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CHILD-COMPUTER INTERACTION DESIGN AND ITS EFFECTIVENESS

LAI-CHUNG LEE†

Graduate Institute of Interactive Media Design, National Taipei University of Technology, 1, Chung-Hsiao East Road, Section 3
Taipei, 10604, Taiwan
f10666@ntut.edu.tw

WHEI-JANE WEI

Department of Early Childhood Education, Taipei Municipal University of Education, 1, Ai-Kuo West Road,
Taipei, 10048, Taiwan
tmuewwj1@gmail.com

The paper develops Child-Computer Interaction (CCI) for 86 children including 42 boys and 44 girls aged 4-6 out of four kindergartens in Taipei City, Taiwan. CCI*e* is an implication of embodied interaction with Kinect. CCI*t* is tactile interaction with iPad. CCI*m* is a multimodal interaction, an innovative integration of iPad and Kinect. The effectiveness of the CCI is evaluated by problem-solving test and the differences of the CCI are also compared by ANOVA and posteriori comparison. Findings indicate that the CCI enhances problem-solving. Pairing comparisons of the CCI are significantly correlated.

Keywords: Child-computer interaction; embodied interaction; tactile interaction; multimodal interaction.

1. Introduction

Human-Computer Interaction community is keen to apply interactive technology in learning environment for young children. The new interaction techniques are thus needed to be developed in order to evaluate the effectiveness of the HCI pedagogy in the early childhood education (Tse et al., 2011). Child-Computer Interaction (CCI) can become an adaptive smart application based on learner-centric approach in which children take initiative in exploration with learning stimulus including people, events and materials.

To avoid from distraction, CCI can better make children concentrate on interests rather than interaction with people (Black et al., 2009). The underlying theories include learning style (Leite et al., 2009), multiple intelligent theory (Gardner, 1983), and learning pyramid in terms of % of average retention rate (Bruner, 1960; Clark & Starr, 1986). For instance, multimedia includes animation, digital photography, and videos that enhance children learning motivation and interests.

Apple iPad has been utilized in the education activities in preschools since 2011 (Hourcade et al., 2012; Manches & Price, 2011). The use of Kinect has been implemented in preschools since 2011 (Follmer et al., 2012). We have been initializing the use of iPads or Kinect in Taiwan's preschools since 2010 (Lee & Wei, 2011). Traditionally, preschool teachers spend too much time preparing learning materials, leading to teachers feeling exhausted. Such tangible materials require storage. In contrast, interactive technology is more sustainable, flexible, and attractive. In addition to the hardware and software, it is essential to develop digital content that is intuitive, simple, easy to use, open-ended and feasible for all themes. In terms of modularization, interactive devices make preschool learning materials easier for changes. Interactive whiteboards are more popular in primary schools rather than applying in preschools. This is a limitation for preschoolers. An introduction of iPad and Kinect could be possible solutions. Kinect is easy to use and instantly fun due to the use of one's entire body movement. Through motion sensing, Kinect enables children to use their gestures rather than a mouse or controller to interact with the content on the screen. Kinect makes children's learning experiences become extraordinary and immersive.

There are two main purposes of this study: the first is the design of the CCI, and second is the effectiveness of the CCI. Six research questions are addressed as follows.

1. How does the interface design be developed for embodied interaction (CCI*e*)?
2. How does the interface design be developed for tactile interact (CCI*t*)?
3. How does the interface design be developed for multimodal interaction (CCIm)?
4. Does children's post-test mean score of problem-solving test is higher than the one of pre-test?
5. Is there any difference of the problem-solving skills as a result of the CCI?
6. Are three pair comparisons of the CCI significantly correlated to one another?

2. The Development and the Design of CCI

CCI focuses on Play, Learning and Communicating in terms of PLC (Read & Bekker, 2011). How CCI is suitable for play and education is an important issue for designers. Enabling technologies are available for learning through play. For instance, tactile interaction like iPad was launched in April 2010 in HCI community (Guernsey et al., 2012). In 2005, 6-month to 6-year-old children spent 1 hour and 36 minutes in reading with screen media. In 2011, they spent 2 hours and 8 minutes on tablets and computers (Guernsey et al., 2012). Embodied interaction such as Kinect was announced in November, 2010 (Yu et al., 2011; Hsu, 2011; Lohr, 2011). The input and output of multimodal interaction are occurred simultaneously that children communicate with computers more efficiently and more engagingly (El Ali et al., 2012).

There are six principles in developing the CCI in terms of embodied interaction device, tactile interaction device, and multimodal interaction device. These principles are: 1) poping up a feature upon a fingertip into a display, 2) matching user's expectation, 3) making reaction visible, 4) designing for errors, 5) being consistent to generate interaction, and 6) being open-ended solutions corresponding to scaffolding inquiry

(Malaka & Porzel, 2009; van de Pol et al., 2010). Based on these principles, we developed the CCI in terms of embodied interaction, tactile interaction, and multimodal interaction. These principles were applied in the process of this study.

Besides, the authors considered how to make the level of technology appropriate for the child to easily manipulate. The authors also reflected that technology should be designed for the child's needs and abilities, and can be used in the learning environment given vacant space and limited resources (Mulligan, 2003). According to these design principles, this study invited children to participate in the design process by inquiry techniques with open-ended questions. The researchers implemented a workshop to prepare the kindergarten teachers for applying inquiry techniques and discussing strategies with children. The teachers put what they learned at the workshop into practice of "scaffolding inquiry, thinking by brainstorming, doing by playing, evaluation by sharing". Children replied their ideas and meanwhile the teachers recorded children's thoughts. These records were analyzed to determine the frequently used ideas for problem-solving. Accordingly, the researchers developed the detailed script of scenarios based on the most frequently used possible solutions for problem-solving. And meanwhile, the visual elements of the interface design were also created by the scenarios.

Furthermore, technology plays an assisted role instead of full substitution of physical learning materials. The underlying theory is Piaget's cognitive development of which 2 to 7 year old children are in the preoperational stage (Piaget, 1950). According to Piaget's theory, young children in preoperational stage can't mentally manipulate information, and thus it is in need of tangible materials for learning. For example, the authors designed various information feedbacks when the child touches the panel of iPad and making gestures in front of Kinect.

Kinect and iPad have been attracted to academic researchers and industrial R&D engineers since 2010. Embodied interactive technology, Kinect, can get young children involved in the immersive learning. Tactile interactive technology like iPad has been popularly integrated in educational App through App store. For example, 'Little Digits' is a fantastic App for preschoolers to learn the basics of counting, adding, and subtracting. By such a feature as iPad multi-touch screen, Little Digits displays number characters by detecting how many fingers the child put down (Cowly Owl, 2012).

In sum, the authors proposed a conceptual research framework based on the literature review on the development of CCI. The following sections present how authors integrate interactive devices, interactive technologies, and interactive modes into the CCI in terms of embodied, tactile, and multimodal interactions.

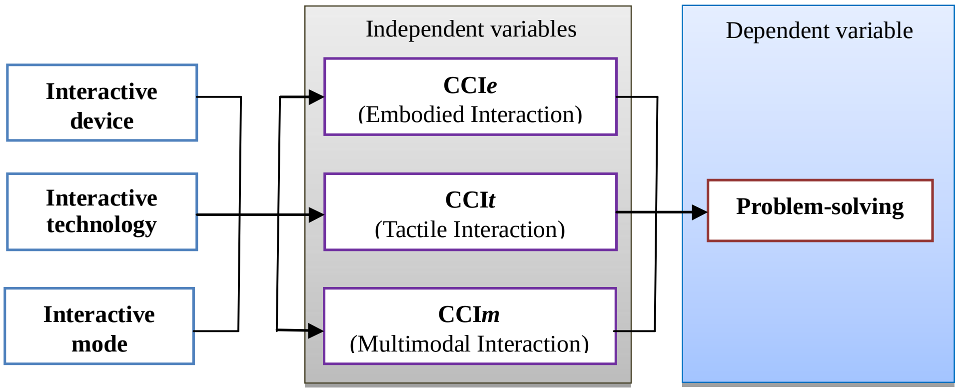

Figure 1. The conceptual research framework.

Figure 1 illustrates the conceptual research framework of this study. The authors apply interactive devices, interactive technology, and interactive modes to develop the CCI. Interactive devices include laptop, camera, projector, iPad, Kinect, and Kinect-iPad integration. Interactive technology embraces tactile technology, wall projection, body skeleton detection, motion sensing technology, and Kinect-iPad integration technology. Interactive modes consist of click, draw, and gesture. Independent variables are the CCI. CCI*e* is entitled embodied interaction. CCI*t* is entitled tactile interaction. CCI*m* is entitled multimodal interaction. Dependent variable is problem-solving ability.

The underlying theories of the CCI are the multiple intelligence theory, learning style, and Problem-Based Learning (PBL) (Gardner, 1983; Leite et al., 2009; Hmelo-Silver, 2004).Therefore, three games of all CCI are especially suited for children who are bodily-kinesthetic intelligence with the strengths of kinesthetic learning. Kinesthetic learning that is also known as tactile learning is one of the three learning styles in terms of visual learners, auditory learners, and kinesthetic learners or tactile learners based on Neil Fleming's VAK/VARK model (Hess & Jung, 2012; Hsu, 2011). According to the goals of PBL, the CCI is to help children to develop effective problem-solving skills and self-directed learning (Treffinger et al., 2000).

The CCI includes CCI*e*, CCI*t* and CCI*m*. To prevent from memory effects, they were designed for solving three different problems. For instance, CCI*e* was designed by embodied interaction. The problem was how to build up a stable wall by Kinect so that the house won't be destroyed by a wolf. CCI*t* was a tactile interactive game by which children drew a solution to avoid from being got wet. CCI*m* was to stress cooperative learning by a multimodal interaction that group one children used an iPad to draw solutions for group two children to gesture those patterns for problem-solving.

Accordingly, the effectiveness of CCI in regard to problem-solving skills is the main focus of the results. The underlying theory is problem-based learning by which the learning effectiveness of the CCI represents children's problem-solving skills.

Figure 2. CCI*e* -- Embodied Interaction.

2.1. *Interface design for embodied interaction*

Hsu (2011) mentioned about the implications of Kinect that a user can make sounds and movements on the screen synchronized by his/her gestures and its movement detected by Kinect (Hsu, 2011). Figure 2 shows that children played in front of a screen to move a virtual object to the right position. The story related to the proverb of Wolf and Three Pigs. Children's task was to build up a wall to prevent the invasion of the wolf. There were five materials on the screen such as brick, paper cartoon, wood, plastic bottle, and stack. Each material comprised different texture and weight. Therefore, children should make a decision to choose a material and move it to the right position. The computer programming allowed children to stick to a chosen material for about one second, then smoothly moves and stack it onto the baseline on the screen. The children tended to use the different materials to construct the wall, by piling up one on top of another. While stacking up the materials, they realized that different texture and weight to make it rigid and solid. The time limit for playing one game is 100 seconds per round.

Figure 2 is an implication of Kinect. An open-ended question was shown in the figure of the left-hand side entitled "Three Little Pigs". The question is to ask children to build a stable wall to prevent from being destroyed by a big wolf. For building the wall, five materials are given in the middle figure. They are brick, wood, plastic, cardboard box, and the straw. There are two criteria to succeed in this embodied interactive game. The first is to stack up the wall by using the brick in the bottom line, the second is to reach the red line shown in the right-hand side figure.

This paper explores the potential of Kinect as interactive technology and discusses how it can facilitate and enhance teaching and learning. Kinect is examined in terms of its affordances of technical interactivity, which is an important aspect of pedagogical interactivity. As it utilizes gesture-based technology, Kinect can support kinesthetic pedagogical practices to benefit the learners with strong bodily-kinesthetic intelligence.

2.2. *Interface design for tactile interact*

Tactile interaction regards to the sensation of pressure rather than temperature or pain (Challis, 2012). For most of young children, drawing on iPad is an exciting experience. CCI*t* was designed to empower children drawing on touchscreen. The story narrated

Figure 3. CCI*t* -- Tactile Interaction.

about “the Adventure of Henry in Forest”. The first scene demonstrated that Henry encountered a heavy rain but he had nothing to prevent from being got wet. He needed to think about how to solve the problem. Seated children drew a picture by which Henry can prevent himself from being wet. Children might draw an umbrella, a big leaf even a tree. The second scene illustrated that Henry was going to cross over one quickly flowing river without a bridge available. Children started brainstorming for creative problem-solving. Figure 3 showed a cooperative learning for problem-solving in which two children discussed the possible cause for the problem and what solutions were available. They drew the solution and projected on screen via PC transmission. With the right solution, such as a bridge, Henry successfully crossed over the river to right side. The interactive game is based on PBL approach. The authors put it into practice as Figure 3.

Left-hand side figure presents how a child drew a bridge on the iPad based on his/her solution to the problem given on the screen. The teacher asked the child about what his/her solution was. If the answer was right, the teacher would press “confirm” key. Upon pressing the “confirm” key, the bridge would appear on the screen and meanwhile Henry crossed over the river.

2.3. *Interface design for multimodal interaction*

Multimodal interaction design includes: use more of users’ senses; users perceive various things at once; and users do multiple things simultaneously (El Ali, 2011). For instance, we employ hand writing, body position, hand gesture by using iPad as shown in Figure 4 and Kinect at the same time as shown in Figure 5.

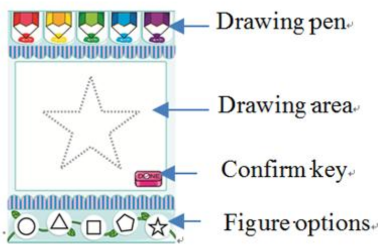

Figure 4. iPad interface design.

Figure 5. CCI*m* -- Scaffolding teaching and discovery learning with Kinect and iPad.

Figure 4 illustrates an interface design for an iPad App. The design principle of this interface is simple and easy for use. For example, figure options show various figures located at the bottom of iPad screen. Pens that draw different color are available for children to choose from the top of iPad screen. During the cooperative learning, two children discussed and figured out what the problem occurred in the hot-air balloon. They clicked on the right figure with the right color and drew out in the drawing area. Upon pressing the confirm key, the colorful figures would appeared on the screen. The authors integrated Kinect and iPad into CCI*m* in terms of multimodal interaction shown in Figure 5.

Figure 5 illustrates how the cooperative learning goes through the process. In practice, children were grouped in two. In group one, two children used iPad to draw the right solutions to the problem by brainstorming. In group two, another two children in front of Kinect cooperatively move the given solutions to solve the problem. Children cooperate to solve problems uniquely toward problem-solving (Al-Mousawi & Alsumait, 2012).

As shown in Figure 6, two children on the left-hand side figured out what the problem was on the screen showing a falling hot-air balloon. They discussed the causes to the problem and tried to use iPad to figure out the solution. While completing, the solutions were popping up by Wi-Fi on the screen. On the right-hand side of Figure 6, another group children in front of Kinect gestured their hands to move any right figures to the balloon. For instance, children used their hands detected by the Kinect to grasp the yellow square received from the iPad. Then they move the figures to the right locations on the balloon. However, the game won't be terminated until all of broken holes were patched.

Figure 6. CCI*m* Interface design and cooperative learning.

3. Method

The purpose of this paper was to develop the CCI in terms of tactile interaction, embodied interaction, and multimodal interaction for kindergarten children. Also, the effectiveness of the CCI was evaluated. To achieve these objectives, we conducted a study with 86 children of mixed-age 4-6 at three kindergartens. Procedures of this study were listed below.

(1). Researchers developed the CCI and evaluation instruments of learning sheets and problem-solving test.
(2). We installed interactive devices by following up standard operational procedures (SOP) and set up two video cameras for videotaping throughout the experiment.
(3). For technical trial, we asked two children to play with the interactive games.
(4). We adjusted all hardware equipments and software debugs.
(5). Before the study, we offer workshops to prepare kindergarten teachers for writing nine lesson plans with concentration on scaffolding inquiry and discovery learning.
(6). During the study, we put the CCI into practice with nine lesson plans for nine weeks.
(7). After the study, we asked children to fill out a learning worksheet.

4. Results

The authors have developed the CCI*e*, CCI*t* and CCI*m* described in section 2. In this section, we discuss the effectiveness of the CCI by problem-solving test with ANOVA analysis and posteriori comparison.

4.1. *Effectiveness evaluation by problem-solving test*

The researchers revised the Problem-Solving Test (PST) with three scenarios to assess children's social problem-solving skills by asking a child how you will solve the problem in the given situation (Rubin, 1983; Yang, 2006). For example, one scenario describes a situation of which two children playing in the slide. The given problem is one child blocks another one playing in the slide. PST was coded and measured by prosocial (scored as 6), authority intervention (5), manipulate affect (4), trade/bribe (3), agonistic (2), and abandon (1). After data collection and analysis, the results were summarized in Table 1 and Table 2.

Table 1 indicates pre-test and post-test mean scores of problem-solving test for young children. Pre-test mean score of problem-solving test is 4.8312. After experiment, post-test mean score of problem-solving test is 4.8501.

Table 1. Descriptive analysis on problem-solving test.

	Mean	N	Std. Deviation	Std. Error Mean
Pre-test	4.8312	86	.81374	.08775
Post-test	4.8501	86	.79466	.08569

Table 2. T-test between pre-test and post-test scores of problem-solving test.

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Upper	95% Confidence Interval of the Difference Lower			
Pre-test – Post-test	-.01895	.80713	.08704	-.19200	.15410	-.218	85	.828

Table 2 shows that there is no difference between pre-test and post-test scores of problem-solving test. Subjects of this study are composed of two schools located at Taipei city suburb and one school is in the Taipei city center. Teachers of suburb kindergarten are more conservative that children follow teachers' direction most of the time. In the contrary, researcher suggested that teachers encourage children to learn independently rather than follow up teacher's instruction (Oster, 2005).

Table 3. Descriptive analysis summary.

Name of kindergartens	N	Mean	Std. Deviation
1. Hwai-Sheng	28	5.30	.61
2. Tan-Mei	29	4.43	.75
3. Cheng-Yang	29	4.84	.79
Total	86	4.85	.80

Table 3 illustrates descriptive analysis summary of problem-solving in three kindergartens. The highest mean of problem-solving is 5.30 from Public Hwai-Sheng Elementary School Supplementary Kindergarten located in the Center of Taipei City. The lowest score is 4.43 from Public Tan-Mei Elementary School Supplementary Kindergarten located in the suburb of Taipei City.

Table 4 shows that the problem-solving scores of three kindergartens reach extremely significant differences at p=.000. The CCI can effectively enhance children's problem-solving. The finding indicates that interactive technology enhances student's problem-solving (Leavitt, 2011; NAEYC, 2012). The finding is also supported by the related

Table 4. ANOVA of CCI effectiveness evaluation on problem-solving.

	SS	*df*	*MS*	*F*	*Sig.*
Between Groups	10.626	2	5.313	10.243^{***}	.000
Within Groups	43.050	83	.519		
Total	53.676	85			

$^{***}p < .001$

Table 5. Multiple comparisons on problem-solving between groups.

	(I) VAR00001	(J) VAR00001	Mean Difference (I-J)	Std. Error Difference	Sig. (2-tailed)	95% Confidence Interval of the Difference Lower	Upper
Tukey HSD	1. Hwai-Sheng	2. Tan-Mei	.86356*	.19081	.000	.4082	1.3189
		3. Cheng-Yang	.45046	.19081	.053	-.0049	.9058
	2. Tan-Mei	1. Hwai-Sheng	-.86356*	.19081	.000	-1.3189	-.4082
		3. Cheng-Yang	-.41310	.18913	.080	-.8645	.0383
	3. Cheng-Yang	1. Hwai-Sheng	-.45046	.19081	.053	-.9058	.0049
		2. Tan-Mei	.41310	.18913	.080	-.0383	.8645

studies that young children possess better problem-solving (Marco et al., 2009). Multiple comparisons and posteriori comparison are followed. The results are shown in Table 5 and Table 6.

Table 5 presents multiple comparison results between three kindergartens. Two pairs of kindergarten children reach significant differences in problem-solving performance. One of them is shown between Hwai-Sheng kindergarten and Tan-Mei kindergarten. Another comparison is found between Hwai-Sheng kindergarten and Cheng-Yang kindergarten. Hwai-Sheng kindergarten is located in the center of Taipei City. In Hwai-Sheng kindergarten teachers encourage children the independent exploration in their learning centers such as the drawing center. The finding is same as the one from the related study that drawing facilitated problem-solving (Lambert, 2006). Therefore, Hwai-Sheng kindergarten children perform the highest score than the others. For discussion of non-significance, a posteriori comparison by Tukey HSD is conducted in Table 6.

Table 6 shows that there are two clusters of homogeneity. One cluster of homogeneity is between Tan-Mei and Cheng-Yang, and another one is between Cheng-Yang and Hwai-Sheng. It is too homogeneous to reach significant difference between Tan-Mei and Cheng-Yang shown in Table 5.

Table 6. The posteriori comparison on problem-solving by Tukey HSD.

	Name of kindergartens	N	alpha = 0.05 clusters 1	2
Tukey HSD	2. Tan-Mei	29	4.4297	
	3. Cheng-Yang	29	4.8428	4.8428
	1. Hwai-Sheng	28		5.2932
	Significance		.082	.052

Table 7. ANOVA on the learning effectiveness of CCI.

Source of variation	*SS*	*df*	*MS*	*F*
Between	8010.023	2		8.737***
Within				
Within-Subjects	65353.167	85		
Error (CCI)	77928.397	170	458.402	
Total	151291.587	257		

4.2. *Effectiveness evaluation between the CCI*

The authors developed worksheets with concentration on problem solving based on each lesson plan. The content of worksheets was based on the problems of the CCI. The purpose of the worksheet was designed to evaluate the learning effectiveness of CCI. After data collection and analysis, the results were summarized in Table 7 and Table 8.

Table 7 illustrates children's worksheet scores that are significantly different between the CCI. Questions of the worksheets are reflected to the problems designed in the CCI. Children's worksheet scores represent the learning effectiveness through the CCI. Table 7 also claims that interactive technology does enhance learning for young children (Char, 1990).

4.3. *Evaluation of multiple comparisons of the CCI*

The authors designed CCI*e* by Kinect, CCI*t* by iPad, and CCI*m* by an integration of CCI*e* and CCI*t*. The authors attempted to identify the relationship between the CCI. A correlation analysis is conducted as follows.

Table 8 indicates that the three pair comparisons of the CCI are significantly correlated with one another. Elgan (2011) reported that children can learn how to solve problems by playing the App of puzzles and games using iPad. Teachers and parents may arrange suitable contents of iPad in advance. Children can discover through play and satisfy their curiosity. Lee et al. (2012) proved that by playing an interactive and educational math game using Kinect, children in elementary school can improve their

Table 8. Multiple comparisons of the CCI.

	CCI*e* (Three little pigs)	CCI*t* (Adventure of Henry)	CCI*m* (Hot-air balloon)
CCI*e*	—	.024*	.000***
CCI*t*	—	—	.025*
CCI*m*	—	—	—

**p*<.05, ****p*<.001

Table 9. The advantages and disadvantages of the Kinect and the iPad.

Interactive technology	Advantages	Disadvantages
Kinect	• It helps children to practice and develop gross motor processing skills. • It makes children to pay more attention to its moving. • It promotes children to connect mind-body coordination.	• It takes time to do technical trial for hardware installation and software calibration. • It constraints a certain number of children to play together concurrently. • Instructions may be necessary throughout children's play.
iPad	• It helps children to practice and develop fine motor skills and hand-eye coordination. • The function of intuitive tactile enhances learning interests and motivation. • It makes learning easier such as acquiring knowledge of galaxy and planets movement due to the booming of App Store.	• It is difficult to identify how children think during playing. • It requires the infrastructure of wireless transmission in the classroom. • It is lack of mechanism for teacher to monitor and control the number of iPads used by children in classroom.

problem-solving skills. In sum, interactive technology results real benefits in early childhood education. According to the findings of this study, the advantages and disadvantages for both Kinect and iPad are summarized in Table 9.

Table 9 describes that iPad and Kinect possess their advantages and disadvantages. From the positive point of view, Kinect engages children to move their bodies to test their ideas and get feedback. App store frequently provides various problem-solving games for iPad. Teachers and parents will put the games into practice for children to learn by iPad and/or Kinect. From the negative point of view, technical trial takes time to ensure the right distance and position for Kinect games. Teachers and parents need to ensure if children involve in learning instead of surfing the internet. Although Kinect and iPad have their disadvantages, we integrate them in terms of multimodal interaction for optimization of advantages.

5. Conclusion and Future Work

Interactive technology has been widely applied in the educational activities from grade 1 to grade 10. However, it is rarely implemented in early childhood education. In this research, we prepared kindergarten teachers to put scaffolding inquiry and brainstorming into practice, according to participatory design, the researchers planned, designed and developed digital contents based on children's feedback ideas.

For integration of hardware and software, we conducted technical trial and usability testing with a couple of children. We accomplish the design of tactile interaction, embodied interaction, and multimodal interaction for young children. Open-ended questions were designed in this study based on approaches both problem-solving and the problem-based learning. Accordingly, children become creative problem solvers throughout the process of playing the designed interactive games. The CCI is significant in enhancing children's problem-solving skills. Posteriori comparisons show that three pairing comparisons are significantly correlated one another as well. This study presents a practical framework to develop more interactive media tools and interactive games. The research outcome presented in this paper backs up the existing theoretical idea in the literature with experimental evidence (NAEYC, 2012). The study therefore offers a validated example of the evidence-based practice for the effective and appropriate uses of interactive technology.

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References

Al-Mousawi, Z., & Alsumait, A. (2012). A digital storytelling tool for Arab children. iiWAS '12: In *Proceedings of the 14th International Conference on Information Integration and Web-based Applications & Services* (pp. 26–35). Bali, Indonesia.

Black, M., Chang, J., Chang, J., & Narayanan, S.(2009). Comparison of child-human and child-computer interactions based on manual annotations. In *Proceedings of the Workshop on Child, Computer and Interaction*. Cambridge, USA.

Bruner, J. S. (1960) *The process of education*. Cambridge: Harvard University Press.

Challis, B. (2012). *Tactile interaction*. Retrieved February 14, 2013, from http://www.interaction-design.org/encyclopedia/tactile_interaction.html

Char, C. A. (1990). *Interactive technology and the young child*. Newton, MA: Center for Learning, Teaching, and Technology, Education Development Center.

Clark, L., & Starr, I. (1986) *Secondary and middle school teaching methods*. London, UK: Macmillan Publishers.

Cowly Owl Ltd. (2012). *Little Digits*. Retrieved February 14, 2013, from https://itunes.apple.com/app/little-digits/id511606843?&mt=8

El Ali, A. (2011). *Multimodal interaction: An introduction*. Retrieved February 14, 2013, from http://staff.science.uva.nl/~elali/

El Ali, A., Kildal, J., & Lantz, V. (2012). Fishing or a Z?: Investigating the effects of error on mimetic and alphabet device-based gesture interaction. In *Proceedings of the 14th international conference on Multimodal Interaction (ICMI '12)* (pp. 93–100). Santa Monica, USA.

Elgan, M. (2011). *Why every child in America needs an iPad*. Retrieved February 15, 2013, from http://www.cultofmac.com/93887/why-every-child-in-america-needs-an-ipad/

Follmer, S., Ballagas, R., Raffle, H., Spasojevic, M., & Ishii, H. (2012). People in books: Using a flashcam to become part of an interactive book for connected reading. In S. Poltrock et al. (Eds.), *Proc. of CSCW'12* (pp. 685–694). Seattle, USA.

Gardner, H. (1983). *Frames of mind: The theory of multiple intelligences*. New York: Basic Book Inc.

Guernsey, L., Levine, M., Chiong, C., & Severns, M. (2012). Pioneering literacy in the digital wild West: Empowering parents and educators. In *Proceedings of The Joan Ganz Cooney Center at Sesame Workshop*. New York, NY: New America Foundation.

Hess, S., & Jung, J. (2012). Does the iPad add value to business environments? *In Proceedings of the CHI'12* (pp. 335–350). Austin, USA.

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review, 16*(3), 235–266.

Hourcade, J. P., Bullock-Rest N. E., & Hansen, E. H. (2012). Multitouch tablet applications and activities to enhance the social skills of children with autism spectrum disorders. *Personal and Ubiquitous Computing*, *16*(2), 157–168.

Hsu, H. M. (2011). The potential of kinect in education. *International Journal of Information and Education Technology*, *1*(5), 365–370.

Lambert, E. B. (2006). Can drawing facilitate problem solving? An exploratory study. *Australian Journal of Early Childhood, 31*(2), 42–47.

Leavitt, S. (2011). *Interactive problem solving: Incorporating interactive whiteboard technology with problem solving in the math classroom*. Un-published dissertation, Omaha, NE, USA.

Lee, E., Liu, X., & Zhang, X. (2012). *Xdigit: An arithmetic kinect game to enhance math learning experiences*. Retrieved February 14, 2013, from http://www.elwinlee.com/portfolio/game/xdigit/

Lee, L. C., & Wei, W. J. (2011). Impacts on attention with computer-supported learning devices. In W. Shen et al. (Eds.), *Proceedings of CSCD'11* (pp. 722–726). Lausanne, Switzerland.

Leite, W. L., Svinicki, M., & Shi, Y. (2009). Attempted validation of the scores of the VARK: Learning styles inventory with Multitrait-Multimethod Confirmatory Factor Analysis Models. *Educational and Psychological Measurement, 70*(2), 323–339.

Lohr, M. (2011). e-Learning using iPads: An e-learning scenario using mobile devices and sensors for measurements. In *Proceedings of 2011 11th IEEE International Conference on Advanced Learning Technologies* (pp. 237–238). Athens, USA.

Malaka, R., & Porzel, R. (2009). Design principles for embodied interaction: The case of ubiquitous computing. In M. Bärbel et al. (Eds.), *Proceedings of KI'09* (pp. 711–718). LNAI 5803, Springer.

Manches, A., & Price, S. (2011). Designing learning representations around physical manipulation: Hands and objects. In T. Moher et al. (Eds.), *Proc. of IDC'11* (pp. 81–89). Ann Arbor, USA.

Marco, J., Cerezo, E., Baldassarri, S., Mazzone, E., & Read, J. C. (2009). Bringing tabletop technologies to kindergarten children. In A. Blackwell et al. (Eds.), *Proceedings of BCS HCI'09* (pp. 103–111). Cambridge, UK.

Mulligan, S. A. (2003). Assistive technology: Supporting the participation of children with disabilities. *Young Children on the Web,* 1-2.

NAEYC. (2012). *Technology and interactive media as tools in early childhood programs serving children from birth through age 8*. Washington, DC: National Association for the Education of Young Children.

Oster, A. (2005). The effect of introducing computers on children's problem-solving skills in science. *British Journal of Educational Technology, 36*(5), 907–909.

Piaget, J. (1950). *The psychology of intelligence*. London: Routledge and Kegan Paul.

Read, J. C., & Bekker, M. M. (2011). The nature of child computer interaction. In *Proceedings of the 25th BCS Conference on Human-Computer Interaction (BCS-HCI '11)* (pp. 163–170). Swinton, UK.

Rubin, K. H. (1988). *Social problem solving test*. Unpublished manuscript, University of Waterloo, Department of Psychology, Ontario, Canada.

Tse, E., Schöning, J., Huber, J., Marentette, L., Beckwith, R., Rogers, Y., & Mühlhäuser, M.(2011). Child computer interaction: Workshop on UI technologies and educational pedagogy. In *Proceedings of CHI Workshop*. Vancouver, BC, Canada.

Treffinger, D. J., Isaksen, S. G., & Dorval, K. B. (2000). *Creative problem solving: An introduction* (3rd ed.). Waco, TX: Prufrock Press.

van de Pol, J., Volman, M., & Beishuizen, J. (2010). Scaffolding in teacher–student interaction: A decade of research. *Education Psychological Review, 22*, 271–296.

Yang, Y. H. (2006). *The impact of parenting on the children's problem solving ability*. Unpublished dissertation, Taipei Municipal University of Education, Taipei, Taiwan.

Yu, X., Wu, L., Liu, Q., & Zhou, H. (2011). Children tantrum behaviour analysis based on kinect sensor. In *Proceedings of Intelligent Visual Surveillance (IVS 2011)* (pp. 49–52). Lanzhou, China.