig. 3. Some Photos of EMT Activity.

Table 2
Selected items from literature for each data collection tool.

TAM Survey	Teachers' opinions (Teo, 2009)	Perceived usefulness		Using EMT will improve my work.
				Using EMT will enhance my effectiveness.
				Using EMT will increase my productivity.
		Perceived ease of use		My interaction with EMT is clear and understandable.
				I find it easy to get EMT to do what I want it to do.
				I find EMT easy to use.
		Attitude toward using EMT		EMT makes work more interesting.
				Working with EMT is fun.
				I look forward those aspects of my job that require me to use EMT.
		Behavioral intention to Use		I will use EMT in the future.
				I plan to use EMT often.
Observation Form	Behavioral pattern (Cheng & Tsai, 2014b)	Children's behaviors of operating EMT	*Controlling*	The child controls the operation of EMT.
			Turning	The child turns the mobile device/web camera or EMT to view the different dimensions of the AR elements.
			Inspecting	The child inspects the AR elements and tries to touch it.
		Children's interaction-oriented behaviors regarding the AR elements	*Pointing*	The child points at the details of the AR elements.
			Commenting	The child makes comments on the AR elements.
			Questioning	The child asks questions about the AR elements.
			Responding	The child responds to the teacher's questions or comments on the AR elements.
			Repeating	The child repeats the teacher's additional information regarding the AR elements.
Interview Forms	Children's opinions	1 Do you like EMT? Why? Can you explain it?		
		2 Which toys mostly attract you? Can you tell me why it is?		
	Cognitive attainment (Cheng & Tsai, 2014b)	3 What AR elements did you see on these toys? Can you describe their appearance? Do they have any distinguishing features?		
		4 Do you have any other thoughts about the content presented by EMT? For example, the story you have watched, the details of the toys you have seen, or any interesting things that you want to share with us.		

one frequency counts in extensive description category. Lastly, correlation test was conducted to understand the relationships between their behaviors and cognitive attainment. As a result of abnormal distribution of data, Spearman Correlation test was used. To ensure the reliability and validity of the study, two instructional technology experts checked all research process. In addition, all data collection tools were selected from literature. Analyses of cognitive attainment as well as behavioral pattern analyses was performed by the researcher twice. Detailed information about data analyses according to the research questions is presented in Table 3.

Table 4
Teachers' opinions about EMT.

Survey's factors	N	Mean	SD
Attitude toward using EMT	30	4.70	.37
Behavioral Intention to Use		4.33	.40
Perceive Usefulness		4.30	.56
Perceive Ease of Use		3.96	.99
Total		**4.32**	**.42**

3. Findings

3.1. Teachers' and children's opinions about EMT

In the present study, teachers' and children's opinions about EMT activity have been determined respectively. Firstly, we asked 30 teachers depending on their age group and their positive or negative attitudes towards EMT activities. All teachers liked this activity ($f = 30$) and they said the toys were used in 4–6 age group ($f = 25$). When we examined their opinions in detail, their attitudes toward these toys had the highest value ($M = 4.70$, $SD = .37$). Their general attitudes were positive ($M = 4.32$, $SD = .42$) and they perceived them as useful ($M = 4.30$, $SD = .56$) and easy to use ($M = 3.96$ $SD = .99$). Detailed information are presented in Table 4.

Next, we examined children's opinions about these toys. They all like them ($f = 33$) especially flashcards and puzzles. While some of them preferred magic puzzles because they liked stories, puzzles and big toys, the rest preferred flashcards because 3d objects appeared on cards and they seemed as if they were real and magical. In addition, they stated that toys' reality and animation preferences, and magical and funny effects made them attractive. Detailed explanations are presented in Fig. 4.

3.2. Children's behaviors and interactions during EMT activity

In the present study, children's behaviors for EMT were analyzed with video recordings. All codes and their percentages are listed in

Table 3
Data analyses methods for each research question.

Research questions	Data collection tools	Data analyses methods
1. Research question (Teachers' opinions)	TAM Survey (Teo, 2009)	Descriptive analyses *(Quantitative analyses)*
2. Research question (Children's opinions)	Interview form	Content analyses *(Qualitative analyses)*
3. Research question (Children's behaviors)	Observation Form (Cheng & Tsai, 2014b)	Descriptive analyses *(Quantitative analyses)*
4. Research question (Children's cognitive attainment)	Interview Forms (Cheng & Tsai, 2014b)	Descriptive analyses *(Qualitative analyses)*
5. Research question (Relationships between children's behaviors and cognitive attainment)	Observation Form and Interview Forms (Cheng & Tsai, 2014b)	Correlational analyses *(Quantitative analyses)*

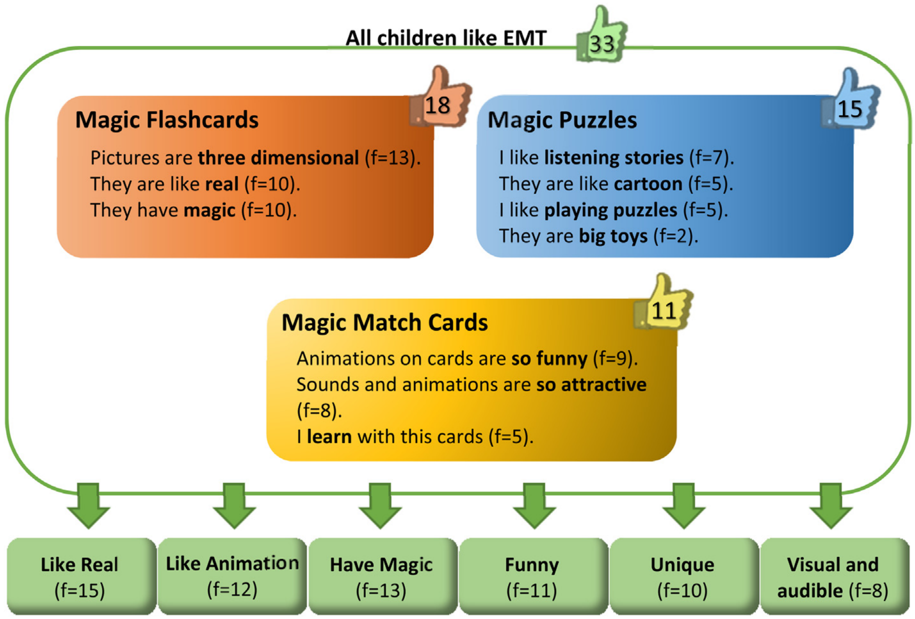

Fig. 4. Children's opinions about EMT.

Table 5. Totally 2265 behaviors were counted. Children pointed at the details of EMT mostly (Count = 371, 16.38%). In addition, they responded to teachers (Count = 347, 15.33%), inspected AR elements (Count = 345, 15.23%) and turned toys (Count = 326, 14.39%) while playing with them. That is, children preferred mostly pointing, responding and inspecting behaviors during EMT activity. Children's behaviors of operating EMT (Count = 958, 42.30%) was relatively low compared to children's interaction-oriented behaviors regarding the AR elements (Count = 1307, 57.70%).

3.3. Children's cognitive attainment during EMT activity

Children's cognitive attainments after playing with EMT were determined via interview responses. Totally 200 codes were revealed in terms of two category as appearance and extensive description. The findings showed that there were 152 codes in the category of appearance description to describe the appearance of the AR elements. On the other hand, there were only 48 codes in the category of extensive description to describe them by using their imagination. This can be explained that children's appearance description (M = 4.61, SD = 2.74) were better than their extensive description (M = 1.45, SD = 1.14). Related findings are presented in Table 6.

Table 6
Count of codes for children's cognitive attainment (N = 33).

Cognitive attainment	Total count	Mean	SD	Max	Min
Appearance description	152	4.61	2.74	10	1
Extensive description	48	1.45	1.14	4	0

3.4. The relationships between children's behaviors and cognitive attainment

In this study, relationships between children's behaviors and cognitive attainment were examined through Spearman correlation analyses and results are revealed in Table 7. All behaviors as well as two categories of them (CIAR and COMT) and 2 description categories of cognitive attainment were included in correlation analyses. According to the results, both appearance and extensive description were related to their behaviors. While behaviors of pointing (r = .40, $p < 0.05$), responding (r = .43, $p < 0.05$) and

Table 5
Count of codes for their behaviors (N = 33).

	Behaviors descriptions	Count	SD	Percentage
Behaviors	CIAR (Pointing, commenting, questioning, responding, repeating)	1307	22.98	57.70
	COMT (Controlling, turning, inspecting)	958	16.10	42,30
	Total numbers of behaviors	**2265**	**35.82**	**100%**
	Pointing at the details of EMT	371	9.59	16.38
	Responding to the teachers' prompts	347	8.55	15.33
	Inspecting the AR elements	345	6.38	15.23
	Turning EMT	326	6.29	14.39
	Children control EMT	287	5.79	12.68
	Repeating teachers' additional information	248	5.14	10.94
	Commenting on EMT	222	5.50	9.80
	Questioning about EMT	119	3.43	5.5
	Total numbers of behaviors	**2265**	**35.82**	**100%**

CIAR: Children's interaction-oriented behaviors regarding the AR elements.
COMT: Children's behaviors of operating EMT.

Table 7
The correlations between Children's behaviors and cognitive attainment (N = 33).

	Appearance description	Extensive description
CIAR	**.37***	**.50****
COMT	**.43***	.16
Pointing	**.40***	.32
Commenting	−.01	**.66****
Questioning	.01	**.66****
Responding	**.43***	.33
Repeating	.19	.24
Controlling	.31	.27
Turning	**.42***	.14
Inspecting	.20	.30

** $p < 0.01$, * $p < 0.05$.
CIAR: Children's interaction-oriented behaviors regarding the AR elements.
COMT: Children's behaviors of operating EMT.

turning (r = .42, $p < 0.05$) were related to appearance description, extensive description had relationships with their behaviors of commenting (r = .66, $p < 0.05$) and questioning (r = .66, $p < 0.05$). Lastly, we can say that while CIAR was related to both appearance description (r = .37, $p < 0.05$) and extensive description (r = .50, $p < 0.05$), COMT were only related to appearance description (r = .43, $p < 0.05$).

4. Discussion

In this study, teachers' and children's opinions on EMT were determined. Children's behavioral patterns and their cognitive attainment while playing EMT and relationship between them were also examined. Our results showed that all teachers and children liked them. Teachers had a high level of positive attitude toward EMT and perceived them as useful. When a new technology is integrated in education, teachers' positive opinions is important. If a teacher accepts the new technology, they will always want to use it and maintain their intention to use it in the future (Teo, 2009). Individuals' inner judgment is also important to adopt new technology. When they especially perceive the technology as easy and useful, their attitude will be positive (Venkatesh, Morris, Davis, & Davis, 2003). Therefore, determining the attitudes toward a new technology is an important factor (Kucuk, Yilmaz, & Goktas, 2014). Thus, we can say that teachers can use EMT in early childhood education in the future because they accept and have positive attitude towards these toys. Children's opinions as well as teacher's are important. They mostly like flashcards because 3d objects appear on cards. Appearing 3D objects makes them attractive and provide real and magical sense. According to the literature, AR application is perceived as magical by children (Billinghurst, Kato, & Poupyrev, 2001; Bujak et al., 2013). In this study, this situation can result from the quality of 3D objects and being perceived as unique toys by them. Our qualitative results have supported this assumption.

When we examine children's behaviors, our results showed that they prefer mostly pointing, responding, inspecting and turning behaviors while playing with EMT. In Cheng and Tsai (2014b) study, children mostly showed the behavior of controlling. However, the number of our total behaviors is close their study. In addition, turning and inspecting are mostly used behaviors in their study similar with our study. These behaviors show us the reflection of interaction. Interaction is one of the most important features of the learning experience (Moore, 1993). Although interaction is provided in some cases, poor interaction designs cause ineffective learning, leading to disorientation and cognitive overload (Calisir & Gurel, 2003; Lustria, 2007). Therefore, interaction should be properly provided. According to Sabry and Baldwin (2003), multimedia components may increase users' interaction. Providing proper interaction and having different multimedia components can be said to lead the children to have high level of interaction with EMT. This situation shows us the importance of using EMT in education.

When we examine children's cognitive attainment, it can be said that they had low level of cognitive attainment. This is because there were only 48 counts in the category of extensive appearance description. Similar results were shown in Cheng and Tsai (2014b) study. This result can result from children's less cognitive effort. They only watched multimedia tools and sometimes ask questions and respond teachers' questions. As can be seen in this study's results, behaviors of questioning and responding were used at least. Therefore, activities enhancing children's cognitive efforts should be provided them. Besides, collaborative and interactive learning with these toys should be implemented. Lastly, this study revealed the relationships between children's behaviors and cognitive attainment. As a result, both categories of appearance and extensive description for determining the cognitive attainment are related to children's behaviors. While the category of appearance description was related to the behaviors of pointing, responding and turning, the category of extensive description was related to the behaviors of commenting and questioning. That is, while they are pointing toys, responding to teachers and turning toys, they can describe what they see in detail. In addition, the more they comment and question, the more extensively they describe. Moreover, we can say that while CIAR is related to both appearance description and extensive description, COMT is only related to appearance description. That is, when the children are more active in EMT, they display more cognitive attainment in terms of both descriptions.

5. Conclusions and suggestions

In this study, teachers' and children's opinions on EMT were revealed and children's behavioral patterns and their cognitive attainment, and the relationship between them while playing EMT were determined. The results revealed that teachers and children liked EMT activity. Teachers had a high level of positive attitude toward EMT and perceived them as useful. We can say that teachers can use EMT in early childhood education in the future because they accept and have positive attitude towards these toys. Children like EMT, mostly flashcards, because 3D objects appear on cards. Moreover, children interactively played with these toys but not had high cognitive attainment. Our results showed that they prefer mostly pointing, responding, inspecting and turning behaviors while playing with EMT. Behavioral pattern analyses showed us their interaction levels in detail. However, this study is limited due to presenting descriptive findings of behavioral pattern. As a result, we can say that these toys can be effectively used in early childhood education.

Other suggestions are stated below:

- To enhance reality and magical sense for EMT, smart glasses can be used when playing toys.
- To provide proper interaction, multimedia tools for EMT such as sounds, graphics, animations, videos and 3D objects should be properly designed according to children's level.
- To enhance the level of cognitive attainment, collaborative activities should be done with children and their own teachers.
- In the future, new designed EMT activities should provide them to comment about something and ask more questions to other.
- In the future, similar EMT can be developed for different sample groups and for different educational fields. Moreover, their

learning experiences and other variables related to learning can be examined.

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References

Azuma, R. T. (1997). A survey of augmented reality. *Presence: Teleoperators and Virtual Environments, 6*(4), 355–385.

Azuma, R. T. (2004). Overview of augmented reality. In *Proceeding of SIGGRAPH'04*. http://dx.doi.org/10.1145/1103900.1103926.

Bacca, J., Baldiris, S., Fabregat, R., Graf, S., & Kinshuk. (2014). Augmented reality trends in education: a systematic review of research and applications. *Educational Technology & Society, 17*(4), 133–149.

Balog, A., & Pribeanu, C. (2010). The role of perceived enjoyment in the students' acceptance of an augmented reality teaching platform: a structural equation modelling approach. *Studies in Informatics and Control, 19*(3), 319–330.

Billinghurst, M., Kato, H., & Poupyrev, I. (2001). The magic book-moving seamlessly between reality and virtuality. *IEEE Computer Graphics and Application, 21*(3), 6–8.

Bujak, K. R., Radu, I., Catrambone, R., MacIntyre, B., Zheng, R., & Golubski, G. (2013). A psychological perspective on augmented reality in the mathematics classroom. *Computers & Education, 68*, 536–544.

Butterworth, G., & Harris, M. (1994). *Principles of developmental psychology*. Hove: Erlbaum.

Calisir, F., & Gurel, Z. (2003). Influence of text structure and prior knowledge of the learner on reading comprehension, browsing, and perceived control. *Computers in Human Behavior, 19*(2), 135–145.

Chang, K. E., Chang, C. T., Hou, H. T., Sung, Y. T., Chao, H. L., & Lee, C. M. (2014). Development and behavioral pattern analysis of a mobile guide system with augmented reality for painting appreciation instruction in an art museum. *Computers & Education, 71*, 185–197.

Chen, Y.-C. (2006). A study of comparing the use of augmented reality and physical models in chemistry education. In *Proceedings of the 2006 ACM international conference on virtual reality continuum and its applications* (pp. 369–372). http://dx.doi.org/10.1145/1128923.1128990.

Cheng, K.-H., & Tsai, C.-C. (2012). Affordances of augmented reality in science learning: suggestions for future research. *Journal of Science Education and Technology, 22*, 449–462. http://dx.doi.org/10.1007/s10956-012-9405-9.

Cheng, K. H., & Tsai, C. C. (2014a). The interaction of child–parent shared reading with an augmented reality (AR) picture book and parents' conceptions of AR learning. *British Journal of Educational Technology*. http://dx.doi.org/10.1111/bjet.12228.

Cheng, K. H., & Tsai, C. C. (2014b). Children and parents' reading of an augmented reality picture book: analyses of behavioral patterns and cognitive attainment. *Computers & Education, 72*, 302–312.

Chien, C. H., Chen, C. H., & Jeng, T. S. (2010). An interactive augmented reality system for learning anatomy structure. In *Proceedings of international conference of engineers and computer scientists* (pp. 370–375).

Damala, A., Cubaud, P., Bationo, A., Houlier, P., & Marchal, I. (2008). Bridging the gap between the digital and the physical: design and evaluation of a mobile augmented reality guide for the museum visit. In *Proceedings of 3rd ACM international conference on digital and interactive media in entertainment and arts* (pp. 120–128).

Demir, S., & Sahin, F. (2014). Assessment of prospective science teachers' metacognition and creativity perceptions and scientific toys in terms of scientific creativity. *Procedia – Social and Behavioral Sciences, 152*, 686–691.

Dünser, A., & Hornecker, E. (2007). An observational study of children interacting with an augmented story book. In *Proceedings of 2nd international conference of e-learning and games (Edutainment 2007)* (pp. 305–315).

Hall, T., & Bannon, L. (2006). Designing ubiquitous computing to enhance children's learning in museums. *Journal of Computer Assisted Learning, 22*(4), 231–243.

Hinske, S., Langheinrich, M., & Lampe, M. (2008, February). Towards guidelines for designing augmented toy environments. In *In proceedings of the 7th ACM conference on designing interactive systems* (pp. 78–87). ACM.

Hou, H. T. (2012). Exploring the behavioral patterns of learners in an educational massively multiple online role-playing game (MMORPG). *Computers & Education, 58*(4), 1225–1233.

Hou, H. T., & Wu, S. Y. (2011). Analyzing the social knowledge construction behavioral patterns of an online synchronous collaborative discussion instructional activity using an instant messaging tool: a case study. *Computers & Education, 57*(2), 1459–1468.

Hsiao, K. F., Chen, N. S., & Huang, S. Y. (2010). Learning while exercising for science education in augmented reality among adolescents. *Interactive Learning Environments, 20*(4), 331–349. http://dx.doi.org/10.1080/10494820.2010.486682.

Hughes, C. E., Smith, E., Stapleton, C. B., & Hughes, D. E. (2004, November). Augmenting museum experiences with mixed reality. In *Paper presented at knowledge sharing and collaborative engineering, St. Thomas, US Virgin Islands*.

Ivanova, M., & Ivanov, G. (2011). Enhancement of learning and teaching in computer graphics through marker augmented reality technology. *International Journal on New Computer Architectures and Their Applications, 1*(1), 176–184.

Johnson, J. E., & Christie, J. F. (2009). Play and digital media, computers in the schools: interdisciplinary journal of practice. *Theory, and Applied Research, 26*(4), 284–289. http://dx.doi.org/10.1080/07380560903360202.

Johnson, L., Levine, A., Smith, R., & Stone, S. (2010). *The horizon report 2010 edition*. Austin, Texas: The New Media Consortium.

Kandikonda, K. (2011). *Using virtual reality and augmented reality to teach human anatomy*. Unpublished doctoral dissertation. Ohio: The University of Toledo.

Kara, N., Aydin, C. C., & Cagiltay, K. (2012a). User study of a new smart toy for children's storytelling. *Interactive Learning Environments, 22*(5), 551–563. http://dx.doi.org/10.1080/10494820.2012.682587.

Kara, N., Aydin, C. C., & Cagiltay, K. (2012b). Design and development of a smart storytelling toy. *22*(3), 288–297. http://dx.doi.org/10.1080/10494820.2011.649767.

Kara, N., Aydin, C. C., & Cagiltay, K. (2013). Investigating the activities of children toward a smart storytelling toy. *Educational Technology & Society, 16*(1), 28–43.

Kaufmann, H. (2004). *Geometry education with augmented reality*. Austria: Vienna University of Technology. Unpublished doctoral dissertation.

Kaufmann, H., & Schmalstieg, D. (2003). Mathematics and geometry education with collaborative augmented reality. *Computers and Graphics, 27*(3), 339–345.

Kerawalla, L., Luckin, R., Selijefot, S., & Woolard, A. (2006). Making it real: exploring the potential of augmented reality for teaching primary school science. *Virtual Reality, 10*(3–4), 163–174.

Kien-Sin, A., & Zaman, H. B. (2010). Live solar system (LSS): evaluation of an augmented reality book-based educational tool. In *Information technology (ITSim), 2010 international symposium, 1* (pp. 15–17). http://dx.doi.org/10.1109/ITSIM.2010.5561320.

Klemenović, J. (2014). How do today's children play and with which toys? *Croatian Journal of Education, 16*(1), 181–200.

Klopfer, E., Perry, J., Squire, K., Jan, M. F., & Steinkuehler, C. (2005). Mystery at the museum: a collaborative game for museum education. In *Proceedings of international society of the learning sciences* (pp. 316–320).

Klopfer, E., & Yoon, S. (2004). Developing games and simulations for today and tomorrow's tech savvy youth. *TechTrends, 49*(3), 41–49.

Kucuk, S., Yilmaz, R. M., & Goktas, Y. (2014). Augmented reality for learning English: achievement, attitude and cognitive load levels of students. *Education and Science, 39*(176), 393–404.

Kye, B., & Kim, Y. (2008). Investigation of the relationships between media characteristics, presence, flow, and learning effects in augmented reality based learning. *International Journal for Education Media and Technology, 2*(1), 4–14.

Lampe, M., & Hinske, S. (2007). Integrating interactive learning experiences into augmented toy environments. In *Proceedings of the workshop on pervasive learning 2007, Toronto* (pp. 1–9).

Lau, N., Oxley, A., & Nayan, M. Y. (2012). An augmented reality tool to aid understanding of protein loop configuration. *Computer and Information Science International Conference, 1*, 500–505. http://dx.doi.org/10.1109/ICCISci.2012.6297297.

Lester, J. C., Converse, S. A., Kahler, S. E., Barlow, S. T., Stone, B. A., & Bhogal, R. S. (1997). The persona effect: affective impact of animated pedagogical agents. In *Proceedings of conference on human factors in computing systems* (pp. 359–366). http://dx.doi.org/10.1145/258549.258797.

Liarokapis, F., Petridis, P., Lister, P. F., & White, M. (2002). Multimedia augmented reality interface for e-learning (MARIE). *World Transactions on Engineering and Technology Education, 1*(2), 173–176.

Lin, T. J., Duh, H. B. L., Li, N., Wang, H. Y., & Tsai, C. C. (2013). An investigation of learners' collaborative knowledge construction performances and behavior patterns in an augmented reality simulation system. *Computers & Education, 68*, 314–321.

Lin, T. J., Wang, H. Y., Duh, H. B. L., Tsai, C. C., & Liang, J. C. (2012, July). Behavioral patterns and learning performance of collaborative knowledge construction on an augmented reality system. In *Paper presented at 12th international conference on advanced learning technologies (ICALT), Rome, Italy*.

Lustria, M. L. A. (2007). Can interactivity make a difference? Effects of interactivity on the comprehension of and attitudes toward online health content. *Journal of the American Society for Information Science and Technology, 58*(6), 766–776.

Lytras, M. D., & Ordóñez de Pablos, P. (2011). Software technologies in knowledge society. *Journal of Universal Computer Science, 17*(9), 1219–1221.

Marco, J., Cerezo, E., & Baldassarri, S. (2010, June). Playing with toys on a tabletop active surface. In *Proceedings of the 9th international conference on interaction design and children* (pp. 296–299). ACM.

Moore, M. G. (1993). Three types of interaction. In K. Harry, M. John, & D. Keegan (Eds.), *Distance education: New perspectives. London: Routledge*.

Nicholson, D. T., Chalk, C., Funnell, W. R. J., & Daniel, S. J. (2006). Can virtual reality improve anatomy education? A randomised controlled study of a computer-generated three-dimensional anatomical ear model. *Medical Education, 40*(11), 1081–1087.

Núñez, M., Quiros, R., Núñez, I., Carda, J. B., & Camahort, E. (2008). Collaborative augmented reality for inorganic chemistry education. In *Proceedings of the 5th WSEAS/IASME international conference on engineering education* (pp. 271–277).

O'Shea, P. (2008). Developing an augmented reality game: lessons learned from gray anatomy. In K. McFerrin vd (Ed.), *Proceedings of society for information technology and teacher education international conference* (pp. 1776–1777). Chesapeake, VA: AACE.

Oh, S., & Byun, Y. C. (2012). The design and implementation of augmented reality learning systems. In *Computer and information science IEEE/ACIS 11th international conference* (pp. 651–654). http://dx.doi.org/10.1109/ICIS.2012.106.

Oh, S., & Woo, W. (2008). ARGarden: augmented edutainment system with a learning companion. *Transactions on Edutainment I Lecture Notes in Computer Science, 5080*, 40–50.

O'Brien, H. L., & Toms, E. G. (2005, November). In *Engagement as process in computer mediated environments. Paper presented at ASISveT, Charlotte, North Carolina*.

Plowman, L., & Stephen, C. (2005). Children, play, and computers in pre-school education. *British Journal of Educational Technology, 36*(2), 145–157.

Sabry, K., & Baldwin, L. (2003). Web–based learning interaction and learning styles. *British Journal of Educational Technology, 34*(4), 443–454.

Schmalstieg, D., Fuhrmann, A., Hesina, G., Szalavári, Z., Encarnação, L. M., Gervautz, M., et al. (2002). The studierstube augmented reality project. *Presence: Teleoperators and Virtual Environments, 11*(1), 33–54.

Serio, Á. D., Ibáñez, M. B., & Kloos, C. D. (2013). Impact of an augmented reality system on students' motivation for a visual art course. *Computers and Education, 68*, 586–596.

Shelton, B. E., & Hedley, N. R. (2002). Using augmented reality for teaching earth-sun relationship to undergraduate geography students. In *The first IEEE international augmented reality toolkit workshop* (pp. 1–8). http://dx.doi.org/10.1109/ART.2002.1106948.

Singhal, S., Bagga, S., Goyal, P., & Saxena, V. (2012). Augmented chemistry: interactive education system. *International Journal of Computer Applications, 49*(15), 1–5. http://dx.doi.org/10.5120/7700-1041.

Stapleton, C., Hughes, C., & Moshell, J. (2002). Mixed reality and the interactive imagination. In *Proceedings of the First Swedish–American workshop on modeling and simulation*.

Sumadio, D. D., & Rambli, D. R. A. (2010). Preliminary evaluation on user acceptance of the augmented reality use for education. In *Proceedings of second international conference on computer engineering and applications* (pp. 461–465). http://dx.doi.org/10.1109/ICCEA.2010.239.

Teo, T. (2009). Modelling technology acceptance in education: a study of pre-service teachers. *Computers & Education, 52*(1), 302–312.

Thomas, R. G., John, N. W., & Delieu, J. M. (2010). Augmented reality for anatomical education. *Journal of Visual Communication in Medicine, 33*(1), 6–15.

Venkatesh, V., Morris, M., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: toward a unified view. *MIS Quarterly, 27*(3), 425–478.

Wang, X., Kim, M. J., Love, P. E. D., & Kang, S. C. (2013). Augmented reality in built environment: classification and implications for future research. *Automation in Construction, 32*, 1–13.

Wojciechowski, R., & Cellary, W. (2013). Evaluation of learners' attitude toward learning in ARIES augmented reality environments. *Computers and Education, 68*, 570–585.

Wood, E., & Bennett, N. (1997). The rhetoric and reality of play. *Early Years, 17*, 22–27.

Wu, H. K., Lee, S. W. Y., Chang, H. Y., & Liang, J. C. (2013). Current status, opportunities and challenges of augmented reality in education. *Computers and Education, 62*, 41–49.

Yelland, N. (1999). Technology as play. *Early Childhood Education Journal, 26*(4), 217–220.

Yilmaz, R. M., Baydas, O., Karakus, T., & Goktas, Y. (2015). An examination of interactions in a three-dimensional virtual world. *Computers & Education, 88*, 256–267.

Yoon, S. A., Elinich, K., Wang, J., Steinmeier, C., & Tucker, S. (2012). Using augmented reality and knowledge-building scaffolds to improve learning in a science museum. *International Journal of Computer-Supported Collaborative Learning, 7*(4), 519–541.

Yuen, S., Yaoyuneyong, G., & Johnson, E. (2011). Augmented reality: an overview and five directions for AR in education. *Journal of Educational Technology Development and Exchange, 4*(1), 119–140.

Zhang, X., Ordóñez de Pablos, P., & Zhu, H. (2012). The impact of second life on team learning outcomes from the perspective of IT capabilities. *International Journal of Engineering Education, 28*, 1388–1392.

Zhou, Z., Cheok, A. D., & Pan, J. (2004). 3D story cube: an interactive tangible user interface for storytelling with 3D graphics and audio. *Personal Ubiquitous Computing, 8*, 374–376. http://dx.doi.org/10.1007/s00779-004-0300-0.

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