ISSN 2078-4775

IJDMD

International Journal of Digital Media Design/ Volume 9/ Number 1/ June 2017

理事長序

科技與數位媒體,並結合藝術發展,開創了各領域創新思考與數位媒體設計之整合。數位媒體設計學會致力於台灣數位媒體學術專業領域之研究與交流，以產業、技術、人才之培育作為宗旨。創新思維與設計，已經跳脫出傳統媒體，運用數位科技、將傳統媒介經由設計的脈絡，建構出豐富的面向與深度。美學、設計、情感、科技等不同領域領結合文化創意產業、透過視覺傳播方法達到文化行銷與傳播，亦提供國內產、官、學、研界科技發展相關趨勢與未來展望。

自 2009 年 IJDMD 國際數位媒體設計學刊發刊以來，已進入第九年，本期為今年發行之第九卷第一期期刊，共收錄一篇英文研究論文、兩篇中文論文。探討內容包括有(1)英文論文「An Exploration of Origami Integrated Teaching with Virtual and Physical Manipulatives 」運用摺紙融合數位教具，透過物理折紙的平行應用，空間、幾何和線對稱的學習，幫助學生掌握一刀剪折紙的概念和操作，同時深化學習。；(2)中文論文「探討幼兒使用擴增實境學習形狀及顏色之科技接受模式及學習成效」利用「CoShaper」擴增實境學習應用程式搭配立體圖像及彩色的圖卡，以幼兒學習的顏色、形狀圖卡作為學習教材，讓學習變得更有趣，也有助於提升學習的動機。；(3)中文論文「互動式電子白板融入國小特教班功能性數學課程教學之行動研究」了解教師實施互動式電子白板搭配虛擬教具融入國小數學課程領域教學，根據研究結果顯示互動式白板有助於提昇學生的學習成效、學習態度，並有助於改善教師實際教學困境，增進多元的教學方法及教材設計的能力。；

本期來稿 8 篇，經專家匿名審查後，3 篇論文接受刊登。感謝各方學術先進賜稿，擴展本刊研究範疇，以及協助審查的委員們給予學術專業協助，深化本刊學術深度及內容專業。

理事長 徐道義

Preface by the Editor-in-chief

The gathering of technology, digital media and the development of art inspires new thoughts and digital media design integration in various fields. TADMD contributes base values for industry skills and talent development based on the goal of moving forward the research and interaction of Taiwan's professional digital media academics, aiming at the development of industry, technology and talents. It is important to understand the meaning of the design and interpreting traditional mediated environment with digital tools. In order to become more diverse and more depth. According to current research from the points of views of aesthetics, design, sentiment and technology, combine cultural with creative industries through visual communication to achieve culture marketing and communication, and also provide the latest technology development and future perspectives for Taiwan's industries, government, academy and researchers.

Since 2009, the first published of International Journal of Digital Media Design (IJDMD), has been 9 years. This Issue is the volume 9th, issue 1st of this year, and including 1 English and 2 Mandarin papers. This issue including: (1) English paper of "An Exploration of Origami Integrated Teaching with Virtual and Physical Manipulatives". This study designs a set of integrated teaching materials with physical origami manipulatives, through the parallel application of physical origami learning of spatial, geometric, and line-symmetric, helps students grasp the concept and operation of origami of one straight cut. (2) Mandarin paper of "The Study of Using Augmented Reality in Children Learning of Shape and Color to Investigate Technology Acceptance Model and Learning Effectiveness". This study uses augmented reality alongside 3D graphics and colors. Color & Shape-recognition cards for children are used as the learning material to observe. In order to achieve more effective learning, augmented reality supported learning is used as well as mobile devices to boost motivation for learning and make learning more interesting. (3) Mandarin paper of "The Action Research of Using Interactive Whiteboard on Teaching Functional Mathematic for Self-contained Special Classes in Elementary School". This study aims to understand the implementation while teachers using the interactive whiteboard and virtual teaching manipulatives in functional mathematics curriculum of self-contained special classes in the elementary school. According to the result, Applying interactive whiteboard helps to improve student learning outcome and learning attitude. Through the action research, teachers could improve plight of teaching, promote teaching methods and enhance the abilities of teaching material design.

This issue had received 8 papers, and we accept 3 papers after experts anonymous reviewed. Appreciate for all the papers that sent to us and support the journal to increase research range. Also thanks to the academy support by all the assist from the committees, allow our journal to have more academy depth and professional content.

Editor-in-Chief ***Tao-I Hsu***

An Exploration of Origami Integrated Teaching with Virtual and Physical Manipulatives

Hsi-Hsun Yang[1], Yuan-Ting Chen[2], Sheng-Kai Yin[3,*]
1 National Yunlin University of Science and Technology, Taiwan. jimmy@yuntech.edu.tw
2 National Yunlin University of Science and Technology, Taiwan. imdmao@gmail.com
3 Cheng Shiu University, Taiwan. ysk651224@gmail.com

ABSTRACT

Physical origami helps students understand the properties of graphic symmetry, rotation, and folding, improving mathematical learning, geometric reasoning, and conjecturing through mental rotation, spatial orientation and visualization. Using the digital origami simulation system, technology is integrated into learning origami, facilitating physical origami challenges related to precision, paper thickness, and crease elimination. This study constructs the Web of Origami Simulator II (WOOS II) in order to train learner spatial ability, and designs a set of integrated teaching materials with physical origami manipulatives. The technique of origami of one straight cut is used as the basis for teaching material, emphasizing the steps of folding paper, making one straight cut, and observing the shapes when unfolded.

This experiment adopts the one-group pretest-posttest design, with teaching materials integrated into virtual and digital manipulatives applied to 41 fifth-grade students in an elementary school in central Taiwan. Resulting experimental data are collected, analyzed, and discussed. Results show better performance in WOOS II and physical origami relates to better manifestation of learner spatial ability. Analysis of the learning sheet shows the line-symmetric and spatial abilities influenced the students' performances in origami of one straight cut. The digital origami simulation environment can help students grasp the concept and operation of origami of one straight cut, while deepening learning through the parallel application of physical origami. Learning of spatial, geometric, and line-symmetric concepts is also improved.

***Keywords*:** Origami, Computer Assisted Learning System, Spatial Ability, Virtual Manipulatives, Physical Manipulatives, Symmetry

1. Introduction

Moyer (1978) pointed out that inadequate spatial ability hinders pupils from understanding a numerical system. According to Homan (1970), perceptual skills were one of the factors influencing students' mathematical learning. Lack of perceptual skills, such as spatial relationship, distance, and size relationship presented obstacles to students in activities related to measurement, estimation, problem solving, and geometry. Spatial ability can affect the development of mathematical learning (Kali & Orion, 1996). Likewise, and Tso and Liang (2001) indicated spatial ability can affect geometric learning.

In addition to traditional approaches to teaching geometry, some researchers have employed origami to teach geometric skills (Cipoletti & Wilson, 2004; Chen, 2005; Hull, 2002). Tam and Chen (2009) tried using origami to overcome learner fear of ruler-and-compass construction. The National Council of Teachers of Mathematics encourages students to learn mathematical concepts through hands-on experiences (NCTM, 2000; Boakes, 2009; Cakmak, 2009). Origami is one such teaching activity. Origami trains coordination skills, such as hand-eye-brain coordination (Chan, 2007). Skills applied during the process of origami include geometric and line-symmetric concepts, as well as mental rotation. In Taiwan, origami is used in elementary mathematical courses to teach students the properties of line-symmetry and the angle bisector theorem–basic concepts for junior and senior high school geometric textbooks (Ministry of Education, 2008). The concept of symmetry derives from geometric transformation, including relative graphic positions in space, as well as congruent and symmetrical relationships (Libeskind, 2008). In Taiwan elementary schools, symmetry instruction includes graphic cutting, drawing, and characteristics of perpendicular bisector symmetric point of symmetry axis. Such knowledge is fundamental, yet some students have weak spatial ability, unable to mentally process visual graphs or understand graph symmetry. As pointed out by Tso (2003) and Liu and Liu (1994), when learning line-symmetric graphs, students were only familiar with the top/bottom and left/right symmetric graphs, finding it difficult to identify the symmetry axis of other symmetric graphs. All such knowledge can be grasped through origami.

Physical origami teaching is an intuitive method to help students in learning through visual observations and operations, along with transform of abstract geometric graphs into tangible origami (Arici & Tutak, 2015; Pope, 2002). However, during physical origami teaching, the multiple rotations and complex steps can easily confuse students. When implementing physical origami, students with inadequate finger dexterity have difficulty folding paper precisely. This can lead to failure to finish the origami (Tam and Chen, 2009).

Origami teaching can be extended into a digital environment, easing teacher burden. This approach decreases costs of learning tools (Izydorczak, 2003; Suh, Moyer & Heo, 2005). Using computer images to simulate physical manipulatives is referred to as virtual manipulation, which can provide an operating interface for teachers and students via a mouse. When virtual manipulation is integrated into teaching, it presents abstract concepts in a visually dynamic manner. Virtual manipulatives represent abstract concepts, bridging the gap between tangible objects, graphs, and symbols. This approach facilitates learner understanding (Moyer, Bolyard, & Spikell, 2002; Reimer & Moyer, 2005). In addition, the dynamic graphs within a digital environment can easily represent 3-dimensional changes. This feature helps students comprehend the origami steps and processes, while allowing adjustments as necessary (Lu & Lin, 2013). Origami digitalization improves origami precision (Yang, Yin, & Chen, 2014) and avoids errors, such as those arising from the multiple folds, common in physical origami. This approach also avoids the limitation of paper thickness, allowing the paper to be folded multiple times, and with more variation in shapes. Within a digital environment, students can practice repeatedly without using paper, reducing environmental waste (Yang & Chen, 2016). A digital environment, however, cannot present a stereoscopic origami process. The training of finger and muscle dexterity and coordination is also missing from a digital exercise.

The effects of using virtual manipulatives are directly influenced by several factors, including manipulative design, teacher experience, teaching units, and course design. Some literature reports virtual manipulatives have a better effect than traditional physical manipulation (Suh, Moyer, & Heo, 2005; Moyer, Niezgoda, & Stanley, 2005; Steen, Brooks, & Lyon, 2006; Moyer, Salkind, & Bolyard, 2008). However, contrary results have also been reported, finding no significant difference between virtual and traditional physical manipulatives (Drickey, 2000). A few researchers have pointed out that simultaneous use of both physical and digital manipulatives had better effects than the single use of either (Terry, 1995; Ball, 1988). Therefore, this domain deserves to be further explored and understood. The current study proposes adopting integrated origami teaching with virtual and physical manipulatives, probing the influence of such teaching on students and laying the foundation for future improvement.

Given the abovementioned reasons, this study design includes a set of virtual and physical manipulatives focused on the technique of origami of one straight cut—a the technique of folding a sheet of paper, cutting the paper along a straight line, and observing the geometric shape that results after the paper is unfolded (Figure 1). Limited to one straight cut, students are required to explore how to create various geometric shapes with the single cut. This training involves repeated application of line-symmetric concepts, not limited to the vertical, horizontal, or tilted symmetry axis, while requiring attention to each origami step's influence on the final shape. During the process, students learn about line-symmetric and geometric relationships of two-dimensional shapes, while applying mental rotation and spatial orientation in order to extrapolate resulting shapes after folding and cutting. All these concepts are important in mastering spatial and geometric proofs. Though origami has been used to train students' spatial ability (Boakes, 2009; Tam and Chen, 2009), there are no related teaching materials targeted at training concepts like line-symmetry and spatial relationships.

Figure 1. Origami of One Straight Cut

The technique of origami of one straight cut, as adopted in this study, is limited to making one cut along a straight line. It is more difficult for a digital system to simulate curved cutting. Elementary school students are also challenged by curved cuts—possibly above their cognitive development stage. Therefore, this study focuses exclusively on single straight cuts.

This study employees the Web of Origami Simulator II (WOOS II), an incremental improvement on WOOS I (Yang, Yin, & Chen, 2014). The WOOS II (virtual manipulative) system, as with physical origami of one straight cut, helps learners comprehend geometric symmetry. The purpose of this study is to observe acquisition of origami of one straight cut operational skills and the improvement of knowledge of both virtual and physical environments.

2. Literature Review

2.1 Spatial Ability and Origami

Spatial ability is an important skill for both school settings and general life. When students solve geometric problems, their spatial visualization and spatial orientation (the two constructs of spatial ability) are positively correlated with the effects of their learning about geometric problem solving (Tso & Liang, 2001). Ambrose and Falkner (2002) used shapes familiar to students, such as the triangle, quadrangle, and pentagon, as teaching materials to develop spatial concepts of elementary school students in lower grades. Likewise, Nilges and Usnick (2000), and Boakes (2009) indicated that spatial ability would influence the students' acquisition of spatial ability, geometry, measurement, and numerical concepts.

Since spatial ability can play such a key role, it is important to first clearly define the term? Kelley (1928) considered special ability to be a kind of visual cognition and memory. Thurstone (1938) and Kelley (1928) shared an identical view of this. As defined by Thurstone (1938), spatial ability references the ability to mentally remember an image, shift and rotate the image, and generally create and apply images in the mind. Spatial ability is classified in different ways across scholars. Based on the spatial ability classification of McGee (1979), Linn, and Petersen (1985), and Lohman (1988), the current study classifies spatial ability into three categories: spatial orientation, spatial visualization, and mental rotation. Spatial orientation refers to quick mentally identification of the spatial elements of objects, such as direction, position, and angle. Spatial visualization refers to mentally creation or identification of object shapes after two-dimensional or three-dimensional objects are folded or unfolded. Mental rotation refers to quick and precise mental rotation of spatial imagines.

The origami process includes 2D to 3D conversion, which entails the application of spatial ability. From this study's perspective, students must apply the spatial orientation skill, of spatial ability, to observe the symmetry axis of the graph. This includes considering how to fold the paper. Spatial visualization is employed to identify the shape of the paper, while mental rotation is used in order to imagine the post-cutting shape. Cakmak, Isiksal, and Koc (2014) also have shown that origami instruction positively impacts the spatial ability of elementary school students. Chen (2012) used origami to inspire students with creativity and observed students' development of graphic creativity, finding that students could see and create different shapes during the origami process. Li (2014) applied origami teaching to performance assessment, integrating mathematical problems into the process of making diagonal folds, in order to teach multiplication formula and the Pythagorean theorem. Yang and Yin (2015) utilized origami to develop the concept of symmetry axis and improve student ability with geometric conjectures.

When origami is used as a teaching tool, different creases and geometric shapes are created in the folding process. For example, when students learn folding line-symmetric graphs, they should be able to judge whether the shapes on both sides of the symmetry axis are equal and be able to mentally remember and maintain these shapes. All such activities involve the application of spatial ability.

2.2 Origami's Fold and Cut

When discussing the fold-and-cut problem (Shen, 1721), Demaine, Demaine, & Lubiw (1998) found that the symmetry axis of the graph was key to solving the problem. The straight-skeleton method produced a correct folding line, and just one straight cut could create the shape. For complex shapes, the folding process is very complicated. In another research that created different shapes with the symmetry axis, Wang and Tzeng (2015) discussed paper folding and cutting in terms of two-dimensional shapes. According to their research, the post-cutting shape arrangement correlates with the position of the folding line. Two basic graphs, the triangle and square, are categorized for paper folding. When the paper is folded in the same way as these two basic graphs, regular shapes can be cut out.

Taiwan's elementary and junior school mathematical courses emphasize teachers helping students learn line-symmetric graphs through paper folding and cutting activities (Ministry of Education, 2008). Related studies show tilted symmetry axis is more difficult than either vertical or horizontal symmetry axis. Elementary pupils tend to be clear about the property of left-right symmetry, second to which is top-bottom symmetry. However, such students are relatively unfamiliar with tilted symmetry (Liu, Sheu, Yih, Juan, & Liu, 1994). In the current study, the technique of origami of one straight cut specifically refers to folding the paper several times, making a single straight-line cut, and unfolding the paper, resulting in a geometric shape. With such teaching material, students learn to predict the post-cutting shapes; each way of folding and cutting generates different geometric shapes. The angle and step sequence of paper cutting influences the final geometric shape (Wang & Tzeng, 2015; Yang, Chen, & Yin, 2016). For such operations, students must apply their spatial visualization, spatial orientation, and mental rotation skills, as well as their understanding of line-symmetry, to judge the correct angle of folding. These concepts are a crucial foundation to be applied in junior and senior high school courses, as well as daily life.

2.3 Physical Manipulative and Virtual Manipulative

Easy to operate, physical manipulatives have long been an important tool to assist teachers with teaching. For mathematical teaching, physical manipulatives are tangible objects that connect previous concepts. This helps students construct, enhance, and link numerous mathematical representations (Taylor, 2001; Drickey, 2000; Clements, 1999). Physical manipulatives can be touched, rotated, repositioned, and collected (Perl, 1990). The common physical manipulatives include the tangram, dice, building blocks, figure cards, alphabet cards, charts, set squares, protractors, and compasses (Suh, Moyer & Heo, 2005). Most researchers recognize the positive effects and functions of physical manipulatives in teaching mathematics through operating and utilizing other representations (Moyer & Westenskow, 2013; Kim, 1993). For instance, Tam and Chen (2009) helped students solve problems related to ruler-and-compass construction via the practice of physical origami, with the six basic origami movements improving through Huzita-Hatori axioms. The creases in the paper folding process and the folded overlapped line segments or angles serve as the tools to solve ruler-and-compass construction problems. Chen (2012) inspired students with creativity through physical origami. As a result, it is showed that the combination of physical origami and creative teaching favorably improved students' graphic creativity. The origami teaching of Cakmak, Isiksal, and Koc (2014) positively influenced students' spatial visualization and orientation, and helped students simulate mental rotation. However, some empirical analysis has exposed problems, such as the lack of physical manipulatives, the difficulty in storing physical manipulatives (due to large volume), the difficulty in class management, the limitations of size and quantity, the high costs of materials, and less varied resources (Chou & Lin, 2010). Moyer (2001) discovered that operationally physical manipulatives did not have sufficiently clear connections with abstract mathematical symbols.

In recent years, rapidly changing computer software and hardware technology, as well as the popularization of networks, has brought numerically intense computations into easy availability. Manipulatives do not only involve the implementation of physical objects any more as they previously did. The National Council of Teachers of Mathematics (2000) emphasized scientific and technological products are indispensable to modern mathematical instruction. Therefore, many manipulatives can presented through information technology equipment and multimedia channels (Moyer, Bolyard, & Spikell, 2002). As pointed out by Kim (1993), virtual manipulatives simulate physical manipulatives and replace the manual operation of objects via a keyboard operation. Such cases retain properties of physical manipulatives are referred to as virtual manipulatives. Currently, a large amount of evidence supports the positive effects of virtual manipulatives (Li & Ma, 2010; Moyer & Westenskow, 2013). Char (1989) stated that one single type of manipulative cannot be applicable to all students and instructional situations. Different virtual manipulatives satisfy the instructional needs of different students. Izydorczak (2003) summarized eight main advantages of virtual manipulatives, including that virtual manipulatives are easier to operate and more extendable than physical manipulatives. Virtual manipulatives provide guidance, give real-time feedback, monitor learning activities automatically, and reduce teacher homework correction workload (Durmus & Karakirik, 2006; Suh, Moyer & Heo, 2005).

Current existing origami-related virtual manipulatives include the Origami Club (2002) (an origami website with animated instruction) the Open Media Lab of Chukyo University produced by Miyazaki, Yasua, Yokoi, and Toriwaki (1996) (a set of origami simulators) the Origami Simulator of Takumi (2015) (designed by David in 2008) as well as the Make-a-Flake (2016) (an educational game based on paper folding and cutting). While all such virtual manipulatives can promote understanding of origami, they are not sufficient to serve the purpose of true manipulatives.

Numerous researchers have shown both virtual and physical manipulatives have their own respective advantages (Suh, Moyer & Heo, 2005, 2005; Moyer, Niezgoda, & Stanley, 2005; Steen, Brooks, & Lyon, 2006; Moyer, Salkind, & Bolyard, 2008; Drickey, 2000). Some researchers have pointed out it is better to use both types of manipulatives simultaneously than to use either of them individually (Terry, 1995; Ball, 1988). In addition to interactive features of virtual manipulatives, developers must be able to emphasize the learning goals (Leathrum, 2001), staying within a cognitively appropriate learning context. Therefore, this study proposes that origami instruction should integrate both virtual and physical manipulatives, adopting different teaching methods at different stages, in the belief that both physical operation and virtual simulation help learners.

3. Research Method and Experimental Design

3.1 Experimental Design and Process

This study adopts the quasi-experimental one-group pretest-posttest design. Subjects include 41 fifth-grade students from two classes in an elementary school. The experiment is conducted using the technique of origami of one straight cut. The first session includes an origami of one straight cut written pre-test. The second to fourth sessions (40 minutes per session) include teaching activities of digital origami employing the one straight cut technique, where the schoolchildren operate the WOOS II software. The fifth session is a teaching activity including the learning sheet of physical origami of one straight cut. The sixth session focuses on self-examination and discussion. The final session includes origami of one straight cut written post-test. Test scores are then collected, statistically analyzed, and discussed.

3.2 Materials

3.2.1 Teaching materials

Wang and Tzeng (2015) studied the patterns of origami creation, finding that multiple geometric shapes can be cut with triangular and square origami. Thus, this study extends these two geometric shapes and classifies the folded paper into the two categories of triangle and rectangle, as shown in Figure 2. After further folding, one straight cut produces the basic L shape or the basic V shape. Other shapes created by one straight cut are derived from these two basic shapes. For example, the shapes on the left side of Figure 2, the shapes of T, □ and 王, are developed using the symmetry of the L shape. Regarding the shapes on the right side of Figure 2, the W shape is generated by copying the left-right symmetry of the basic V shape; the same rule applies to the 米 shape. When performing origami of one straight cut, students must be familiar with the relation of two-dimensional graphs and line-symmetry.

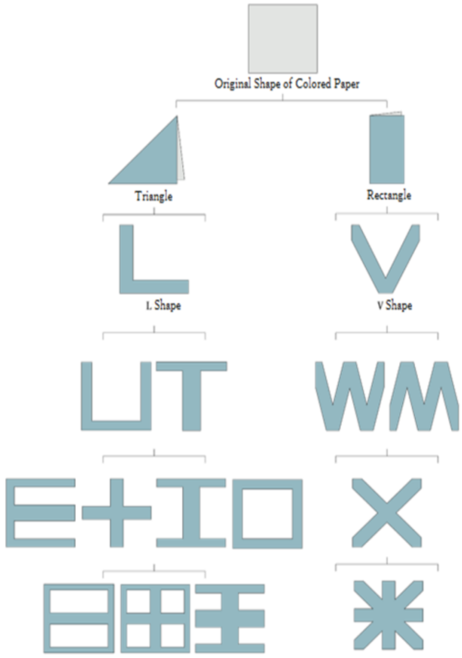


Figure 2. Basic Shape of Origami of One Straight Cut

Figure 3 shows the origami of one straight cut process to form the □ shape. As shown in Figure 3, the □ shape is comprised of 4 line-symmetric L shapes. The paper is first folded along the symmetry axes of these four L shapes, respectively, and then cut in the L shape, producing the □ shape (Figure 4). Therefore, the origami of the one straight cut technique can help students learn line-symmetry, spatial ability, and graphic conjecture.

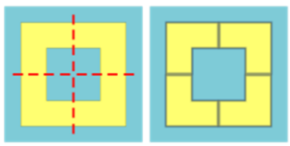


Figure 3. Deconstruction figure of the □ Shape

Additionally, origami of one straight cut includes more than one way of folding for each resulting shape. For instance, there are two ways of folding the above-mentioned □ shape. First, the □ shape can be considered as the mirror of 4 small L shapes. Thus, the paper is folded in half twice, into the rectangular shape, and then, folded in the L shape. Second, the □ shape can be considered as the mirror of 2 big L shapes. Thus, the paper is folded in half once into the triangular shape, and then, folded into the L shape. The other shapes are extended from the □ shape, such as the 日

shape and the 田 shape, which can also be folded in ways derived from these two approaches.

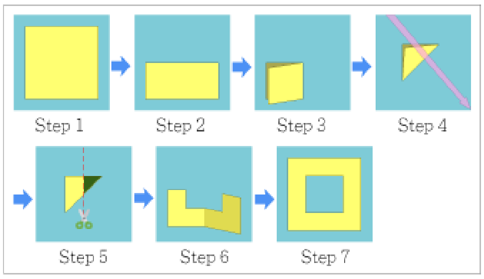


Figure 4. The □ Shape of the Operation Steps

3.2.2 The digital origami simulation system

The WOOS II program was derived from WOOS I (Yang, Yin, & Chen, 2014). WOOS II allows manipulation of multiple origami directions, as well as the new functions of paper cutting, ruler, and protractor. The WOOS II program combines the functions of origami animation with clicking operations. WOOS II's origami of one straight cut teaching materials are designed in accordance with the competence indicators of Grades 1-9 Curriculum Guidelines (Ministry of Education, 2008). WOOS II consists of 8 missions, the contents of which are designed with increasing difficulty. The 8th mission is a general review, and the students must finish the current mission before moving onto the next one. Each level includes a test consisting of operation questions, gap questions, and multiple-choice questions. A perfect score for each level is 100.

In addition, steps shown in Figure 4 show the WOOS II interface, which represents a 3D image of origami users can manipulate. Figure 5 shows the four areas interface areas:

A (Question Area): This area mainly holds the questions. The students must read the questions and understand the main points.

B (Gizmos Area): The area provides various tools, such as a ruler, protractor, and scissors to assist students in learning. There is also a button to return to homepage.

C (Operating Area): The virtual paper to be manipulated is displayed here. Students manipulate the paper by clicking and dragging with the computer mouse.

D (Answer Area): Answers to questions are submitted in this space.

Teaching activities are carried out across 3 sessions. The first session executes missions 1-4 in order to test learner familiarity with line-symmetric graphs. Specifically, students are required to identify a line-symmetric graph and practice the concept of corresponding angles. The second session introduces missions 5-6, teaching geometric properties of the triangle and quadrangle, as well as the basic shapes of origami of one straight cut. These materials will enable a learner to deconstruct geometric graphs into basic shapes through mental rotation and the line-symmetric concept. The third session introduces missions 7-8 that practice different geometric shapes, building upon concepts learned in previous missions. Manipulation and animation are provided so students can practice creating results from the one straight cut process.

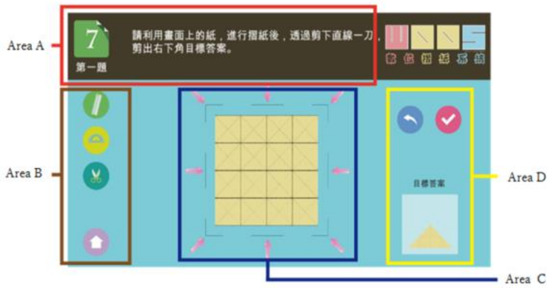


Figure 5. WOOS II Operating Interface

3.2.3 Teaching materials for physical origami of one straight cut

After the WOOS II learning activities, this study applies physical origami of one straight cut activities. Eight questions are selected and revised in the learning sheet for physical origami of one straight cut (as shown in Figure 6).

Figure 6. Physical Origami of One Straight Cut Teaching Materials

First, the teacher demonstrates the operation of origami of one straight cut. The English letter X is taken as an example. Step 1: graph X is drawn on physical colored paper (Figure 7). Step 2: the line-symmetric concept is applied to determine the symmetry axes of graph X. As easily seen, there are 4 symmetry axes of X. The paper is first folded along any one symmetry axis. Next, the learner searches for other symmetry axes. Step 3: all the lines drawn in Step 1 are overlapped, and one single cut is made along the line. After the above-mentioned demonstration, students begin to respond to the learning sheet questions. As directed by the questions, students next paste the finished colored paper onto the learning sheet. Full marks are 100 for a complete learning sheet of physical origami of one straight cut. How well the students learned the one straight cut is judged according to the creases and shapes created by the students. In the case of students not cutting the paper with one straight cut, points are deducted.

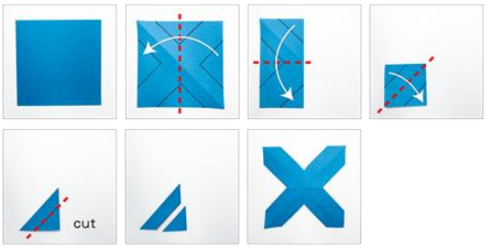


Figure 7. Demonstration of Physical Origami of One Straight Cut Operation-The English Letter X

3.2.4 Origami of one straight cut test

In order to observe the impact of digital origami instruction on students' spatial ability, this study adopts variables from theory of spatial ability, and categorized spatial ability into spatial orientation, spatial visualization and mental rotation. These indicators are next aligned with of competence indicators of Grade 1-9 from the Curriculum Guidelines of the Ministry of Education (2008), as shown in Table 1. Cronbach's α of the pretest is 0.803 and Cronbach's α of posttest is 0.822, demonstrating the assessment tool's consistency and reliability. Origami of one straight cut test questions include four items, each made up of five questions. The full score for each question is 5 points, totaling 100. The test time is 40 minutes.

Table 1. Origami of one straight cut test, corresponding spatial ability and competence indicators of Grade 1-9 Curriculum Guidelines

Item	Corresponding competence indicators	Corresponding spatial ability
Observation of meaning of graphic symmetry	S-2-06, S-3-03	Spatial orientation, spatial visualization, mental rotation
Translation and overturning of graphics	S-2-05, S-2-07	Spatial orientation, mental rotation
Graphics formed by one straight cut	S-2-02, S-2-06, S-3-01, S-3-03	Spatial orientation, spatial visualization, mental rotation
Geometric modeling of one straight cut	S-2-02, S-2-06, S-3-01, S-3-03	Spatial orientation, spatial visualization, mental rotation

4. Experimental Results and Discussion

4.1 Learning outcome analysis of origami of one straight cut instruction

In order to recognize the learning outcome of one straight cut instruction for elementary school fifth graders, the researcher conducted t test analysis by SPSS, comparing pretest and posttest scores of origami of one straight cut test of 41 students. Results are shown in Table 2.

Table 2. Pretest and posttest t test analysis of origami of one straight cut test

	Average mean	Standard deviation	t	Significance
Pretest	63.09	16.80	-2.83	.007**
Posttest	69.30	17.55		

*. *p<.05*; **. *p<.01*

According to Table 2, the pretest average score is 63.09 with a standard deviation of 16.80. After WOOS II and physical origami learning interventions, the average posttest score is 69.30 with a standard deviation of 17.55, *p=.007*(*p<.01*). The difference is statistically significant. Students exhibit progress in posttest score, demonstrating the efficacy of WOOS II and physical origami instruction in improving students' spatial ability.

4.2 WOOS II Performance Analysis

Students performance in WOOS II operation is analyzed next. Each of the 8 missions have full marks of 100, with points given according to the number of answered questions. Results are shown in Table 3, including the average scores and standard deviations of WOOS II operation and the average time spent on each question across all missions.

Table 3. Descriptive Statistics regarding Digital Origami of One Straight Cut Learning Sheet

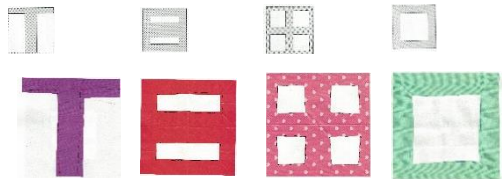
	NO. of Questions	Average Scores	SD	Avg. Time Spent on Each Question (Second)
Mission 1	8	83.23	14.18	33.26
Mission 2	6	84.31	14.56	11.94
Mission 3	5	87.80	13.33	13.42
Mission 4	8	95.73	6.62	8.91
Mission 5	12	83.79	13.12	30.77
Mission 6	7	74.29	13.73	20.34
Mission 7	8	80.55	22.77	142.19
Mission 8	10	72.63	21.27	7.48

For Mission 1, the average score is 83.23 (14.18) taking on average 33.26 seconds. Mission 1 aims to examine whether the students can identify line-symmetric graphs. Mission 1 took a longer time for participants to complete. This is mainly because they were not yet familiar with the operating environment of WOOS II. Mission 4 received the highest scores 95.73 (6.62) taking 8.91 seconds on average. The key point of Mission 4 is to "apply the same way of folding the paper and observe whether the shapes cut out in different angles are line-symmetric graphs." Results indicate students are familiar with the key point of Mission 4. In Mission 7, the average score is 80.55 (22.77) taking on average 142.19 seconds. The main point of Mission 7 is to "learn to present different geometric shapes, such as □ and T, with the basic shapes of origami of one straight cut". When executing Mission 7, students performed folding and cutting movements and produced shapes with one straight cut. Thus, they could quickly tell whether or not they completed the question correctly. When students detected a wrong answer, they tried again. In this mission, the students can practice the entire process of one straight cut. These efforts, thus, consumer more time. For Mission 8, the average score is 72.63 (21.27). Mission 8 requires students to watch an animation about creating geometric shapes with one straight cut. They next need to practice predicting the final cut-out shapes. Two students answered the questions at a relatively slow speed, failing to complete some of the questions in Mission 8. The other students managed to correctly predict the unfolded shapes through the origami of one straight cut animation.

4.3 Physical Origami of One Straight Cut Learning Sheet Analysis

The eight questions of the physical origami of one straight cut learning sheet are next scored. A full score is 100 points. The average score is 69.82 (24.36) with a maximum score of 100 and a minimum score of 12.5. Performance variance is high in the physical origami of one straight cut. Results led to further analysis of the special students' learning sheets.

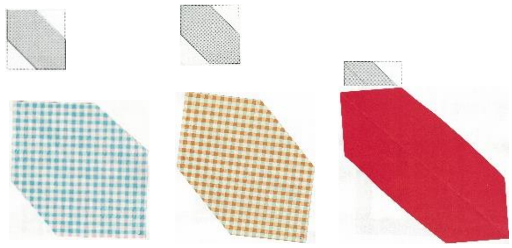
This study defines students with higher than average performance, in the physical origami activities of the one straight cut learning sheet, as Excellent Students. In Figure 8, four Excellent Students, A, B, C, and D, first drew the target shapes on the colored paper, and then, determined the symmetry axes. This approach is typical of the Excellent Students. Such repeated operation produces the final correct shapes with one straight cut. More complex shapes can be obtained with the help of auxiliary lines. However, how well did Excellent Students perform in simple graphs?



(a)Student A (b)Student B (c)Student C (d)Student D

Figure 8. The Works of Excellent Students A and B for Physical Origami of One Straight Cut

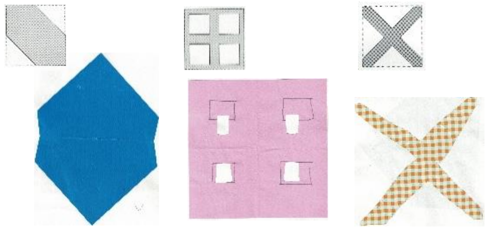
When operating simple graphs, Excellent Students mentally maintain the target shapes. They can identify graphic symmetry axes without drawing the shapes. This is precisely the type of skill this study has set out to examine to examine. In the hexagonal cases, as shown in Figure 9, two students did not draw the hexagonal on the colored paper in advance, because they were mentally maintaining the target shapes, allowing them to directly cut out the hexagons. It was particularly worth mentioning that Student G, when analyzing this question, drew the symmetry line of the hexagon. In this way, this student could visualize more clearly the direction and position of the paper during the actual manipulation.



(a)Student E (b)Student F (c)Student G

Figure 9. Excellent Students' Hexagonal Works of Physical Origami of One Straight Cut

Incorrect responses on the learning sheets are categorized into four types. The first case is shown as (a) in Figure 10. About 2% of the students failed to accomplish the shapes as indicated by the questions and directly pasted the final cut-out paper on their learning sheets. The second case is shown as (b) in Figure 10. As many as 68% of the incorrect responses fell into this category. Generally, these students folded the paper in half only once and then obtained the target shapes with several cuts (rather than the single cut as required). This occurred mostly when students did not draw the shapes on the colored paper. They did not select the correct spatial orientation due to their insufficient spatial ability. However, their operation was partially correct, meaning they clearly understood the target shapes. Therefore, when encountering difficulty in creating the target shape with one straight cut, these students decided to use multiple cuts. The third case, experienced by about 24% of the students, is shown as (c) in Figure 10. This student directly generated the target shape with 4 cuts, unable to identify the correct axis of symmetry. When students performed in this way, the teacher had to repeatedly remind them that they could only apply one straight cut. This approach is clearly the simplest way for a student to overcome difficulty with the exercise. The fourth case, experienced by around 6% of the students, is simply not providing any answers on the learning sheet. Reasons for this behavior may include lack of time, lack of understanding, or simply giving up.



(a)Type I (b)Type II (c)Type III

Figure 10 .Wrong Type Analysis of Physical Origami of One Straight Cut

4.4 Correlation between WOOS II and Physical Origami of One Straight Cut

To explore student performances with virtual and physical manipulatives, this study conducts a Pearson correlation analysis on the performances of 41 students' using WOOS II and the physical origami activities of the one straight cut study list, where full marks are 100 points. As shown in Table 4, the correlation coefficient between WOOS II and the physical origami activities is .325, reaching the statistical significance level (p<.05), indicating that the students' learning effects are highly correlated between the two approaches. In this experiment, students were involved in the teaching activities of origami of one straight cut for the first time. Despite any previous experience in origami, they were unfamiliar with the technique of origami of one straight cut. Most students were competent at operating the virtual manipulatives, meaning if the students grasped the basic line-symmetric concepts, they would not encounter many problems.

Table 4. Posttest Pearson Correlation Analysis of WOOS II and Physical Origami of One Straight Cut Study List

	WOOS II	Physical Origami of One Straight Cut Study List
WOOS II	.721**	-
Physical Origami of One Straight Cut Study List	.392*	.325*

*. p<.05; **. p<.01

4.5 Learning Performances of WOOS II and Physical Origami of One Straight Cut

This study examined how well students learned during a digital simulation (WOOS II) and then how well they performed in a physical origami of one straight cut activity. Students were divided into two groups, a high-score group and a low-score group, as based on their average scores in WOOS II operation and the physical origami activities. Student performance is divided into four categories, with results described here:

(1) WOOS II-Physical Origami low-score group: This group consisted of 8 students. Most of these students failed to complete all the missions, and had multiple failures in WOOS II operation. They tended to spend more time answering the questions because of their unfamiliarity with the line-symmetric concepts. These students could not correctly answer any questions that entailed more than two times of folding on the physical origami activity. Due to their deficiency in spatial orientation and visualization skills. These students could not identify the correct target shape after the paper was folded. As shown by the 田-shaped and 日-shaped questions. In other words, they did not look for the symmetry axis of the next graph after folding the paper in half.

(2) WOOS II low-score and Physical Origami high-score group: There were 8 students in this group. They excelled in the physical origami activities, where they could first draw the shapes on colored paper. They accomplished the tasks step-by-step. They even answered the difficult questions successfully. However, they spent a longer time in operating the WOOS II virtual system with less repeated attempts and higher error rates, indicating they were not good at practicing with the digital environment. These students had to memorize or predict the post-rotation shapes mentally, unable to use the digital representations, causing a loss of interest in practicing origami of one straight cut in the digital environment. These students exhibited more skill in physical operations, but disliked the virtual operating environment. They mastered the physical operation skills and were able to concentrate more easily on the learning of the

physical operation.

(3) WOOS II high-score and Physical Origami low-score Group: There were 10 students in this group. Although they spent a longer time on WOOS II operation, but they answered all the questions correctly. Students grasped the line-symmetric knowledge and operation through their trials within the virtual system, which indicates a digital environment can help these students. Additionally, they enhanced their spatial visualization and mental rotation via WOOS II. However in the physical origami exercise, their performances was not good. These students did complete the cut-out shapes, and they drew the target shapes on the colored paper. Members of this group simply did not answer difficult questions, such as the 田 and 日 shapes, exhibiting a lack of capacity to transform from virtual implementation to physical operation. This group's virtual and physical spatial abilities were not yet effectively linked.

(4) WOOS II-Physical Origami high-score group: This group included 15 students, and account for the largest proportion of the class (36.6%). These students were able to learn the line-symmetric concepts by properly applying both the physical and virtual environments. In the process of operating physical origami, these students drew the shapes on the colored paper, cut out the shapes quickly and correctly. They effectively accomplished the questions with their mental rotation ability. They fulfilled the tasks at a faster speed, quickly identified the angles and positions of the shapes, and made fewer mistakes. In addition, they managed to swiftly become proficient in line-symmetric concepts, as well as one straight cut and computer skills, all showing a strong grasp of spatial ability.

As can be seen from the above-mentioned discussion and analysis, WOOS II helped students develop the basic concepts and operational steps of origami of one straight cut. Through repeated attempts within the digital environment, as well as the practical exercises of the physical origami skills were improved. These students applied the concepts learned in the digital environment to physical origami, such an integrated teaching strategy is able to help students reflect on their spatial abilities.

4.6 Discussion

WOOS II operation can help students develop and reinforce line-symmetric concepts. As described by Boakes (2009) and Cakmak, Isiksal, and Koc (2014) origami-based teaching improve the effects of student learning, and enables them the understanding of various concepts, such as line symmetry and spatial ability in an intuitive manner. However, during the WOOS II process, some students required more time to become familiar with the system interface. In addition, before WOOS II operation, physical manipulatives were applied in order to simulate the steps of origami of one straight cut, and questions were raised for students to consider. This teaching process could help students develop accurate conceptualizations. As in the origami instruction of Cakmak, Isiksal, and Koc (2014), questions raised in the learning process, for student consider, can deepen knowledge acquisition and retention. When physical manipulatives are used for simulation, the aim is to help students create a link between physical practice and virtual operation, promoting learning in a visual manner. Likewise, as mentioned by Lu and Lin (2013), origami digitalization facilitates student conceptual transformation, and repeated practices in the digital environment positively influences learning effects.

In the current study, a small number of students had a vague idea about line symmetry; however, they were only familiar with left-right symmetric graphs, not conversant with tilted symmetry axes, a common issue among learners (Tso, 2003; Liu and Liu, 1994). When operating WOOS II, these students were often confused about graphic rotation and the folding process, requiring teacher intervention. In other words, these students could not establish the folding and cutting process in their minds. A practical paper demonstration by the teacher did help these learners develop the basic symmetric concepts, and thereby, link their virtual and physical spatial abilities.

When learning the physical origami of one straight cut, students in this study answered the questions according to the three steps taught by the teacher. In the first step, the target shapes are drawn on the colored paper. The second step identifies the symmetry axes of the graphs. The final step includes one single cut when all the folded lines are overlapped. During the physical origami of one straight cut instruction, most students could accomplish the tasks following the teacher's demonstration. However, when expected to conduct the operation on their own, students often forgot the three previously-taught steps. As a result, such students failed to mentally maintain the target shapes while folding the paper. Of course, the personal spatial orientation, spatial visualization, and mental rotation ability of each student directly influences the learning effects.

During the teaching of physical origami of one straight cut, several students in particular were observed employing different solutions for the same question. For instance, both the 王-shaped and □-shaped questions had two solutions. Such students, after discussion with their peers, deduced the key, and tried to share the skills with their fellow students. Likewise, this case also occurred in the WOOS II operation, exhibiting a growing self-efficacy among the students.

5. Conclusion

Application of WOOS II can reduce the drawbacks of hand dexterity problems and paper waste. This approach provides an auxiliary tools that allows students to repeatedly practice operations. The features of the virtual manipulatives in WOOS II emphasize displaying results in real time. During the physical origami activities, the required visual observations and hands-on operations improved finger dexterity and hand-eye-brain coordination. The physical origami activities effectively established cognition. In both virtual and physical manipulatives, the folding and cutting movements are applied in an order that students better understood the relationship between line symmetry and graphs, and are better able to identify the relationship between graphs and space. This mode of learning improves student cognition, and helps geometric, line-symmetric, and spatial concept acquisition.

When learning with virtual and physical manipulatives, students with insufficient spatial ability and line-symmetric conceptualization spend a longer time practicing, but they do not reject the teaching of virtual manipulatives. Students who excel at operating the virtual environment understand the questions and problem-solving steps within the virtual environment. Skill in physical manipulative operations gives full play to learner hand-eye-brain coordination skills, and quickly improves physical operations. Students who excel both in the virtual and physical environments are able to complete properly by using their virtual and physical spatial abilities. Moreover, some students in this study employ different methods to cut out the same target shapes, suggesting that this process enhances the self-efficacy of highly-competent and motivated students, which increases confidence and future motivation.

Acknowledgment

This research is supported as part of project MOST 103-2511-S-224-001 by Ministry of Science and Technology, Taiwan, Republic of China.

References

Ambrose, R. C., & Falkner, k. (2002). Developing spatial understanding through building polyhedrons. *Teaching Children Mathematics*, 8(8), 442-447.

Arici, S. & Tutak, F. A. (2015). The Effect of Origami-based Instruction on Spatial Visualization, Geometry Achievement, and Geometric Reasoning. *International Journal of Science and Mathematics Education*, 13(1), 179-200.

Ball, S. (1988). Computers, concrete materials and teaching fractions. *School Science and Mathematics*, 88(6), 470-475.

Boakes, N. J. (2009). Origami instruction in the middle school mathematics classroom: Its impact on spatial visualization and geometry knowledge of students. *Research in Middle Level Education*, 32(7), 1-12.

Cakmak, S. (2009). *An investigation of the effect of origami-based instruction on elementary students' spatial ability in mathematics* (Unpublished master's thesis). Middle East Technical University, Ankara, Turkey.

Cakmak, S., Isiksal, M., & Koc, Y. (2014). Investigating effect of origami-based instruction on elementary students' spatial skills and perceptions. *The Journal of Educational Research*, 107(1), 59-68.

Chan, D. C. W. (2007). Origami of Brain Builder. Retrieved from http://paper.people.com.cn/smsb/html/2007-04/03/content_12675356.htm. (in Chinese)

Char, C. A. (1989). *Computer graphics feltboard: New soft-ware approaches for young children's mathematical exploration*. San Francisco: American Education Research Association.

Chen, K. (2005). Math inMotion: Origami Math for Students Who are Deaf and Hard of Hearing. *Journal of Deaf Studies and Deaf Education*, 11(2), 262-266.

Chen, H. Y. (2012). *The Influence of Creative Teaching of Origami to the Graphic Creativity Development of Elementary Students* (Unpublished master's thesis). Taipei, Taiwan. (in Chinese)

Chou, W. C., & Lin, T. H. (2010). The Reflection of the Physical and Virtual Manipulative on the Teaching Application, *Journal of Computer Science and Application*, 6(2), 33-46. (in Chinese)

Cipoletti, B., & Wilson, N. (2004). Turning origami into the language of mathematics. *Mathematics Teaching in the Middle School*, 10(1), 26–31.

David, H. (2008). Tabula. Retrieved from http://numeracyworks.com/apps/tabula/app/index.html

Demaine, E. D., Demaine, M. L., & Lubiw, A. (1998). Folding and cutting paper. In Japanese Conference on Discrete and Computational Geometry. 104-118.

Drickey, N. A. (2000). *A comparison of virtual and physical manipulatives in teaching visualization and spatial reasoning to middle school mathematics students* (Unpublished doctoral dissertation). Utah State University, UT.

Durmus, S., & Karakirik, E. (2006). Virtual manipulatives in mathematics education: A theoretical framework. *The Turkish Journal of Educational Technology*, 5(1), p117-123.

Fumiaki S. (2002). Origami club. Retrieved from http://en.origami-club.com/

Homan, D. R. (1970). The child with a learning disability in arithmetic. *The Arithmetic Teacher*, 17(3), 199-203.

Hull, T. (2002). Origami 3rd International Meeting of Origami Science*, Mathematics, and Education,* Natick, MA: AK Peters.

Izydorczak, A. E. (2003). A study of virtual manipulatives for elementary mathematics. Retrieved from http://proquest.umi.com/pqdlink?did=765118631&sid=2&Fmt=2&clientId=23855&RQT=309&VName=PQD.

Kali, Y., & Orion, N. (1996). Spatial abilities of high-school students in the perception of geologic structures. *Journal of Research in Science Teaching*, 33, 369-391.

Kelley, T. K. (1928). Crossrodas in the mind of man. Stanford. CA: Stanford University Press.

Kim, S. (1993). *The relative effectiveness of hands-on and computer-simulated manipulatives in teaching seriation, classification, geometric, and arithmetic concepts to kindergarten children* (Unpublished doctoral dissertation). University of Oregon, OR.

Leathrum, T. (2001). Writing Mathlets I: A Call to Math Professionals. Journal of Online Mathematics and its Applications. 1(2). Retrieved from: http://mathdl.maa.org/mathDL/4/?pa=content&sa=viewDocument&nodeId=460

Li, J. S. (2014). Brief Talk About Performance Assessment: Learning mathematics from Origami, *Science Education Monthly*, 367, 42-54. (in Chinese)

Libeskind, S. (2008). Euclidean and Transformational Geometry: A Deductive Inquiry, Jones & Bartlett Learning.

Linn, M.C., & Petersen, A. C. (1985). Emergence and characterization of sex in spatial ability: A meta-analysis. *Child Development*, 56, 1479-1498.

Liu, H. C., & Liu, H. H. (1994). A Study of conceptual Aspects of Reflection Symmetry, *Part D: Mathematics, Science and Technology Education*, 4(1), 10-24. (in Chinese)

Liu, H. C., Sheu, T. W., Yih, J. M., Juan, S. Y., & Liu, H. H. (1994). A Study on the Development of Point-symmetry-concept of Middle Grader of Elementary School, *Journal of National Taichung Teachers College*, 8, 409-436. (in Chinese)

Lohman, D. F. (1988). Spatial abilities as traits, processes, and knowledge. *Advances in the psychology of human intelligence*, 4, 181-248.

Lu, S. Y., & Lin, T. W. (2013), Learning Effects through the Multimedia Animation in Teaching Origami, *Journal of National Taichung University: Humanities & Arts*, 27(1), 111-130. (in Chinese)

Make-a-Flake. (2016) Retrieved from http://snowflakes.barkleyus.com/

McGee, M. G. (1979). Human spatial ability: Psychometric studies and environmental, genetic, hormonal, and neurological influences. *Psychological Bulletin*, 86(5), 889-918.

Ministry of Education (2008). Grades 1-9 Math Curriculum Guidelines, Taipei: Ministry of Education. (in Chinese)

Miyazaki S., Yasua T., Yokoi S., & Toriwaki J. (1996). An Origami CPlaying Simulator in the Virtual Space. *The Journal of Visualization and Computer Animation*, 7(1), 25-42.

Moyer, M. (1978). *An investigation of spatial visualization abilities in normal and learning disabled children* (Unpublished doctoral dissertation), Northwestern University, Evanston, IL.

Moyer, P. S. (2001). Are we having fun yet? How teachers use manipulatives to teach mathematics. *Educational Studies in Mathematics*, 47(2), 175-197.

Moyer, P. S., Bolyard, J. J., & Spikell, M. A. (2002). What are virtual manipulatives?. *Teaching Children Mathematics*, 8, 372-377.

Moyer, P. S., Niezgoda, D. & Stanley, J. (2005). Young children’s use of virtual manipulatives and other forms of mathematical representations. *Technology-supported mathematics learning environments*, 671, 17-34.

Moyer P. S., Salkind, G., & Bolyard, J. J. (2008). Virtual manipulatives used by K-8 teachers for mathematics instruction: Considering mathematical, cognitive, and pedagogical fidelity. *Contemporary Issues in Technology and Teacher Education*, 8(3), 202-218.

Moyer, P. S., & Westenskow, A. (2013). Effects of virtual manipulatives on student achievement and mathematics learning. *International Journal of Virtual and Personal Learning Environments*, 4(3), 35-50.

National Council of Teachers of Mathematics (2000). *Principles and Standards for school Mathematics*. Reston, Va.: NCTM.

Nilges, L., & Usnick, V. (2000). The role of spatial ability in physical education and mathematics. *Journal of Physical Education, Recreation & Dance. Reston*, 71(6), 29-33.

Pope, S. (2002). *The Use of Origami in The Teaching of Geometry*. Proceedings of the British Society for Research into Learning Mathematics, 22(3).

Reimer, K., & Moyer, P. S. (2005). Third-graders learn about fractions using virtual manipulatives: A classroom study. *The Journal of Computers in Mathematics and Science Teaching*, 24(1), 5.

Shen K. C. (1721). Retrieved from http://erikdemaine.org/foldcut/sen_book.html

Steen, K., Brooks, D., & Lyon, T. (2006). The impact of virtual manipulatives on first grade geometry instruction and learning. *The Journal of Computers in Mathematics and Science Teaching*, *25*, 373-391, 4, Academic Research Library.

Suh, J., Moyer, P. S., & Heo, H. J. (2005). Examining technology uses in the classroom: Developing fraction sense using virtual manipulative concept tutorials. *Journal of Interactive Online Learning*, 3(4), 1-21.

Takumi F. (2015). Retrieved from https://github.com/takumif/origami/

Tam, H. P., & Chen, Y. L. (2009). Using paper folding to promote students' ability in straightedge-and-compass problem solving. *Science Education Monthly*, 323, 15-24. (in Chinese)

Taylor, F. M. (2001). *Effectiveness of concrete and computer simulated manipulatives on elementary students' learning skills and concepts in experimental probability* (Unpublished doctoral dissertation). University of Florida, FL.

Terry, M. K. (1995). *An investigation of differences in cognition when utilizing math manipulatives and math manipulative software* (Unpublished doctoral dissertation). University of Missouri-Saint Louis, MO.

Thurstone, L. L. (1938). *Primary mental abilities*. Chicago: University of Chicago Press.

Tso, T. Y. (2003). Understanding and Learning of Symmetry Concept: Junior High School Students, NSC Research Project Report (NSC91-2522-S-003-009), Taiwan.

Tso, T. Y., & Liang, Y. N. (2001). The Study of Interrelationship between Spatial Abilities and Van Hiele Levels of Thinking Geometry of Eighth-Grade Students, *Journal of Research in Education Sciences*, 46(1,2), 1-20. (in Chinese)

Wang, Y. Y., & Tzeng, C. S. (2015). Geometric Form Arrangement in Paper Cutting, *Journal of Design*, 20(2), 43-62. (in Chinese)

Yang, H. H., Chen, Y. T., & Yin, S. K., (2016). *Design and Developing Technology Integrated into Learning Origami: Using the Origami of One Straight Cut as an Example*, The Asian Conference on Arts & Humanities. 379-390.

Yang, H. H., Yin, S. K., & Chen, P. Y. (2014). Design and Implementation for the Web of Origami Simulator, *Applied Mechanics and Materials*. 536-537, 593-598.

Yang, H. H., & Yin, S. K., (2015). *Applying Graphic Reasoning Simulation Tool to Explore the Scientific Creativity*. The 23rd International Conference on Computers in Education. 196-198.

探討幼兒使用擴增實境學習形狀及顏色之科技接受模式及學習成效

許一珍
國立臺北教育大學，yichen@tea.ntue.edu.tw

摘要

在科技化的世代，學習已不再侷限於紙本教學，而是越來越多的行動裝置加入學習的方式。為達到較佳的學習成效，除了搭配行動裝置外，利用擴增實境輔助教學，讓學習變得更為有趣，也有助於提升學習的動機。本研究透過擴增實境技術搭配立體圖像及彩色的圖卡，以幼兒學習的顏色、形狀圖卡作為學習教材，經由觀察、記錄探討兒童對於擴增實境的科技接受模式(Technology Acceptance Model, TAM)及學習成效(Learning Effectiveness)等相關研究。本次研究之結果，對於大部分的幼兒在使用本研究自製的「CoShaper」擴增實境學習應用程式後，在形狀及顏色的辨識學習力並無較高數據，針對科技接受模式之施測分析數據，在知覺有用性、知覺易用性、使用態度及行為意願各構面皆顯示透過應用程式學習接受度較高；針對學習成效之施測分析數據，在各項構面皆顯示以圖卡學習而未使用應用程式學習之成效較高。

關鍵詞：幼兒學習、科技接受模式、學習成效、擴增實境

The Study of Using Augmented Reality in Children Learning of Shape and Color to Investigate Technology Acceptance Model and Learning Effectiveness

Yi-Chen Hsu
National Taipei University of Education, yichen@tea.ntue.edu.tw

ABSTRACT

In this technological age, learning is no longer restricted to physical books. More and more mobile devices are integrated into learning methods. In order to achieve more effective learning, augmented reality supported learning is used as well as mobile devices to boost motivation for learning and make learning more interesting. In this study, we use augmented reality supported learning to boost motivation for learning. This study uses augmented reality alongside 3D graphics and colors. Color & Shape-recognition cards for children are used as the learning material to observe, discuss, and record the Learning Effectiveness and Technology Acceptance Model of augmented reality applied to children. The results of this study show that most students had higher recognition ability towards colors and shapes when using the Color & Shape-recognition cards. After analyzing Technology Acceptance Model test data, the data shows that the fields of perceived usefulness, perceived ease of use, attitude towards using, and intention to use are all higher when learning through the app. After analyzing learning efficiency data, the data shows that all fields show a higher efficiency when learning through the Color & Shape-recognition cards.

Keywords: Children Learning, Technology Acceptance Model, Learning Effectiveness, Augmented Reality.

1 前言

隨著數位技術的發展，學習已不再侷限於紙本教材，而如何建立幼兒的有效學習，是本研究的重要目標。現今的技術，已逐漸進步到視訊媒體，甚至將擴增實境(Augmented Reality, AR)技術應用在學習的輔助教材上，讓學習過程變得更生動活潑。近年來，許多智慧型裝置研究開始著重於幼兒的學習，在學習上結合手機應用程式(Application, App)，除了增添娛樂性與趣味性，更讓幼兒進一步達到學習教育價值(Azuma, 1997)。

根據 Fantz(1961)於嬰兒形狀知覺與視覺偏好方面所作的研究，對於一歲以後的孩子，在形狀概念的發展，已能作基本的形狀配對，如方形、圓形、三角形。因此，本研究透過擴增實境的技術呈現形狀的立體樣貌，讓幼兒在學習形狀時，同時也能加深對於立體的概念及印象，強化幼兒對於形狀的認知與描述能力。

「動機」是行為的動力，學習動機會間接影響幼兒的學習成效，並反應幼兒之需求與興趣。因此，我們希望藉由本研究探討幼兒透過擴增實境技術結合形狀及顏色的學習情形、專注力與興趣，讓幼兒不僅是平面式的學習，更在圖形的立體結構上有一定程度的了解，並加以探討幼兒在學習後的成效。在整個實驗活動結束後，幼兒亦向研究者表示很喜歡此種學習方式、希望往後的課堂也能使用此模式學習其他的形狀及顏色。本研究之目的想利用透過擴增實境的學習方式，探討幼童以 AR 學習方式的科技接受模式與學習成效，進而促進幼童在操作的過程中快樂學習。因此歸納出研究問題：

(1) 幼兒是否接受擴增實境的科技學習方式進行形狀與顏色的學習？以科技接受模式為施測依據。
(2) 擴增實境的學習方式是否提昇幼兒對於形狀與顏色的學習成效？

2 文獻探討

2.1 幼兒顏色與形狀學習分析

兒童是國家未來的主人翁，而這些兒童的學習更是關乎社會與國家的未來發展，良好的家庭、社會或是學習環境，乃是世界各個教育界所致力的目標。對幼兒而言，最簡單與基礎學習有的顏色與形狀，且幼童所使用的色彩、形體與構圖並非來自偶然，而是出自幼童對自己與外界的感覺(Lowenfeld & Brittain, 1987)。再者，幼兒在色彩排序能力實驗中已證實在明度與彩度排列均無失誤，而是在色相排序普遍表現較為不佳（趙敏雲，民 93），因此需要再加強幼兒在色相認知的學習。國內研究在幼兒學習形狀上多利用七巧板建構圖像與形狀的認知（蔡雅如，民 104；江蓓，民 99；姜敏琳，民 99；洪勁亭，民 98），而且幼兒在形狀圖形認知學習很快，多已能辨別圓型、方形與三角形（張靜文、張麗芬，民 103；劉金花，民 102）與近乎半數可以進行菱形辨識（江蓓，民 99），但是卻有半數以上的幼兒對於物體的名稱會出現平面與立體的混淆情形（張淑玲、簡秀芬，民 104）。

而市面上已有數款兒童學習形狀及顏色的 App，例如「寶寶學形狀」是一款學習形狀的 App，使用對象為 3 歲以上的兒童，其介面可愛、吸引人，同時支援 Android 及 iOS 兩大平台，在語言方面也有高達九種版本（寶寶巴士 BabyBus，2017）。市面多款的顏色與形狀學習 App 雖不在少數，然而在應用擴增實境在幼兒學習形狀的 App 卻是相當稀少。

2.2 擴增實境

擴增實境(Augmented reality, AR)是一種新的資訊科技，跳脫出傳統顯像方式，結合虛擬化技術來觀察與體驗世界的方式，這種技術的目標是在螢幕上把虛擬世界套在現實世界並進行互動，例如目前當紅的行動平台擴增實境遊戲「精靈寶可夢 GO」(Niantic, 2017)（如圖 1），玩家可以在行動裝置上經由相機鏡頭看到真實環境與遊戲中的虛擬精靈寶可夢以及相關遊戲介面。

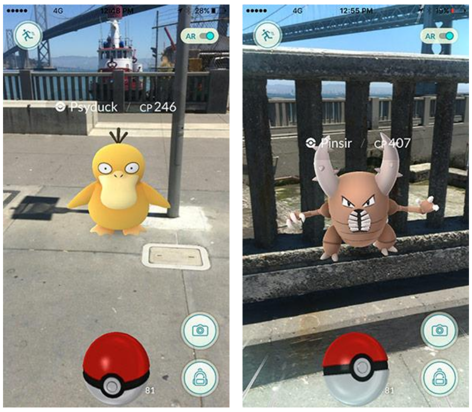


圖 1. 寶可夢 GO」的遊戲畫面

（資料來源：Niantic, 2017）

擴增實境逐漸與人類的現實生活融合，為現今之娛樂事業、商業廣告、創意簡報與數位學習等，加入創新的元素，跳脫原本的互動模式。根據 Milgram 和 Kishino(1994)提出的現實ー虛擬連續統(Milgram's Reality-Virtuality

Continuum)。他們將真實環境和虛擬環境分別作為連續統的兩端，位於它們中間則被稱為混合實境(Mixed Reality)。其中靠近真實環境的是擴增實境，靠近虛擬環境的則是擴增虛境(Augmented Virtuality, AV)，如圖 2。

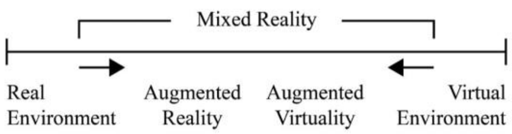


圖 2. 實結合的混合實境圖

（資料來源：Milgram & Kishino, 1994）

目前擴增實境已廣泛應用於日常生活中，在教育方面的研究，已有立體拼圖結合地球科學，以遊戲化方式學習設計教具，林宜樺(民 98)、買安政(民 99)、郭晉谷(民 102)也在研究中使用擴增實境結合幼兒認知、學習之研究；在觀光方面，則有交通部推出的「旅行台灣」App 提供台灣許多著名景點的導覽資訊，方便民眾瞭解學習（交通部觀光局，民 106）。

2.3 科技接受模式

科技接受模式(Technology Acceptance Model, TAM)指的是一套用來解釋資訊科技接受決定因素的理論，以理性行動理論(Theory of Reasoned Action, TRA)為發展基礎，解釋人們使用科技的行為(Fishbein & Ajzen, 1975)。

此模式提供了一個理論的基礎，用來了解外部因素對於使用者的信念(Beliefs)、態度(Attitude)與意向(Intention)的影響， 認為態度是影響使用者行為的重要因素，進而影響科技使用的情形(Davis, 1989)。其中，態度受知覺有用性與知覺易用性兩變數影響，而知覺有用性又正向影響了知覺易用性，知覺有用性和知覺易用性又會受到外部變數影響（如圖 3）。本研究採用其中的四個構向，各項定義如下：

(1) 知覺有用性：對於學習的提升，所感受到的學習績效程度。
(2) 知覺易用性：對於其功能的使用過程中，所花費、付出的心力。
(3) 使用態度：對於學習的提升，所感受到的正負面影響。
(4) 行為意願：幼兒學習使用 CoShaper 的意願程度。

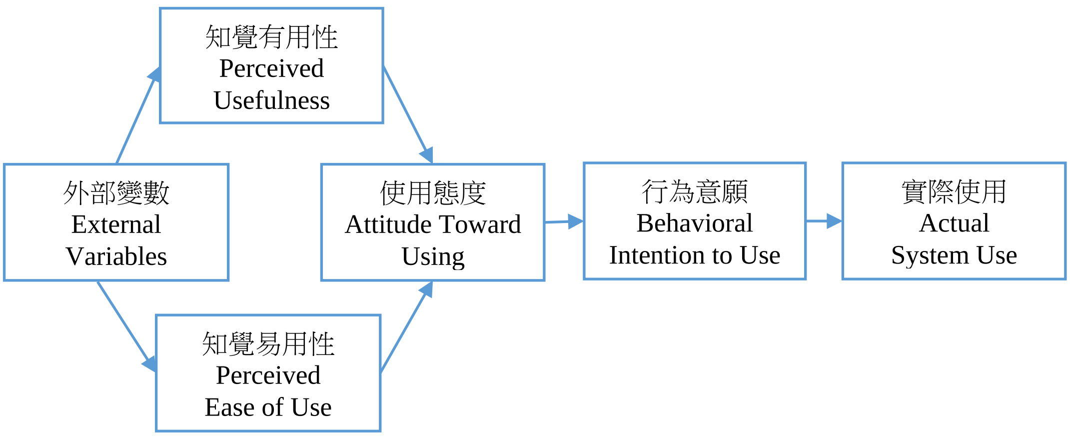


圖 3. 接受模式架構圖（資料來源：Davis, 1989）

若數位學習者對於學習系統不需花費很多精力與時間，且可以隨時上手、容易使用，使用者就會相信這個系統是有用的、易用的，進而產生正向的學習態度，並願意使用該系統學習（周君倚、陸洛，民 103）。

2.4 學習成效

學習成效(Learning Effectiveness)指學習者參與學習活動一段時間後，在某種形式測驗上的表現。一般廣泛認知的學習成效，是藉由各種評量方式以了解學生達成教學目標的程度與瞭解教師教學效果。而這些測驗、評量中我們可得知學習者對於學習內容所學之成效（鄭明韋，民 88）。幼兒教育近日來也逐漸受到各界的關注與推廣，且幼兒教育應營造優質的學習環境外更需讓幼兒有學習到可以帶走的能力（許碧勳、吳青蓉，民 97），葉尚旻(民 96)也提到資訊科技融入繪本教學有助於提昇幼兒的注意力、激發學習興趣、增進幼

兒參與教學活動之興趣與期待以及促進幼兒主動閱讀，其中對於文句、短文等之理解力皆不相同，與在學習系統的設計有很大的關係。

2.5 小結

為了讓幼兒可以開心輕鬆學習顏色與形狀的內容，因此先透過各相關研究的分析，了解到幼兒在學習的互動模式與遊戲模式之不同與差異，因此將不同的學習模式-擴增實境，加入到 App 中來探討幼兒的對於利用過增實境學習的科技接受度及學習成效，希望藉由顏色與形狀的學習內容，可以激發小朋友的興趣，促進主動學習。

3 研究方法

本研究運用擴增實境技術結合形狀及顏色之數位學習，設計開發一款名為「CoShaper」的學習應用程式，針對幼兒在使用後對於科技接受模式與學習成效的影響作探討。實驗進行方式以 CoShaper 學習應用程式教導幼兒，並針對學習後做科技接受模式及學習成效等相關問卷及深入探討。

3.1 CoShaper

以 Unity 結合 3Ds Max 及 Vuforia，設計一款形狀及顏色教學應用程式，名為「CoShaper」。CoShaper 包含兩項功能，左邊書本圖案為平面學習模式，右邊相機圖案為立體學習模式，藉由擴增實境學習立體形狀及顏色（如圖 4）。在形狀部分，包含圓錐、圓柱、球體、長方體及三角柱等五種形狀，讓幼兒認識基礎立體圖形；在顏色部分，有別於選擇紅、黃、藍、綠等基本色彩，列舉出灰色、粉紅色、墨綠色、褐色及紫色等五種顏色，供孩童認識與學習。

圖 4. oShaper 主畫面圖

點擊左邊書本圖案，即會呈現各形狀及顏色的介紹畫面；左上角小鳥圖為返回鍵，回到首頁，如圖 5。點擊右邊照相圖案，即會出現擴增實境的拍照畫面，掃描紙本圖片後，即出現形狀的立體樣貌，如圖 6-7。

圖 5. 圓錐、灰色

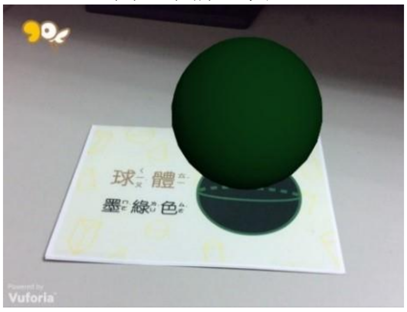


圖 6. 球體、墨綠色

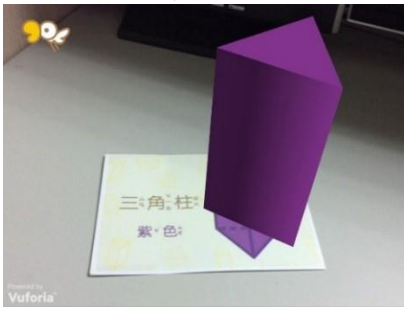


圖 7. 三角柱、紫色

3.2 研究架構

本研究主要以國立臺北教育大學附設實驗國民小學附設幼兒園的幼兒為施測對象，並針對受測幼兒之個人基本資料背景變項進行瞭解。自變項為教學方法，對照組使用傳統紙卡教學、實驗組使用擴增實境教學，依變項為幼兒的學習成效，同時在實驗組進行科技接受模式施策。

3.2.1 科技接受模式

本研究以 Davis(1989)提出的科技接受模式為理論基礎，主要探討知覺有用性、知覺易用性、使用態度及行為意願等四個構面，其中知覺有用性及知覺易用性皆會影響使用態度。參考蕭鈞彥(民 100)之研究，以科技接受模式為基礎，探討影響學齡兒童使用態度和行為意圖之因素，以及加入認知玩興和認知流行性後，探討各變項之間的相互影響關係。

3.2.2 學習成效

在施測部分,幼兒在學習成效實驗所做的填答問卷,採用研究者自行編製 CoShaper 學習成效相關問卷。

3.3 研究方法

本研究採用問卷調查法來蒐集實驗資料,針對幼兒使用 CoShaper 應用程式之形狀及顏色學習做研究,並以本研究編寫之問卷量表做為研究工具。於問卷回收後分析有效問卷並進行編碼建檔,並以統計軟體 SPSS 12.0 中文版軟體進行資料統計分析。

3.3.1 問卷計分方式

本研究量表採用李克特五點量表(Likert scale),選項分別為「非常同意」、「同意」、「普通」、「不同意」、「非常不同意」,並依序給予 5、4、3、2、1 分,分數愈高代表愈同意。

3.3.2 問卷設計

在問卷設計的部份分為三部分,第一部份為個人基本資料調查,包含性別及年齡;第二部分為科技接受模式量表(僅實驗組有);第三部分為學習成效的前、後測問卷。

(1)科技接受模式

科技接受模式問卷中,參考 Davis(1989) 所提出之理論,其用來解釋資訊科技接受的決定因素,而其四個構面分別為知覺有用性、知覺易用性、使用態度、行為意願四個構向來做問卷設計。而張玲娟(民 102)、王瑋伶(民 103)、林芳瑜(民 104)也在研究中使用此模式之問卷探討幼兒對資訊之科技接受模式之研究,了解幼兒對於擴增實境的學習方式是否可以接受以及行為操作方式,進而幼兒透過 CoShaper 增加學習動機、學習意願,嘗試學習新事物。

(2)學習成效

在形狀及顏色的學習成效前測問卷,了解幼兒在學習前對形狀及顏色的認知程度;在形狀及顏色的後測問卷,幼兒透過 CoShaper 或傳統紙卡學習後對形狀及顏色的認知程度,並且針對 App 的一些相關學習感受做調查。且在施測過程中,亦針對幼兒做前測及後測的實驗,以了解幼兒對於形狀學習的學習成效。

(3)問卷內容

在形狀及顏色的學習成效前、後測問卷中,分別針對形狀(題目 1-1 至 1-5)及顏色(題目 2-1 至 2-5)的分辨詢問幼童對其認知程度,並且詢問幼童使用後的感受,其實驗組題目如 3-1 至 3-6,而對照組之問卷題目則將 CoShaper 替換成圖卡。

(1-1) 我能清楚分辨圓柱
(1-2) 我能清楚分辨三角形
(1-3) 我能清楚分辨長方體
(1-4) 我能清楚分辨圓錐
(1-5) 我能清楚分辨球體
(2-1) 我能清楚分辨粉紅色
(2-2) 我能清楚分辨紫色
(2-3) 我能清楚分辨褐色
(2-4) 我能清楚分辨灰色
(2-5) 我能清楚分辨墨綠色
(3-1) 我認為 CoShaper 很好玩
(3-2) 透過 CoShaper 的學習,可以認識許多形狀及顏色
(3-3) 使用完 CoShaper,我知道如何正確的判斷形狀
(3-4) 使用完 CoShaper,我知道如何正確的判斷顏色
(3-5) 使用完 CoShaper,使我感到快樂
(3-6) 我希望未來的課程,也能採用 CoShaper 的方式同步進行

而在科技接受模式的問卷中,針對知覺有用性(題目 1-1 至 1-3)、知覺易用性(題目 2-1)、使用態度(題目 3-1 至 3-3)及行為意願(題目 4-1 至 4-2)四個面向探討,其題目如下:

(1-1) 透過 CoShaper 的學習,我能夠分辨不同的形狀
(1-2) 透過 CoShaper 的學習,我能夠分辨不同的顏色
(1-3) 透過擴增實境的方式學習,使我覺得很有趣
(2-1) 對我而言,使用 CoShaper 的內容及功能是容易的
(3-1) 我認為使用 CoShaper,使我感到收穫良多
(3-2) 我認為透過 CoShaper 中的擴增實境,會增加我對形狀、顏色學習的意願
(3-3) 我認為透過 CoShaper 中的擴增實境,會讓我想再學習一次
(4-1) 我認為使用 CoShaper 可以滿足學習上的需求
(4-2) 整體來說,我未來繼續使用 CoShaper 的意願相當高

3.4 施測情形

施測過程分為兩階段：第一階段實驗組以平板偵測實體紙卡上的圖形，於螢幕上顯現出立體圖像，並讓幼兒實際操作平板；對照組則是以顏色與形狀學習圖卡進行教學，正面圖卡有彩色立體圖像與說明，而背面圖卡僅有彩色立體圖像。第二階段以問答方式協助幼兒進行問卷作答。同時有七組幼兒進行施測，平均每位學童約進行 12-15 分鐘的實驗過程，實際施測情形，如圖 8-9。

圖 8. 教導幼兒使用平板

圖 9. 教導幼兒使用擴增實境功能

4 實驗結果

4.1 樣本之基本資料分析

實驗組共有 21 名幼童參與，對照組亦有 21 名幼童參與實驗，共 42 名幼童參與本實驗。在科技接受模式之問卷調查回收之有效樣本數共 21 人；學習成效之問卷調查回收之有效樣本數共 42 人，在針對受測幼兒之個人基本資料背景變項進行瞭解，包括受測幼兒之性別及年齡等變項，分別描述其次數及百分比分配。

(1)性別

總施測人數共 42 人，在實驗組部分包含男性 11 人(52.4%)，女性 10 人(47.6%)；對照組部分包含男性 12 人(57.1%)，女性 9 人(42.9%)。

(2)年齡

在實驗組部分包含 5 歲的有 9 人(57.1%)，6 歲的有 12 人(42.9%)；在對照組部分包含 5 歲的有 17 人(81%)，6 歲的有 4 人(19.0%)，各 21 人施測。

4.2 問卷信度分析

本節在瞭解其施測問卷的信度，於問卷結束後回收，並進行問卷信度分析。根據問卷信度分析後的結果，本研究之科技接受模式問卷全體量表之總信度為 0.891，而各構面之數值如下表，其皆大於 0.6（如表 1）。

表 1. 問卷信度分析表-科技接受模式

構面	個數	Cronbach's α
知覺有用	21	0.607
使用態度	21	0.887
行為意願	21	0.948

本研究之學習成效問卷全體量表之總信度為 0.88，而各構面之數值如下表，其數值落在 0.4 至 0.8 之間，表示本問卷信度可信度高（如表 2）。在形狀分辨之前後測的比較中，後測數值較低，其原因是幼童在使用擴增實境 App 時，由於形狀從平面變成立體，故在分辨時有時會有誤，而影響到後測數值。

表 2. 問卷信度分析表-學習成效

構面	個數	Cronbach's α			
		實驗組		對照組	
		前測	後測	前測	後測
形狀分辨	21	0.555	0.404	0.477	0.673
顏色分辨	21	0.500	0.702	0.655	0.852
使用態度	21	0.835		0.847	

4.3 研究結果分析

(1)科技接受模式

幼兒在科技接受模式的整體及各層面情況意指在「科技接受度量表」中的平均得分，得分越高，表示科技接受模式越高，以下就以「科技接受模式量表」的四個層面，依平均數、標準差、變異數做說明，如表 3。根據科技接受模式量表分析後的結果，對照李克特五點量表，本研究之知覺有用性、知覺易用性、使用態度及行為意願之數值皆大於平均數 3，表問卷可靠性高，其中又以知覺易用性為

最高。標準差及變異數部分最低數值皆為使用態度，表施測對象之正負面感受相近。

表 3. 「科技接受模式量表」平均數、標準差及變異數

構面	個數	題數	平均數	標準差	變異數
知覺有用性	21	3	4.29	0.07	0.00
知覺易用性	21	1	4.48	0.22	0.06
使用態度	21	3	4.38	0.07	0.00
行為意願	21	2	4.21	0.10	0.00

(2)學習成效

幼兒在學習成效的整體及各層面情況意指在「學習成效量表」中的平均得分，得分越高，表示學習成效越高，以下就以本研究所設計之問卷，依平均數、標準差、變異數做說明，如表 4 與表 5。根據學習成效量表分析後的結果，對照李克特五點量表，本研究之實驗組及對照組之形狀學習、顏色學習及使用態度構面之數值皆大於平均數 3，表問卷可靠性高。標準差及變異數部分最低數值皆為學習感受，表施測對象之正負面感受相近。在顏色學習及使用態度上之信度較低，在於擴增實境的模型色彩會有光影之差異，造成幼兒對於顏色的記憶與辨認度並不高，而影響顏色學習之情況。

表 4. 「實驗組」之平均數、標準差及變異數

構面		個數	題數	平均數	標準差	變異數
前測	形狀學習	21	5	3.44	0.03	0.00
	顏色學習	21	5	4.44	0.04	0.00
後測	形狀學習	21	5	4.08	0.04	0.00
	顏色學習	21	5	4.60	0.04	0.00
使用態度		21	6	4.44	0.04	0.00

表 5. 「對照組」之平均數、標準差及變異數

構面		個數	題數	平均數	標準差	變異數
前測	形狀學習	21	5	3.22	0.03	0.00
	顏色學習	21	5	4.32	0.04	0.00
後測	形狀學習	21	5	3.97	0.04	0.00
	顏色學習	21	5	4.49	0.04	0.00
使用態度		21	6	4.25	0.04	0.00

施測過程中，實驗組的幼童起初拿到平板時皆表現出興奮的神情，打開 CoShaper 的畫面後，更是表示介面可愛且很喜歡。在操作使用上，幼童一開始時對於相機掃描平面圖片的位置還不太會抓取，但經過解說及練習掃描數次後，漸漸的對螢幕上顯示的立體圖像感到有興趣，逐漸克服剛開始所具有的挫折感。

而從表 4 及表 5 的數據中，形狀學習的實驗組後測較前測之平均數高 0.64，顏色學習的實驗組後測較前測之平均數高 0.16；形狀學習的對照組後測較前測之平均數高 0.75；顏色學習的對照組後測較前測之平均數高 0.17。由此可知，幼童在圖卡學習形狀及顏色較本研究所開發之 CoShaper 學習形狀及顏色佳，故對於幼童學習較不適用平板，仍偏向舊有的圖卡教學。此結果與李來春、郝光中(民 102)的結果不太一至，該研究指出 AR 的教材整提提升學生的學習興趣與學習成效。

5 結論與建議

科技的進步帶來的影響含括各領域、各年齡層以及各行各業，對於擴增實境應用於學習教材的研究也越來越多，本研究建議未來其他研究者可製作更多的教材，讓幼兒、小學、國中、高中生可有不同的方式做學習，並且對於大專院校學生加以訓練撰寫、開發教材。

本研究的實驗結果指出，首先，普遍幼兒可以接受 AR 融入資訊教學，在 AR 融入顏色與形狀教學中，在總分 5 的科技接受模式評分中，平均獲得 4.2 以上的高接受度回饋。再者，使用 AR 在顏色與形狀教學中，幼兒的學習成效並沒有比較好，反而是單純使用傳統圖卡在顏色與形狀教學上的幼兒，其學習成效高於此用圖卡搭配 AR 學習的幼兒。

大部分的幼兒在使用 CoShaper 後，對於形狀及顏色的辨識學習力較高，在本次研究中，針對科技接受模式及學習成效之施測數據做分析，整體的科技接受模式皆有提昇，在知覺易用性更有大幅度的差距，進而提昇正向學習態度與學習意願。在學習成效部分，根據實驗組及對照組的分析數據，以形狀學習來看，實驗組之前後測差距為+0.64，對照組之前後測差距為+0.75；以顏色學習來看，實驗組之前後測差距為+0.16，對照組之前後測差距為+0.17，我們可以看出在前測與後測的差距中，形狀學習的差距數值明顯高於顏色學習，但在學習成效部分，對照組使用圖卡之學習成效高於實驗組使用擴增實境之學習成效。

然而，本實驗進行期間，幼兒在操作 AR 進行學習時，皆為興奮、感到有趣。相信 AR 已吸引幼兒的目光，並順利學習與討論，成為同儕、師生間互動的話題之一。故本研究建議

擴增實境可做為輔助幼兒學習的方法之一，但無法以擴增實境學習來取代原先舊有的圖卡學習。

由於本研究樣本數取得便利，在受測者的年齡差異性並不大，在未來可以探討年齡差距更大的受測者來做分析，也針對更多的形狀及顏色做內容的增加，也將添增語音介紹，應用於雙語教學，用如有聲書的學習方式協助幼兒學習。未來將朝 AR 在幼童學習上的學習興趣、學習動機、學習滿意度…等進行進一步探討與研究。

誌謝

本研究感謝中華民國科技部專題研究計畫之部分經費補助，計畫編號為 105-2420-H-152 -003 -MY2。

參考文獻

王瑋伶（民 103 年）。**運用科技接受模式於幼兒園家長對科技玩具使用意願之探討**。中華大學科技管理學系碩士班碩士論文（未出版碩士論文）。

江蓓（民 99 年）。**幼兒應用七巧板建構圖系認知能力之研究**。南華大學應用藝術與設計學系研究所碩士論文（未出版碩士論文）。

李來春、郝光中（民 102 年）。擴增實境應用於互動式英語教材教學之研究-以國小五年級英語三個單元為例。**國際數位媒體設計學報**，5(1)，51-64。

周君倚、陸洛（民 103 年）。以科技接受模式探討數位學習系統使用態度－以成長需求為調節變項。**資訊管理學報**，21(1)，83-106。

林宜樺（民 98 年）。**以擴增實境技術從遊戲學習觀點探討幼兒視知覺能力影響之研究-以智慧多寶格為例**。嶺東科技大學數位媒體設計研究所碩士論文（未出版碩士論文）。

林芳瑜（民 104 年）。**以科技接受模式探討幼兒園教師透過 Facebook 進行親師互動之行為研究**。南華大學資訊管理學系碩士論文（未出版碩士論文）。

姜敏琳（民 99 年）。**「七巧板創意教學方案」對幼兒創造力表現之研究**。國立臺灣師範大學創造力發展碩士在職專班（未出版碩士論文）。

洪勁亭（民 98 年）。**七巧板遊戲─幼兒之形狀組合表現**。國立臺南大學幼兒教育學系碩士班碩士論文（未出版碩士論文）。

旅行台灣（2.0.20）（民 106 年）。Google Play：交通部觀光局。

張玲娟（民 102 年）。**以科技接受模式探討教保服務人員與家長透過網路互動意願之研究~以彰化市公立幼兒園為例**。亞洲大學資訊工程學系碩士在職專班碩士論文（未出版碩士論文）。

張淑玲、簡秀芬（民 104 年）。初探兒童對形狀保留與錯覺輪廓發展。**崇仁學報，**8，47-58

張靜文、張麗芬（民 103 年）。幼兒幾何圖形辨識之研究。**教育研究學報，48 (2)**，101-126。

許碧勳、吳青蓉（民 97 年）。幼兒英語「融入」教學之探。**教育研究學報，17**，97-116。

郭晉谷（民 102 年）。**應用擴增實境教材增進幼兒認知能力之研究**。大同大學工業設計學系(所)碩士論文（未出版碩士論文）。

買安政（民 99 年）。**擴增實境系統應用於幼兒學習之研究-以學習四季服裝穿著為例**。崑山科技大學數位生活科技研究所碩士論文（未出版碩士論文）。

葉尚旻（民 96 年）。**資訊科技融入繪本教學對幼兒閱讀理解能力效應之研究**。國立臺北教育大學課程與教學研究所學位論文（未出版碩士論文）。

趙敏雲（民 93 年）。**學齡前幼兒色彩認知能力之研究**。樹德科技大學應用設計研究所碩士論文（未出版碩士論文）。

劉金花（民 102 年）。**兒童發展心理學**。台北：五南。

蔡雅如（民 104 年）。**實體七巧板與虛擬七巧板對幼兒創造力、空間能力、學習成效與學習興趣之影響─以互動式電子繪本為例**。國立臺灣科技大學數位學習與教育研究所碩士論文（未出版碩士論文）。

鄭明韋（民 88 年）。**國立空中大學嘉義地區學生學習方式、學習參與程度與學習成效之研究**。國立中正大學成人及繼續教育研究所碩士論文（未出版碩士論文）。

蕭鈞彥(民 100 年)。**採科技接受模式探討學齡兒童社群網站之行為意圖－以大台南市國小高年級學生使用 Facebook 為例**。南華大學(未出版碩士論文）。

寶寶學形狀-幼兒教育遊戲-寶寶巴士（8.10.00.00）（民 106 年）。Google Play：BabyBus Kids Games。

Azuma, R. (1997). A survey of augmented reality. *Teleoperators and virtual environment*s, 6(4), 355-385.

Davis, F. (1989). Perceived Usefulness, Perceived Ease of Use, and End User Acceptance of Information Technology. *MIS Quarterly*, 318-340.

Fantz, R. L. (1961). A method for studying depth perception in infants under six months of age. *Psychol Rec,* 18-22.

Fishbein, M., & Ajzen, I. (1975). Belief, Attitude, Intention and Behavior: An Introduction to Theory and Research, MA: Addison-Wesley.

Lowenfeld, V., & Brittain, L. (1987). *Creative and mental growth* (8th ed). New York: MacMillan Publishers.

Milgram, P., & F. Kishino. (1994). A Taxonomy of Mixed Reality Visual Displays. *IEICE Transactions on Information and Systems,77(12).* 1321-1329.

Niantic (2017). Pokemon Go. Retrived from http://pokemongo.nianticlabs.com/en/

互動式電子白板融入國小特教班功能性數學課程教學之行動研究

林仁智 [1]，陳雪玲 [2]，謝文錡 [3]
1 國立臺北教育大學數位科技學系，yachih@tea.ntue.edu.tw
2 國立臺北教育大學數位科技學系(玩具與遊戲設計在職碩士班)，mama824@gmail.com
3 國立臺北教育大學數位科技學系(玩具與遊戲設計在職碩士班)，pz0928@gmail.com

摘要

本研究旨在了解教師實施互動式電子白板搭配虛擬教具融入國小自足式特教班功能性數學課程領域教學之成效，本研究除解決特教班教師在傳統教學上的困擾，並提昇學生學習成效，研究者經由實際參與的過程也可獲得專業成長。本研究採行動研究法，研究對象為新北市某國小自足式特教班一、三年級學生 4 人，透過 6 週、18 堂課進行教學，研究者擔任教學設計者及教學者，在教學歷程中，學生資料包括上課操作電子白板時的答題紀錄、問卷以及訪談等資料；教師資料則包括教學日誌、教學省思、同儕教師觀察記錄和檢核表以及教學錄影等，進行質性分析。依據研究目的與結果，互動式電子白板搭配虛擬教具應用於國小特教班學生學習功能性數學課程，有助於提昇學生的學習成效，改善學生的學習態度，以及增進學生與教材、教師及同儕之間的互動。透過行動研究的省思有助於改善教師實際教學的困境，並增進教師多元的教學方法及教材設計的能力。

關鍵詞：互動式電子白板、功能性數學課程、虛擬教具、行動研究、自足式特教班

The Action Research of Using Interactive Whiteboard on Teaching Functional Mathematic for Self-contained Special Classes in Elementary School

Jen-Chih Lin [1], Hsueh-Lin Chen [2], Wen-Chi Hsieh [3]
1 National Taipei University of Education Department of Digital Technology Design, yachih@tea.ntue.edu.tw
2 National Taipei University of Education Department of Digital Technology Design (Master Program in Toy and Game Design), mama824@gmail.com
3 National Taipei University of Education Department of Digital Technology Design (Master Program in Toy and Game Design), pz0928@gmail.com

ABSTRACT

This study aims to understand the implementation while teachers using the interactive whiteboard and virtual teaching manipulatives in functional mathematics curriculum of self-contained special classes in the elementary school. This research not only tries to solve problems of special education teachers in the traditional teaching, but promotes to enhance student learning. The researchers of this study can also obtain the professional growth through the actual participation. The study is based on an action research, and the participants of this study are four mental retardation students in self-contained special classes in an elementary school in NewTaipei City. This research is implemented in 18 lessons through 6 weeks, and the researcher, through the action research, plays the role of both course designer and instructor. During the research period, qualitative data are collected and analyzed through the answer recording, questionnaires, student interviews, teacher reflection journals, instructional introspections, co-teacher observations, checklists and video-taping in classes. According to the purpose and the result, Applying interactive whiteboard in elementary special education functional mathematics curriculum really helps to improve student learning outcome, learning attitude and the interaction among the students, teaching materials, teachers and peers. Through the action research, teachers could improve

IJDMD/Vol9. /No.1 23

teaching materials, teachers and peers. Through the action research, teachers could improve plight of teaching, promote teaching methods and enhance the abilities of teaching material design.

***Keywords*: Interactive Whiteboard, Functional Mathematics Curriculum, Virtual Manipulatives, Action Research, Self-contained Special Classes

1 研究背景與動機

特殊教育的最終目標，就是希望身心障礙者能夠獨立自主、成功適應社會生活，因此如何能教導智能障礙學生學習具備適應未來生活的能力，當是特殊教育裡不可或缺的一環。

以往研究者大都以講述搭配圖片或實體教具方式來進行教學，但卻常見到學生上課專注力不夠，學習態度不夠積極，因此，研究者開始思考，有沒有什麼方式，能夠使自己的教學過程更加有趣？可以更吸引學生的注意力，讓學生們可以更加有效的學習到老師所想要教給他們的內容？

1.1 智能障礙學生需要具備適應生活環境的能力

1992 年美國智能障礙協會（American Association on Mental Retadation 簡稱 AAMR）將社區生活所需具備的所有適應行為技能分為：溝通、自我照顧、居家生活、社交能力、使用社區、自我引導、健康及安全、功能性學科能力、休閒娛樂及工作等十大領域（中華民國智障者家長總會，2008）。

功能性課程（functional curriculum）涵蓋許多領域，其中從數學教育發展出功能性數學課程。智能障礙學生學習數學課程應結合功能性課程的觀點（何素華，1995），因此功能性課程在智能障礙者學習數學時，扮演重要意義。

Westling 與 Fox（2000）指出多重與重度障礙者的教育強調功能性教學的理念，以教導學生達成生活中獲得最大的功能為指標，亦即教師應竭盡所能教導學生，使學生得以在未來生活中發揮個人最大的功能，完全參與社區與成人之生活。

功能性數學包含哪些課程內容？功能性數學課程內容必須是每天生活中會使用到的，教材應對學生具有實用性（Browder et al., 2004）。因此，功能性數學課程的內容，包含基礎算術能力、金錢使用、測量和時間等四大領域（Valletutti, Bender, & Sims-Tucker, 1996），例如測量房間、計畫學校的旅遊、查閱公車時刻表、計算購物的花費及購物應該找回多少錢等（Cain, 2007）。

智能障礙學生具有一般認知及後設認知、注意力與記憶力方面的缺陷，以及無法將所學類化遷移、缺乏學習動機，再加上其語言方面的能力也不佳，並有負向的社會情緒等人格特性（黃美瑜，2002；鈕文英，2003），這對於需仰賴複雜認知歷程、抽象程度較高且著重解題的數學學習是一項極其困難的挑戰。

研究者來到服務的學校擔任特教班教學已進入第十五年，特教老師每天必須面臨許多的課前教學準備及班級瑣事，加上學生常有突發狀況，以致常常覺得分身乏術。現今國小特教班學生大多是中重度智能障礙或多重障礙兒童，身心障礙學生在邏輯推理、注意力及記憶力等方面較為缺乏，且無法將所學習的內容類化遷移，以致影響其學習成效。故研究者希望能利用互動式電子白板教學，設計相關的功能性數學課程教學活動，協助中重度智能障礙學生適應生活環境，以期能培養學生帶著走的能力。

1.2 使用電子白板進行教學有助提升學生學習成效

智能障礙學生的學習認知發展遲緩、注意力缺陷無法吸收課程內容、遷移類化困難、缺乏有效學習策略、短期記憶差、學習動機低落等特徵，導致學業成就表現低落（林怡君，2001；侯禎塘，2004）。

教導學生若只注重以書本講授，學習的效果一定是有限的，而多媒體能產生令人印象深刻的視聽效果，可以刺激整個大腦的學習，智能障礙學生當然更需要此種多感官、具刺激性的教學方式以增進其記憶的功能（朱經明，1999）。

因此，如何在教學中維持其注意力，引發學習動機與興趣是一項重要工作。以電子白板教學為例，它能培養學生獨立解決問題、利用互動式的內容理解概念、更能將生活經驗融入教材中、擴大示範步驟，身心障礙學生因身心特質導致學習困難的問題，可藉由電子白板的輔助，提高身障學生學習成就，有助於提升其學習成效（王玲，2010；蔡貞瑩，2010；賴暄頤，2010；梁芯佩，2010；陳明全，2011；覃

業芬，2011；江毓鈞，2012）。

研究者將設計功能性數學課程教材，以學生生活為中心，利用 IWB 電子白板教學，探討對國小特教班學生的功能性數學課程學習成效，輔以 IWB 電子白板教學及互動式評量，藉以協助特教班學生增進未來生活能力。

1.3 互動式電子白板運用在教育上具有簡易可行及好操作的優勢

身心障礙學生常因其生理或心理缺陷，而導致學業成就表現低落，故教師應採用生動活潑且生活化的教學來提高學生的學習興趣與自信心。且許多特殊學生手部精細動作差、視動協調性不佳，操作滑鼠不易，而影響其參與電腦教學遊戲或評量的機會，教師透過互動式電子白板不同的操作模式及寬大的顯示螢幕，使身心障礙學生克服操作電腦的困難，例如操控滑鼠、單擊點選拖曳等能力，改以簡單感應筆觸碰或手指頭點選方式來操作，且顯示教學面板面積大，學生可以清楚地看到整個教學流程，利用視覺互動軟體更可提升學生學習興趣。

互動式電子白板促進了白板與電腦之間雙向互動，也增強了教學現場教師與學生的互動，加上在白板上所書寫的內容都可以轉存為數位化的檔案，所以學生可以運用這些檔案進行複習或重新學習，增強了學生主動學習的資源（蕭英勵，2007）。

本研究採用互動式電子白板來建置互動式的教學環境，期盼藉此替代性的教學媒材，達到活化教學與教材的目的，提升學生的學習成效與態度。互動式電子白板為強調師生雙向互動的教學，能讓學生對學習產生興趣，也符合了身心障礙學生的學習需求。

1.4 採取行動研究可解決教學的困難

Altrichter, H., Plsch, P.和 Somekh, B.（1997）提出行動研究不同於其他研究是因為：1、行動為研究過程中的一個重要部分。2、必定是局內人的研究，由實務工作者對其專業行動。3、進行研究受研究者專業價值觀所主導，而不只是方法論的考慮。

覃業芬（2011）表示行動研究其實施步驟與一般實證研究最大的不同點在於：行動研究所發生的問題是在實際的工作情境當中，且研究焦點將是你自己設定的行動所要達成的目標。它主要的目的是改善實務工作，且在改善的過程中，研究者不斷的檢討、修正以符合研究目的的需要。

而研究者在特教班多年的實際教學經驗中，發現特教班學生在學習的特性上，大都是記得慢、忘得快，在教學過程中也無法提供大量且多元的教具供學生反覆操作練習；電子白板的軟體功能提供大量圖庫的資源，正好省去製作大型教具的時間與精力，也讓老師們不用再苦苦印製圖片，而電子白板的互動性也正好提供了視覺、聽覺、觸覺等多感官的刺激，尤其在像特教班小班的教學環境中，每一位學生都能體驗和互動，程度較弱的學生也可以藉由觀摩其他同學的操作，而能夠加深或提醒自己的不足；

除了實際操作與立即回饋，電子白板的課堂互動工具也提供了特教學生中最需要的精熟學習與大量練習，簡單的步驟就可以讓老師輕易改變題目的位置，讓學生真正理解與練習而非只是單純背誦答案的位置。因此研究者欲解決在教學上所面臨的實際問題。

2 文獻探討

2.1 電子白板

電子白板（Interactive Whiteboard）係指一具有高靈敏度之觸碰式大型螢幕，利用USB傳輸線直接與電腦相連，並連結單槍投影機而運作，即可在白板上投影出電腦畫面內容，近年來因教育部的推廣而大量引入學校使用。電子白板能提供互動學習，利用感應筆或手指直接碰觸白板螢幕來控制電腦，改變傳統以鍵盤或滑鼠輸入的方法，並結合傳統黑板教學的方式與互動式電子白板所提供的軟體，讓學生可以在白板上控制移動教材，書寫文字或畫圖、標記符號、完成學習任務，結合模擬軟體提供立即回饋。所有教學的歷程、學生操作的過程，皆可透過電子白板所提供的軟體將結果記錄下來。

本研究所使用的電子白板，是日商Hitachi 的 StarBoard 超音波感應式電子白板（FX-77G），此電子白板以電子感應筆在白板上觸壓，即可形成滑鼠功能，操控電腦上的各種應用程式或檔案。

2.2 智能障礙兒童

根據我國 2006 年修訂的『身心障礙及資

賦優異學生鑑定標準』對智能障礙的定義，是指『個人之智能發展較同年齡者明顯遲緩，且在學習及生活適應能力表現上有嚴重困難者』（教育部，2006）。其鑑定標準如下：

一，心智功能明顯低下或個別智力測驗結果未達平均數負二個標準差。

二，學生在自我照顧、動作、溝通、社會情緒或學科學習等表現上較同年齡者有顯著困難情形。

本研究所指的『智能障礙兒童』，係指領有中重度智能障礙之身心障礙手冊，經新北市特殊教育學生鑑定及就學輔導委員會鑑定安置，就讀於新北市某國小自足式特教班中的學生。

2.3 功能性課程

Patton, Cronin, Bassett 與 Koppel(1997) 將功能性課程定義為符合個別學生具體的生活需求，及學生轉銜到成人後的生活型態，包括就業和教育、家和家庭、休閒工作、社區介入、身體和感情健康、個人責任等。

本研究所指的功能性數學課程源自於功能性課程，結合生活中數學應用的部分，強調有意義而完整的活動技能，而非孤立的學科技能，在教學中利用經過設計的教材，透過互動式電子白板的操作介面，讓受試學生學習錢幣運用、數量對應、與分類堆疊等符合生活經驗的學習項目。

2.4 行動研究

所謂「行動研究」，就是實務工作者在自己的工作場景中遭遇到一些問題，而研究者以「行動」和「研究」結合，並研擬出解決問題的策略，透過不斷的反省與修正的過程，解決實際所面臨到的困難，強調以研究者的需求和立場出發，透過擬定方案、行動、觀察、反思、批判的循環過程，對問題有系統的處理並留下記錄，以求得實務工作者在專業上的成長與進步。

本研究之互動式電子白板行動研究，研究者透過觀察發覺學生在功能性數學課程方面的需求，閱讀相關文獻、界定問題、擬定研究計畫、選擇研究程序、設計教學活動、實施互動式電子白板研究、蒐集資料、解釋資料、評鑑回饋、反省與修正等研究步驟，進行互動式電子白板應用於特教班功能性數學課程教學，並對該研究進行全面性的評鑑與檢討。

2.5 虛擬教具

虛擬教具是以電腦與軟體互相搭配，利用電腦技術產生數位影像，學習者看得到卻摸不到，但可利用滑鼠或電子白板的設備進行操控，與教學者、數位影像，進行三方面的互動。因此在應用上比傳統實體教具更具彈性，更能幫助學習者進行抽象思考與學習。

國內學者袁媛、陳國龍、張世明（2007）指出虛擬教具這套電腦軟體（程式），結合了實體教具與電腦科技，是適合國小學生使用的數學學習科技輔具。虛擬教具可以像視覺圖像表徵與操弄具體物表徵一樣豐富學生的視覺印象，對無法將抽象的數學符號和具體經驗，視覺影像相連結的特殊學生學習，有很大的幫助。教師應利用輔助工具幫助學生突破數學迷思，解決數學學習的盲點。而虛擬教具既能幫助學生具體的呈現數學題目，還能增加趣味性，提昇數學的自信心（朱淳琦，2011）。

袁媛等人（2007）進一步指出，虛擬教具可以呈現及補足傳統實體教具所缺乏的部分，且不佔空間，容易複製、分享，易於整理；能夠在教學中確實發揮輔助的效果。

本研究所指之虛擬教具，乃是國內學者所開發的中文版本，適合國內教師所使用的數學虛擬教具--【萬用揭示板（Magic Board）】。【萬用揭示板數學教學網】是一個公開的數學教師之社群網站（網址為 http://magicboard.cycu.edu.tw）。於 2005 年初步開發、設計的中文版本，以 Flash MX 2004 作為開發工具，由 95、96 年度國科會計畫補助建置（計畫編號 95-2520-S-033-003）。任何教學者皆可於此虛擬教具網站上隨時存取、分享資料，提供教學上的使用。且本網站沒有智慧財產權的限制，在使用上相當方便。

3 研究方法與設計

3.1 研究方法

本研究主要採行動研究之理念，透過實際教學之觀察與反思進行參與式觀察研究，設計適合學生學習之教材，並視學生學習反應調整教材及教學方式，使研究呈現真實且完整的教學實錄。

本研究以研究者任教的國小自足式特教班班上四名學生（一年級 1 位，三年級 3 位）

作為研究的對象，研究中所產生的問題除與本班另名特教班教師討論研究外，並向校內另外三位在特教領域學有專精的專家教師，作為修正教學活動設計的參考。

此次行動研究，主要是想透過互動式電子白板應用於國小智能障礙學生功能性數學課程教學，進而提昇教學品質及學習成效，促進研究者自身的專業成長；在整個過程，採以透過教學反思與修正的教學活動設計，在教學過程中隨時觀察學生學習，研究者再以修正後的教學課程進行教學實驗，經過不斷的修正、實驗之行動研究程序，以了解應用互動式電子白板運用於功能性數學課程教學之適用性。最後彙整研究結果，提出建議。今將研究架構說明如圖 1。

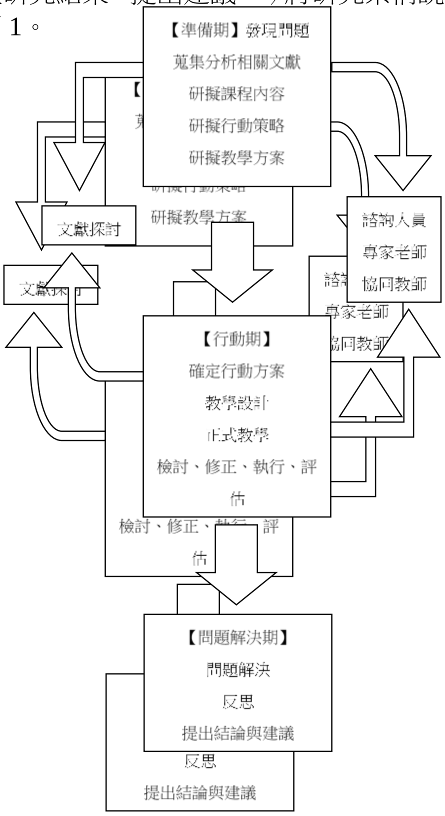


圖 1. 研究架構圖

3.2 研究對象

本研究採行動研究法，研究對象為新北市某國小自足式特教班一、三年級學生 4 人，透過 6 週、18 堂課進行教學。本研究旨在探討互動式電子白板（Interactive WhiteBoard，IWB）應用於國小特教班功能性數學課程教學對中重度智能障礙學生的學習及教師教學的影響。

運用互動式電子白板於課堂教學時，能否有效協助教學，解決教師所面臨的困境，以期在教學實務上獲得專業的成長。

本研究以研究者自己擔任之特教班學生為對象。研究對象為四人，二名男生，二名女生，分屬於一、三年級。本研究四位個案，以下以匿名稱呼如下表：

表 1. 研究對象基本資料一覽表

對象	小羅	小軒	小娟	小輝
年齡(年級)	8 歲 5 個月(三年級)	8 歲 5 個月（三年級）	8 歲 9 個月（三年級）	7 歲 11 個月（一年級）
障礙類別	智能障礙	多重障礙（肢智）	智能障礙	智能障礙
障礙程度	中度	重度	中度	重度

資料來源：研究者自行整理

3.3 行動歷程

行動研究法（Action Research）是研究教育上的實際問題並解決實際問題的方法，其可以一面研究一面改進，並可隨時修正，故又稱為『實施研究法』（蔡清田，2000）。

本研究依據吳宗立（2002）提出的觀點，將此次行動研究分為下列五個步驟，主要方法如下：

3.3.1 確認問題

行動研究與其他研究最大不同點，在於可以協助解決特定之實際教學問題。本校特教班學生由於本身生理因素及家庭因素，對於功能性數學課程的內容不甚瞭解，身為特教班教師的我想為這些學生提供一些協助，哪些情境下需要具備哪種能力來面對解決問題？如何有效採取互動式電子白板融入功能性數學課程教學來解決？

3.3.2 研擬計畫

本研究從分析教學情境、蒐集資料、擬定教學目標及價值的探討、與觀察教師的觀察與討論、參考相關文獻等等過程當中，擬定相關計畫，並發展行動策略，且進一步將所發展的行動策略付諸實踐。

3.3.3 行動策略

在行動研究過程中，研究者是個參與者與行動者，必須透過觀察、自我反省與批判行動策略及實踐情形，並檢視行動後的結果，倘若未能解決實務上的問題，必須再重新回到釐清情境的階段，重新澄清問題、蒐集資料與分析資料，再採取行動，如此重覆以上的步驟直至問題獲得改善或解決為止。

3.3.4 批判反省

行動研究注重的是研究成果的立即性與即時性，它強調的是『計畫→行動→評鑑→再計畫』的循環歷程，即研究與行動不斷的循環驗證，它容許隨時檢驗與修正。故研究者在研究過程中，即不斷經歷計畫、行動、蒐集資料、修正、批判與反省等歷程，以符合實際情境的需要，達到實質改進問題的目標。

3.3.5 評鑑回饋

研究者將每節上課錄影資料記錄於研究者日誌，再輔以觀察及訪談記錄等資料，掌握教學成效，作為改進行動計畫的依據。

3.4 課程內容設計

在本研究中，將針對國小特教班功能性數學課程教學嘗試融入 IWB，以改善過去傳統教學的不足，提昇學生的學習成效。本研究以學生身心發展的特質及需要為依據，在教材的設計上，掌握 IWB 支援教與學的特性及 IWB 軟體功能，並根據特殊教育課程綱要為原則，進行設計、規劃。以下針對課程內容規劃、研究工具、電子白板互動式評量教材、學生及家長訪談評量紀錄、教師觀察檢核表及教學流程等部分加以介紹。

3.4.1 課程內容規劃

根據行動研究的特徵及步驟，設計出了本研究 IWB 應用於國小特教班功能性數學課程的教學方案，並經由專家學者之修正，而發展定稿。

本研究參考特殊教育課程綱要及自編教材，將之設計為九個單元，本課程計畫預計分為二個階段實施，第一階段為『我會招待客人』第一～五單元，每週三節，共計二週六節課，第二階段為錢幣運用第一～第四單元，每週三節，共計四週十二節課，課程結束後給予學生評量、訪談，並檢討、反思教學與修正教學，以期能改善教學。

3.4.2 研究工具

本研究所使用的工具，主要有『電子白板互動式評量教材』、『學生及家長訪談評量紀錄』及『教師觀察檢核表』。

3.4.3 電子白板互動式評量教材

研究者將本研究之功能性數學課程內容依研究目的加以規劃，並使用國內學者所開發的，適合國內教師，公開的數學教師之社群網站

【萬用揭示板-數學教學網】（http://magicboard.cycu.edu.tw/newhelp/），來設計編輯主要教材，並輔以由高雄市岡山國中楊曲昌老師與鮑蕙茹老師設計製作的

『阿牛數錢幣與紙鈔』教學 CAI 軟體（http://www.mlses.mlc.edu.tw:8080/elearning/24/menu/index.htm），以及新北市林口國小林天貴老師所設計之

『金錢與消費』教學 CAI 軟體（http://www.mlses.mlc.edu.tw:8080/elearning/Money99/index.html），（以上兩項教學軟體均已獲得原作者授權同意研究者用於學術研究），應用於實際教學活動中。

主要教材分為兩大部分，第一部份為『我會招待客人』，單元包含有「需要幾張椅子」、「分配盤子和杯子」、「我會倒果汁」、「分配布丁和湯匙」以及「我會幫忙收拾」；第二部份為『錢幣運用』，單元包含有「認識錢幣」、「我會換錢」、「有多少錢」以及「怎麼付錢」。

輔助教材部分則選用了楊曲昌老師與鮑蕙茹老師『阿牛數錢幣與紙鈔 CAI』的設計裡，適合學生程度及教學目標且趣味性高的「認識錢幣和紙鈔」、「點數錢幣和紙鈔」、「兌換金錢」以及「拿出正確的金額」等單元；加上林天貴老師『金錢與消費 CAI』的設計裡的「錢幣連連看」、「硬幣湊湊看」、「硬幣值多少」、「唱數沒問題」和「唱數一百分」，以及消費技能之「自動販賣機」來進行介入。

課程進行方式以電子白板設計出互動式評量教材，並詳定遊戲規則。利用感應筆在電子白板上直接點選出正確解答來進行答題，透過連結畫面揭示答案。以下以第一單元「需要幾張椅子」為例說明其操作注意事項(如圖 2 和圖 3)：

1.學生使用感應筆拖曳畫面中的椅子，到

客人的身旁擺放。

2.程度較好的學生，除了可以一對一將椅子拉給客人坐之外，還可數算客人的數量並在下方答案區內做輸入，答案區右下角並有核對按鈕，若答對者畫面會出現動畫。

圖 2. 需要幾張椅子_教材 01

圖 3. 需要幾張椅子_教材 02

3.4.4 學生及家長訪談評量紀錄

以半結構式晤談方式的進行，預先設定好與互動式電子白板教學活動相關的問題，對學生以及家長分別進行訪談，目的在了解學生及家長對於使用互動式電子白板融入教學的感受。

3.4.5 教師觀察檢核表

同儕教師在課堂觀察中，針對學生的學習反應與研究者教學歷程中師生互動和教學問題的所知所感進行觀察檢核。

3.4.6 研究場域及對象

學校背景與研究場域分別說明如下。

一、研究學校概況

研究者服務的國小位於新北市五股區，該校屬於大型學校，並附設有幼稚園，校地呈四邊形。該校建校已九十餘年歷史，學校計有七棟大樓，包含辦公室、多功能教學大樓和各年級教室及科任教室，各棟樓之間由走廊銜接連結成『口』字型，中間部分為操場。

學校班級數包含普通班五十七班和一班特教班，1.5 班資源班。學校編制方面，計有一位校長，六位主任，教職員一百二十八位，學童約一千六百位。

特教班成立於民國 79 年，辦學績效頗受校內教師及社區家長好評，許多學生家長在孩子畢業離開學校後，還會定期回來班上擔任志工。該班教師皆為合格特殊教育教師，一位特教年資 15 年、一位 7 年，皆具備相當的專業知能。

二、教室環境布置

特教班教室共有二間教室及一間鋪設木質地板的生活及活動教室，本次研究因配合教室單槍投影機架設地點，而選在活動教室的一角進行（教室平面圖如圖 4）。

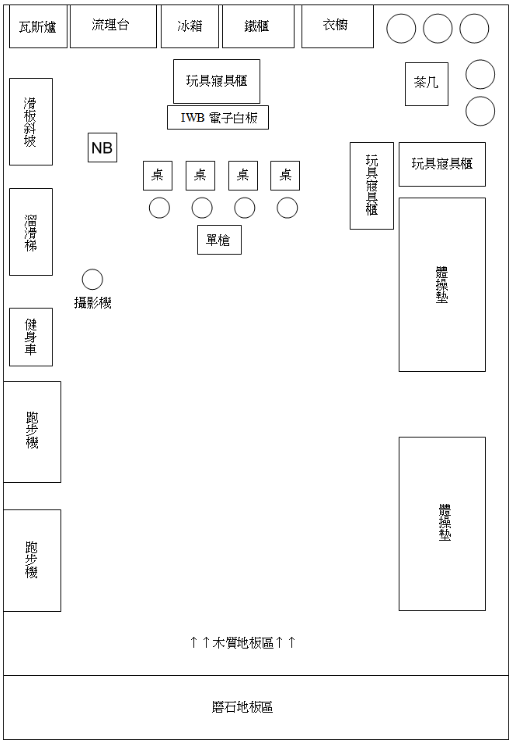


圖 4. 教室平面圖

3.5 研究之信效度

本研究所採取之行動研究，較偏向質性研

究。而質性研究之信效度，重點在於執行者的專業能力與執行時之嚴謹度。因此在研究過程中，研究者盡可能說明整個行動研究的過程，一方面從事評量回饋的教學工作，一方面進行研究資料的蒐集工作，並在研究中進行資料分析、反省、批判、澄清後再繼續觀察與檢視。

3.5.1 研究信度

高敬文（2002）指出，質化研究者主要以觀察、訪談、文獻分析等技術，來建構原始資料。他提出三項提昇質化資料信度的方法：一、盡量從不同資料來源蒐集資料；二、有意識的反省自己的思想背景、觀察偶感及初步的發現；三、隨時提醒自己尋找所謂的「否定證據」。

行動研究旨在瞭解和描述所經歷的一切，強調啟發、寫真和關連，而非對某種結果的測量和預測（林素卿，2002）。以教育行動研究觀點來談，其較偏向「內在效度」的評鑑，而較不重視「外在效度」的追求，較重視研究的可信賴性，而較不重視研究的普遍性（吳明隆，2001）。

為提高本研究之信度，研究者採取以下具體作法，茲分述如下：

一、在研究過程中，所得到之觀察記錄、研究者日誌、訪談記錄、評量等，經過比較與交叉檢核得到一致性的結果，並採低推論的描述與錄音、錄影記錄來增加信度，反覆確認研究對象的想法及思考歷程，避免研究對象不經思考脫口而出的回答影響了資料的可信度。而研究者在整理、分析資料並作成推論時，盡量以原案呈現，且在觀察記錄上，也盡量以客觀、中性的字詞描述，以避免個人主觀的情感加入，以提昇研究之「外在信度」。

二、在研究過程中，請協同教師擔任觀察員，對同一現象或行為進行觀察，並與協同教師一同討論，以獲得較具深度和廣度的資料，作為協助研究者教學修正之參考依據，從觀察結果的一致程度提高其「內在信度。」

3.5.2 研究效度

效度是指獲得正確答案的程度，亦即研究計畫能能夠獲得所要的東西，具有可靠性、可預測性與正確性。行動研究也重視信度和效度的課題，陳惠邦（1998）歸納出以下行動研究效度的四個標準：

1、倫理標準：即教師是否能重組知識與信念體系，並於重新審視教育實現時，能轉化為實踐行動。

2、邏輯標準：即研究問題的產生（除清楚說明研究問題外，還要呈現教師於該情境中，期望能達成的企圖心）、可概化性（清晰呈現與複製性，複製性即行動研究結果而引起他人的共鳴與啟發）、理論架構與嚴謹性（係指教育行動與理論架構之間，應有清楚而可辯論的關聯）。

3、實用性標準：指行動研究的策略、研究工具及研究歷程是否符合實際情境，是否盡可能與教室情境與教師的工作條件相符合。

4、審美標準：經由研究者反省札記、所經歷的協同關係，及研究者與協同研究者，與教育實踐情境中的學生，與其他教師之間的互動與共鳴情形，來加以判斷本研究是否符合行動研究的判斷標準及教師專業成長的精神。

Lincoln 與 Guba(1985)指出：質性研究的效度是指可靠性、穩定性、一致性、可預測性及正確性。

對許多研究問題需結合不同的資料蒐集方法，一種典型的方法組合是「三角檢核法」（triangulation）（夏林清等譯，1997），此種方法綜合了觀察、訪談組合而成，包含了教師的觀點、個別學生的觀點及中立的第三者的觀點。

秦麗花（2000）提到，質性研究一向被誤認為過於主觀，同一筆資料會因不同人而有詮釋上的差異，應運用多種方式、多種資料來源，或多個研究者的向度來增強資料間的相互效度檢驗來呈現研究報告的可信度，這就是所謂的三角測定。

為提高本研究之效度，研究者採取以下具體作法，茲分述如下：

一、在「自我效度」(self validation)方面

為避免研究者本身主觀的偏見，研究者運用三角檢核法(triangulation)，透過觀察、訪談、研究者的反省日誌及蒐集之相關文件資料等，在長期的參與研究中，持續性的觀察、記錄，以獲得多方面的資料，並進行檢核校正，以避免研究者之個人偏見，來提高研究內容的精確度。

二、在「同儕效度」(peer validation)方面

本研究請指導教授及研究者同校的同事專家老師們，作為意見的批判者，將研究活動蒐集的資料、分析歸納的結果，請指導教授及專家老師給予意見，以幫助研究者澄清概念和想法，研究者同時扮演參與者及教學者角色，除長時間參與觀察外，時時刻刻自我澄清、批判及反省，盡量以客觀、公正的角度觀察記錄研究歷程中之最真實事件，並經過不斷的蒐集與分析不同之研究資料，尋找矛盾的證據加以比較，以達到其效度。

三、在「學習者效度」(learner validation) 方面

研究者在教學活動中蒐集學生的文件資料，並不定期與學生晤談，在教師文件資料、學生學習文件和相關資料中，交叉比對，作為研究者想法和修止的依據。本研究歷經長時間的蒐集資料，在資料整理和分析的過程中，不斷與指導教授和研究所同儕定期討論研究的結果與發現，以期能提高本研究的「信賴度」。

3.6 資料蒐集

本研究採行動研究方式，在文獻分析與教學過程中，將持續的進行資料的蒐集與分析的工作。

本研究所採用的資料蒐集方法，以檔案資料為主，包括教師觀察、教學錄影、文件資料蒐集、訪談記錄、研究日誌及省思，分別說明如下。

3.6.1 教師觀察

行動研究強調教學者即觀察者，要求的是研究者個人的參與，故研究者在整個教學行動中，對於教學歷程中所觀察到的事件或行為加以記錄，透過此種方式能提供研究者反省、修正的依據。

3.6.2 教學錄影

從攝影機的視野可以顯現該情境整體串連的一個記錄，藉由呈現時間事件的連續性，錄影較其他資料蒐集的方法較易取得脈絡和因果關聯的現象（夏林清，1997）。研究者每次教學皆全程錄影，並將之轉錄為文字稿。

3.6.3 文件資料蒐集

本研究的文件資料包括教師文件資料及學生文件資料，分述如下：

（一）教師文件資料

包括教學準備資料、教學設計、特殊教育新課程綱要、資訊科技教學教材、評量設計、圖表和網路資源等，以做為資料解釋、佐證的工具，提供三角檢核的依據。

（二）學生文件資料

包括學生的學習單、上台練習紀錄、單元回饋單、課堂表現記錄、學習態度行為紀錄表及其它作品，做為了解學生的學習表現及研究者澄清、反思、修正之依據。

3.6.4 訪談記錄

本研究利用非正式訪談方式，於實施行動研究課程後進行，訪談對象為觀察教師、學生本人以及學生家長。研究者於日常課餘時，便可與觀察教師進行訪談、對話，以反思自己的教學，並從中獲得建議，並將訪談過程以錄音或筆記方式記錄。另外透過訪談瞭解實施行動研究課程後，學生對行動研究課程的接受度為何，以及對於此功能性數學課程的瞭解是否因此有所改變。

3.6.5 研究日誌及省思

研究日誌是最重要的研究方法之一，應將研究日誌視為整個研究歷程的同行伴侶，而不只是一個收集資料或分析資料的工具而已（夏林清等譯，1997）。透過省思日誌來記錄教學過程中所遇到的問題及困難、處理方式、處理結果、疑惑及反思，可提供研究者再次審視自己研究中的優劣得失，讓研究者可以再次反省自己在研究過程中所忽略的面向，提供自己再次行動時的參考。

4 研究結果與發現

本節主要分為三個部份，首先藉由學生接受 IWB 電子白板教學後，分析在電子白板互動評量教材的正確率，以了解電子白板融入本研究中功能性數學課程學生學習的成效。最後利用與學生與家長的訪談紀錄，了解學生對於透過電子白板在本課程中的學習態度。

4.1 學生學習紀錄

針對本教學設計十八節課學生課堂的反應，研究者紀錄學生兩階段的上課過程，檢視學生的 IWB 電子白板評量教材答對率。在『我會招待客人』中，包含「需要幾張椅子」、「分

配盤子和杯子」、「我會倒果汁」、「分配布丁和湯匙」和「我會幫忙收拾」等單元；以及在『錢幣運用』中，包含「認識錢幣」、「我會換錢」、「有多少錢」和「怎麼付錢」等單元，來分析學生本次 IWB 電子白板教學中兩階段的學習成效。

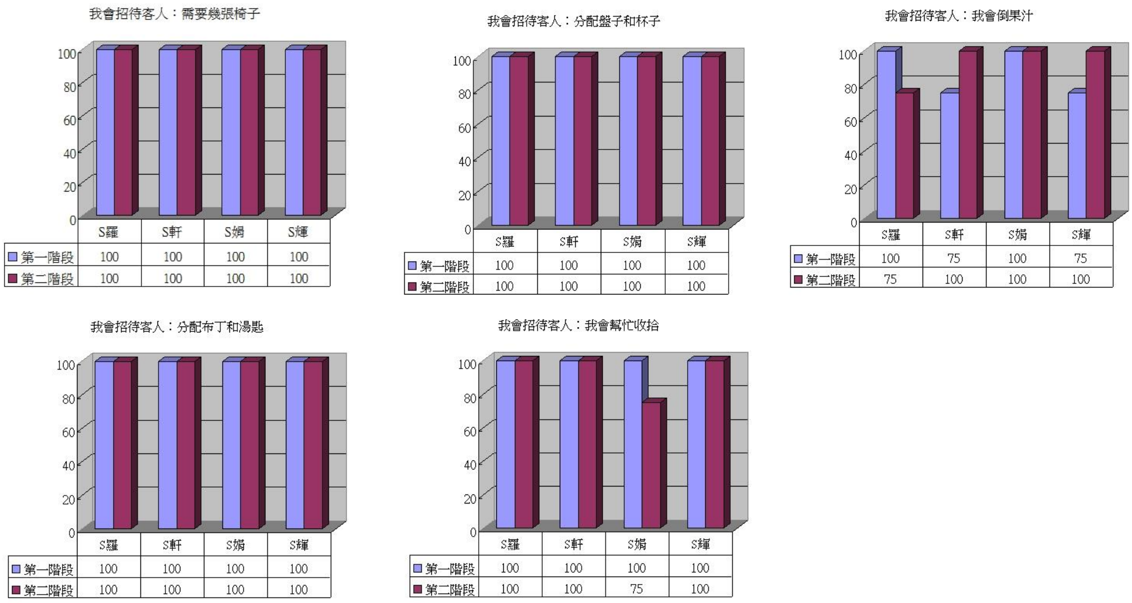


圖 5. 我會招待客人單元學生兩階段答對率統計圖

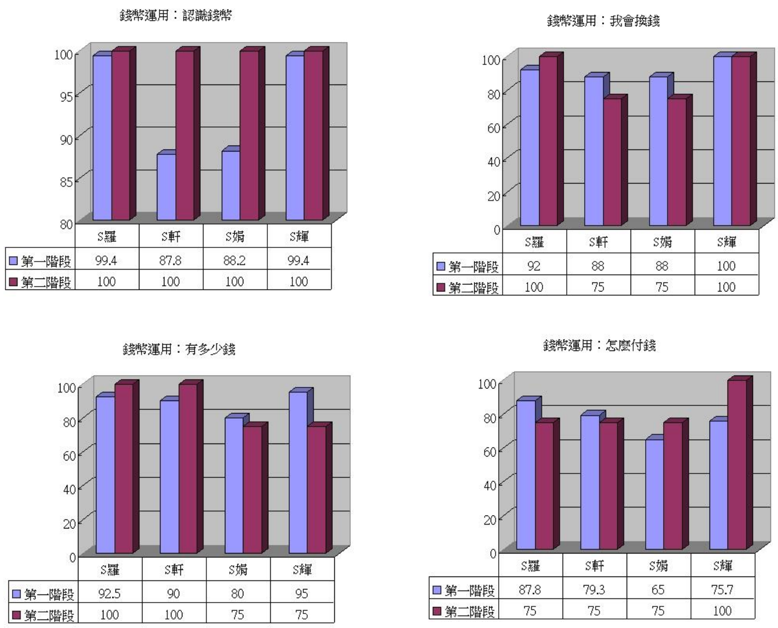


圖 6. 錢幣運用單元學生兩階段答對率統計圖

從圖 5、圖 6 中可得知，四位學生在兩個單元的答對率中，第二階段表現答對百分比，大多比在第一階段上的表現還來得好；S 娟和 S 軒在練習作答時，有較多時間都是老師及台下同學幫忙協助提醒，所以他們的答對率也能和其他同學成績差不多。而圖 7 是將學生在兩個單元中兩個階段的平均答對率來表示：

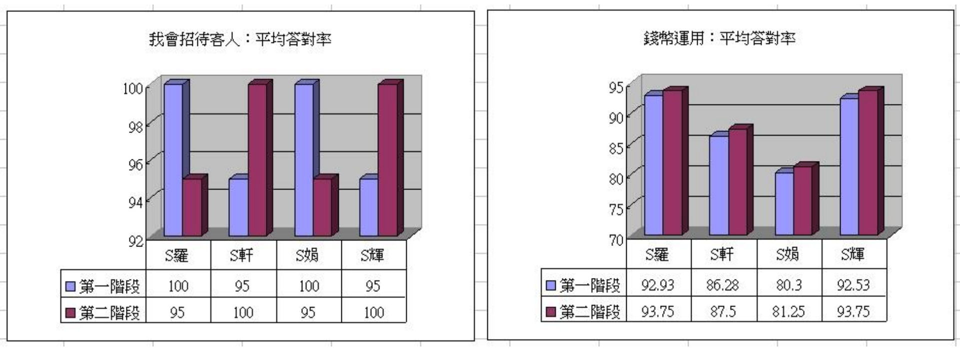


圖 7. 學生兩階段平均答對率統計圖

在我會招待客人單元中，學生的平均答對率大約都在 95%到 100%之間，而在錢幣運用上，每位學生的第二階段平均答對率均高於第一階段的平均答對率。

可見 IWB 電子白板教學應用於國小特教班智能障礙學生的學習，以生活經驗作為教學之依據，亦能使學生在按部就班的學習中，達到最終的學習目標。而經由 IWB 電子白板的教學介入後，S 羅和 S 輝的答題正確率有比另兩位同學情況好，應是障礙程度相對較低的學生，有比較好的教學成效。

整體而言，IWB 電子白板教學可提供學生不同以往的學習經驗和立即的回饋，有趣且具娛樂性，學生學習的動機增強，且能有極佳的反覆練習機會，IWB 電子白板教學對智能障礙學生學習功能性數學課程有學習成效。

4.2 IWB 能提升學生學習態度及專注力

研究者發現，特教班學生的專注力無法超過 15 分鐘，以往上數學課程時，很多時候老師講解到一半，學生不是會玩弄手中的小文具，就是會被教室內外的人、事、物所吸引，不過，使用 IWB 教學過後，學生大部分的眼光都聚焦在 IWB 上，如表 2 說明。

表 2 .學生專注力觀察與訪談結果歸納表

	觀察結果歸納
觀察教師觀察	1.S軒、S羅及S娟，三人平時上課有時會互相鬥嘴聊天，但現在比較沒有發生類似情形，會注意聽老師上課。 2.S輝以往常會玩一些鉛筆盒裡或手邊的一些小玩具，但現在 能在老師提問後舉手回答問題。
教學者觀察	1.經由學生問卷結果發現，全部的小朋友認為老師使用IWB上數學課程時，全部的學生皆認為自己上課更能專心。 2.S輝平時給人的感覺是精神不太好，上起課來也常常懶懶的不專心或是趴靠在自己桌子上，寫功課時動作也較緩慢。但這幾堂課下來發現，他竟能夠常常快速舉手回答老師的提問，學習態度積極，且上課能夠專注在IWB及老師身上。

資料來源：研究者自行整理

4.3 IWB 能提升學生主動表達的能力

經由觀察及訪談結果發現，使用 IWB 教學之後，學生常能主動提問相關問題，而對於老師的提問也較願意舉手回答，學生對於功能性數學領域的學習更為主動積極，上課發言的聲音也變多了；陳莉娜（2011）研究發現，學生長期觀察教師操作，能發揮潛在學習作用，提昇學生資訊能力，此研究與本研究結果相似。

4.4 IWB 能提升學生與教材，教師，同儕互動的能力

經由觀察及訪談結果發現，使用 IWB 教學，學生與教材內容、學生與教師、學生與同儕之間均有良好的互動，其說明如表 3。

表 3.學生與教材、教師、同儕互動觀察與訪談結果歸納表

	觀察結果歸納
觀察教師觀察	1.原本S羅及S軒會對台上操作較慢的小朋友催促，但現在能夠幫台上同學提示

	回答的答案是正確的或是錯誤的。 2.S娟以往對於上課內容及教師提問比較沒有什麼反應，只能靜靜坐在自己座位上，不過現在偶爾能夠舉手回答老師的提問了。
教學者觀察	1.經由訪談結果發現，在使用IWB教學之後，學生更常舉手回答老師的提問。 2.經由學生問卷結果發現，4位受試者中有4位覺得當同學在台上操作IWB時，他們會專心的注意同學的操作過程。 3.經由學生問卷結果發現，全部的學生在使用IWB之後，學生更喜歡上台作答。

資料來源：研究者自行整理

劉正山（2008）研究發現，使用 IWB 之後，師生互動活動積極性高，IWB 的互動性包括角色互換等皆優於單純傳統的單槍教學；董松喬（2011）研究發現，資訊工具的使用更促進了師生與學習內容的互動，此研究與本研究結果相似。根據上述的相關研究與訪談紀錄，發現 IWB 教學對學生與教材、教師、同儕之間互動關係皆有良好的成效。

4.5 IWB 能提升學習成效

經由觀察及訪談結果發現，使用 IWB 於數學課程後，能提昇學生對於相關知識與技能的認識及瞭解，其說明如表 4。

表 4.WB 提昇學生學習成效觀察與訪談結果歸納表

觀察結果歸納	
觀察教師觀察	1.在形成性評量時，學生的正確率不高，但是到了綜合活動的遊戲評量及總複習時，通過率有較為提高，尤其是S娟及S輝。 2.S軒平時上課對於老師的提問反應較慢，但是在操作IWB時，卻大都能夠正確且快速的回答。
教學者觀察	1.於觀察中發現，各單元之遊戲評量時，學生的正確率約在60%~100%之間，但是到了總複習時，老師再一次的給予複習及上台操作， 學生於操作評量及紙筆評量時，其正確率大都有所提昇。 2.於學生問卷結果發現，全部的學生認為使用IWB教數學課程，可以讓他們更了解且更容易學習，並且能夠很快就記住上課的內容。

資料來源：研究者自行整理

經由表 4.顯示，使用 IWB 教學能夠提昇學生學習成效，此結果與學者（高俊豐，2009；

張詠瑄，2011）研究結果相似，IWB 可將抽象概念具體化，以圖片或影片方式傳達出來，可提昇學生的學習成效。

5 結論與建議

5.1 結論

5.1.1 IWB 應用於國小特教班功能性數學課程領域教學，有助於提昇學生的學習成效

經由研究者觀察及觀察教師的觀察檢核及學生的問卷、訪談資料等三角檢核佐證，相對於使用傳統的教學方式下，學生經由 IWB 學習，對於功能性數學課程領域中之『數量對應』、『分類堆疊』及『錢幣運用』內容有更進一步的了解，學生也都表示使用 IWB 上課能讓他們比較容易記住上課內容，而經由研究者的觀察發現，學生經由不斷的練習、操作，很快就能學會，顯示學生在透過 IWB 應用於功能性數學領域的教學中，在本課程內容的學習成就上具有顯著提昇的效果。

5.1.2 IWB 應用於國小特教班功能性數學課程領域教學，有助於改善學生的學習態度

從研究者的觀察、觀察教師的觀察檢核及學生的問卷、訪談資料等三角檢核佐證，相對於使用傳統的教學方式，學生對於透過 IWB 學習功能性數學課程能提高學習的動機及興趣，從觀察中發現，研究者以 IWB 作為教學輔助工具，提供圖片、遊戲軟體等資源，學生上課時對於課程內容的學習興趣均有明顯的提昇，學生上課時的表現較為專注，會積極的主動參與學習，且多樣化的上課方式讓上課氣氛更為活潑，學生對於此種教學方式的接受度頗高，能有助於提昇學生的學習態度。

5.1.3 教師使用 IWB 於國小特教班功能性數學課程領域教學活動有助於學生與教材、教師及同儕的互動

傳統的教學方式，大多是由教師講述，學生在底下聽課學習，所以呈現單向互動較多；而透過 IWB 所呈現的教材，能吸引學生的學習興趣，而多元的活動設計搭配 IWB 更能使學生想上台操作，增進了學生與教材之間的互動；而 IWB 更有助於學生踴躍回答老師的提問，上課更專心學習，師生之間的角色互動變成是：學生在台上操作，教師在台下觀察學生狀況，師生之間角色不停的互換，提昇了彼此之間的互動性；而透過輪流上台操作的上課模式，更增加了學生與同儕間彼此的互動，且台上學生在操作，台下同儕便可幫忙看題目或給予提示。綜合上述，IWB 應用於國小特教班功能性數學領域教學活動，相較於傳統的教學方式下，更能提昇學生與教材、教師及同儕的互動。

5.2 建議

5.2.1 提升教學品質，需靠 IWB 電子白板的軟體硬體相互配合

IWB 電子白板在使用上仍需與電腦及投影機三方面相輔相成，才可順利使用，所以只要其中有一項設備發生問題，便可能影響整個教學的進行。以本次研究所使用的設備來說，由於教室內單槍投影機的位置是安裝在活動教室內，且投射角度是設定為安裝於天花板的下拉式布幕，投射角度較高，而移動式 IWB 為配合學生身高及操作，必須調整到較低的高度，即使將投影機支架及角度降到最低仍有些許不足，且移動式 IWB 也有可能因為學生操作及上下台碰撞造成位移而必須重新定位。針對上述問題，也許可以尋求校內行政支援，在經費許可下，更換更適合之投影機支架以及將 IWB 固定在牆面上適合的位置，減少因設備的因素造成對教學的影響。

5.2.2 教師可透過策略聯盟或班群的方式參與教材 E 化設計，增進互動教材設計的能力

特教班為顧及身心障礙學生個別差異，皆為教師自編教材，坊間出版商所附教學光碟多半不能直接適用，因此教師平時即需耗費許多時間及心力蒐集資料，設計自編教材。在研究者進行實際教學之後才發現教學活動設計有些許的不恰當，或是在設計及操作 IWB 時出現瓶頸，常常要思考在哪一個教學活動中增加一些不一樣的互動設計，才能使學生提高學習興趣及學習成效，這些互動方式又該如何設計，往往需花費許多時間去摸索、熟悉，因此耗費了許多時間。

本校雖有 1 班特教班與 1.5 班資源班，但兩邊學生的障礙程度及各方面能力皆有落差，若能透過策略聯盟方式與他校教師合作，共同進修、成長，增進教師專業能力，彼此分工合作，共同設計互動教材，如此可省下大量備課時間，亦可教學相長；若附近學區有其他班特教班，也可透過班群的方式共同設計，相信也能增進教師設計教材的能力。

5.2.3 適時的將 IWB 電子白板教學與傳統教學做適當搭配

雖然相較於傳統教學方式，IWB 可列舉出許許多多的優點，但不可否認的，有時仍需搭配傳統教學交互運用、相輔相成，才能夠達到更好的教學效果。例如：在本研究之教學過程中仍需搭配提問、寫學習單、實際操作演練等方式；雖然全程皆使用 IWB 教學，但也增加了一些傳統的教學方式，故教師在設計教學活動時，仍可尋找出 IWB 教學與傳統教學之最佳平衡點。

參考文獻

中華民國智障者家長總會（2008）。智能障礙者家長手冊「如何協助我們永遠的寶貝」。台北市：中華民國智障者家長總會。

王玲（2010）。故事結構教學結合互動式電子白板對提升國小學習障礙學生閱讀理解成效之研究。國立臺中教育大學，台中市。

朱淳琦（2011）。動態虛擬教具在數學學習應用成效之實證研究回顧。雲嘉特教期刊，14，45 -53。

朱經明（1999）。多媒體與身心障礙兒童。特殊教育季刊，72，10-12。

江毓鈞（2012）。運用 Wiimote 互動式電子白板融入教學對國小學習障礙學生在分數加減概念與運算之學習成效研究。國立屏東教育大學，屏東縣。

何素華（1995）。國小智能不足兒童錢幣應用教學效果之研究。嘉義師院學報，9，561-598。

吳宗立（2002）。教師行動研究的實踐。國教天地，149，46-54。

吳明隆（2001）。教育行動研究導論－理論與實務。台北市：五南。

林素卿（2002）。教師行動研究導論。高雄市：復文圖書出版社。

林怡君（2001）。建構教學對輕度智能障礙學生數概念應用成效之探討。國立高雄師範大學，高雄市。

侯禎塘（2004）。特殊教育需求兒童數學學習困難之特質、教學策略與創意遊戲數學之應用。特殊教育叢書，9302 輯。

夏林清、中華民國基層教師協會（譯）（1997）。行動研究方法導論－教師動手

做研究。

原作者：Altrichter, H., Posch, P., & Somekh, B.（1993）.Teachers investigate their work an introduction to the methods of action research.。台北市：遠流。

秦麗花（2000）。教師行動研究快易通。台南市：翰林出版事業。

袁媛、陳國龍、張世明（2007）。萬用揭示板(Magic Board)-國小特教老師的數學教學好幫手。特教論壇，3，1-13。

高俊豐（2009）。以合作學習應用電子白板在國小高年級數學縮圖與比例尺單元之成效研究。國立屏東教育大學，屏東縣。

高敬文（2002）。質化研究方法論。台北市：師大書苑。

張詠瑄（2011）。運用互動式電子白板於國小五年級學生社會領域學習成效之研究。國立臺中教育大學，台中市。

教育部（2006）。身心障礙及資賦優異學生鑑定標準。台北市：教育部。

梁芯佩（2010）。互動式電子白板融入面積課程對國小學習障礙學生學習成效之研究。國立臺中教育大學，台中市。

陳明全（2011）。運用 Wiimote 互動式白板結合筆順學習網教導國小智能障礙學生常用字筆順學習成效之研究。國立彰化師範大學，彰化縣。

陳莉娜（2011）。互動式電子白板融入國小低年級識字教學之行動研究。淡江大學，新北市。

覃業芬（2011）。互動式電子白板應用於國小資源班社會領域教學之行動研究。國立屏東教育大學，屏東縣。

鈕文英（2003）。啟智教育課程與教學設計。台北：心理。

黃美瑜（2002）。生活數學教學對國民中學輕度智能障礙學生學習統計與圖表概念成效之研究。國立高雄師範大學，高雄市。

董松喬（2011）。運用互動式電子白板進行社會領域問題導向學習之研究。國立臺北教育大學，台北市。

劉正山（2008）。交互白板環境下國小數學領域教學設計的互動研究。國立臺北教育大學，台北市。

蔡貞瑩（2010）。互動式電子白板結合圖片褪除策略對國小中重度智能障礙學生功能性詞彙教學成效之研究。國立臺中教育大學，台中市。

蔡清田（2000）。教育行動研究。台北市：五南。

蕭英勵（2007）。探討中小學將互動式電子白板導入教學之研究。全國教師在職進修網電子報。2007 年 12 月 07 日，取自

http://www2.inservice.edu.tw/EPaper/200712/indexView.aspx?EID=48

賴暄頤（2010）。探討互動式電子白板教學與直接教學對中度智能障礙學生分數學習成效差異之研究。中原大學，桃園縣。

Altrichter, H., Plsch, P. & Somekh, B. (1997) 夏林清(譯)，1997。行動研究方法導論－教師動手做研究。台北市：遠流 (原作者：Altrichter, H., Posch , P., & Somekh, B.)(原著出版年：1993)。

Browder, D., Flowers, C. , Ahlgrim-Delzell, L., Karvonen, M., Spooner, F., & Algozzine, R. (2004). The Alignment of Alternate Assessment Content with Academic and Functional Curricula. Journal of Special Education, 37(4), 211-223.

Cain, D. (2007). Functioning Mathematically: 1. Mathematics Teaching Incorporating Micromath, (ERIC Document Reproduction Service No. EJ768918) Retrieved June 7, 2008, from ERIC database.

Lincoln, Y.S., & Guba, E. G.(1985). Naturalistic inquiry. Newbury Park: Sage Publications.

Patton, R. S., Cronin, M. , Bassett, D. S., & Koppel, A. E. (1997). A life skills approach to mathematics instruction: Preparing students with learning disabilities for the real-life math demands of adulthood. Journal of Learning Disabilities, 30, 178-187.

Valletutti, P. J., Bender, M., & Sims-Tucker, B. (1996). A functional curriculum for teaching students with disabilities(2th ed.). Austin, TX：Pro-ed.

Westling, D. L., & Fox, L. (2000). Teaching students with severe disabilities. Englewood Cliffs, N. J.: Prentice-Hall.

台灣數位媒體設計學會 入會申請書

<table>
<tr><td rowspan="4">會員類別</td><td>☐ 個人會員</td><td colspan="2">會員證編號</td><td rowspan="4">（二吋脫帽彩色照片）</td></tr>
<tr><td>☐ 學生會員</td><td colspan="2">由本會填寫</td></tr>
<tr><td>☐ 團體會員</td><td colspan="2">入會日期</td></tr>
<tr><td>☐ 榮譽會員</td><td colspan="2">由本會填寫</td></tr>
<tr><td colspan="2">中文姓名</td><td>英文姓名</td><td>性別</td><td>出生日期</td></tr>
<tr><td colspan="2"></td><td></td><td>☐男 ☐女</td><td>年 月 日</td></tr>
<tr><td rowspan="2">學　歷</td><td colspan="2" rowspan="2"></td><td colspan="2">身分證字號</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td>經　歷</td><td colspan="4"></td></tr>
<tr><td>現　職</td><td colspan="4"></td></tr>
<tr><td>專　長</td><td colspan="2"></td><td colspan="2">可以提供團體之服務：</td></tr>
<tr><td>戶籍住址</td><td colspan="4"></td></tr>
<tr><td>通訊住址</td><td colspan="4">☐同戶籍住址</td></tr>
<tr><td>電　話</td><td></td><td colspan="2">E-MAIL</td><td>介紹人</td></tr>
<tr><td>手　機</td><td></td><td colspan="2" rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>傳　真</td><td></td></tr>
<tr><td colspan="5">中 華 民 國 年 月 日 申請人： （簽章）</td></tr>
<tr><td>審查日期</td><td colspan="4">經過 年 月 日 第 屆 第 次理事會議審查：</td></tr>
<tr><td>審查結果</td><td colspan="4">☐通過 ☐不通過 原因：</td></tr>
</table>

《IJDMD 國際數位媒體設計學刊》訂閱表格

致 ： 編輯委員會

地 址： 臺灣數位媒體設計學會
116 台北市文山區木柵路一段 17 巷 1 號
Taiwan Association of Digital Media Design
#1 Lane17 Sec.1 , Mu-Cha Rd. Taipei ,Taiwan ,R.O.C
傳 真： +886-(0)2-22368225

姓名(單位承辦人)：____________________ Name(英文)：________________________
機構名稱：____
郵寄地址：____
聯絡電話(Offile)：____________________ 傳真號碼：________________________
電子郵箱：____

2016 年訂閱價目表(每年)		
□機構訂閱	台灣地區	台幣$2400(含郵資)
	世界其他地區	美元$80(含郵資)
□個人訂閱	台灣地區	台幣$600(含郵資)
	世界其他地區	美元$20(含郵資)

- 學會會員繳交該年度會費，即可免費獲得每期學刊

□茲訂閱《IJDMD 國際數位媒體設計學刊》，由第_______期開始，為期______年。
□補購單本期刊(第 1-7 期)，第________期(若兩期以上以請列明期數)共計_____期。

付款辦法：
專戶資料如下：臺灣銀行 斗六分行
戶名：台灣數位媒體設計學會 帳號：03 1001 12305 8 銀行代號：004
匯款後，請黏貼匯款單據影本於下列方格後傳真，傳真電話：02-2236-5694。

(匯款單粘貼處)

敬啟者 您好：

■ 加入台灣數位媒體設計學會之會員享有以下權益：

1. 參加學會所舉辦之「數位媒體設計國際研討會」報名優惠。
2. 研討會論文刊登優惠，並擇優錄取至國際數位媒體設計學報（IJDMD）。
3. 參加「數位優勢-台灣數位媒體設計競賽」報名優惠。
4. 發表國際數位媒體設計學報（IJDMD）刊登優惠（經審核錄取後，需額外繳交刊登費 NTD 5000 元，會員減免 NTD 2,000 元）。
5. 獲得發表亞洲數位藝術與設計國際期刊（IJ-ADADA）之資格（經審核錄取後，需額外繳交刊登費 USD 200 元）。
6. 與國內及國際媒體設計相關領域同好，相互交流的管道與機會。

■ 台灣數位媒體設計學會繳費資訊如下：

1. 個人會員：常年會費 NTD 2,000 元
2. 團體會員：常年會費 NTD 10,000 元
3. 學生會員：常年會費 NTD 200 元

■ 請將會費繳交匯款至下列帳戶：

戶　　名：**台灣數位媒體設計學會**
帳　　號：**03 1001 12305 8**（台灣銀行斗六分行）
銀行代號：**004**

■ 並煩請填妥入會資料，連同收據郵寄或 E-mail 至秘書處，以利資料建檔。

祕書處相關資訊：

地　　址：116 台北市文山區木柵路一段 17 巷 1 號
世新大學 | 數位多媒體設計學系
傳　　真：02-2236-5694
學會信箱：dmd@dmd.org.tw (郵寄入會申請書)
網　　址：http://www.dmd.org.tw/
聯 絡 人：張裕幸 祕書長

再次感謝您的加入，請讓台灣數位媒體設計學會繼續為您服務。

台灣數位媒體設計學會 敬上

Contents

International Journal of Digital Media Design/ Volume 9/ Number 1/ June 2017

研究論文

Editor-in-Chief
Tao-I Hsu
(Shih Hsin University)

Executive Editors
Yi-Chen Hsu
(National Taipei University of Education)

Publisher Information
Published in Taiwan
by Taiwan Association of Digital Media Design
Address: #1 Lane17 Sec.1, Mu-Cha Rd.
New Taipei City 116, Taiwan
Fax: +886-2-22365694
Website: www.dmd.org.tw
E-mail: dmd@dmd.org.tw
ISSN 2078-4775
©by International Journal of Digital Media Design.
All rights reserved. No part of this publication may
be reproduced or transmitted in any form or by
any means without written permission from the publisher.
Subscription: NT$ 2,400 per year

ISSN 2078-4775

Editorial Board
Jun-Hong Chen
(Asia University)
Kuan-Chun Chen
(National Changhua University of Education)
Kuo-Kuang Fan
(National Yunlin University of Science and Technology)
Ping-Lin Fan
(National Taipei University of Education)
Su-Chu Hsu
(Taipei National University of Arts)
Tao-I Hsu
(Shih Hsin University)
Shih-Chieh Huang
(Natuonal Taiwan University of Sports)
Shu-Ling Lai
(Asia University)
Chang-Jay Shih
(National Taiwan University of Arts)
Tzu-Wei Tsai
(National Taichung University of Science and Technology)
Nien-Tsan Wang
(National Taiwan University of Arts)
Ching-Tang Wang
(Natuonal Taiwan University of Sports)
Der-Lor Way
(Taipei National University of Arts)
Jen Yen
(Ling Tung University)