Design and Developing Technology Integrated into Learning Origami: Using the Origami of One Straight Cut as an Example

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Abstract
The students can learn effectively through folding paper to observe and investigate the property of geometry. Therefore, the origami is getting more valuable. The action of folding paper can train the concepts of geometry like spatial abilities, line symmetry and hand-eye-brain coordination. The main purpose of the study is to investigate the effect of technology integrated into learning origami of one straight cut on elementary school students' spatial abilities. "Origami of one straight cut," which means first folding the paper and then cut the folded paper along one straight line. The unique shape then showed up when spreading out the paper. By rotating, folding and spreading the paper out, it is training the "spatial orientation" and "spatial visualization" at the same time.
A quasi-experimental design is adopted as the methodology. The participants included 40 students, using technology integrated into learning origami of one straight cut. The students were required to complete origami of one straight cut hands-on learning activities and eight levels of WOOS II (Web of Origami Simulator II). The results showed that technology integrated into learning origami of one straight cut had a statistically significant effect on spatial ability achievement. From the results of correlation analysis, the WOOS II and spatial ability achievement have significant positive correlation. The students learned the basis of origami of one straight cut through teacher's demonstration and practice on WOOS II. Technology integrated into learning origami of one straight cut can improve students' spatial ability effectively.

Keywords: Origami of one straight cut, digital origami simulator, e-learning, spatial ability

1. Introduction

Geometry is one of the significant elements of the mathematics curriculum, National Council of Teachers of Mathematics encourage students to understand mathematical concepts through origami. (NCTM, 2000; Pearl, 2002) The action of folding paper can train the concepts of geometry like spatial abilities, line symmetry and hand-eye-brain coordination. Each step will affect the final origami shape, so each decision is the key of final origami shape.

Origami can be use in geometry teaching. The student should learn to determine the geometry of the shape, also be understood that the geometry properties of line-symmetric pattern, which is the basis for elementary school students into junior high school. Teachers use origami to teach students about the concept of symmetry, and let students to use scissors to cut out symmetry figure. (He, 2005) The main purpose of the study is to investigate the effect of the teaching session like this on elementary school students' spatial abilities.

Successful origami requires skill and understanding of spatial ability. (Yuzawa, 1999) Guay and McDaniel (1977) mentioned that the low spatial ability students cannot process visual graphics. Such as whether there is symmetry graphics. The students learn symmetry through folding paper. Bobis, Sweller, and Cooper (1993) study mentioned that the cost of time is shorter through children using graphics to learning origami. The animation can support the conversion of origami concept.

This study is based on the Web of Origami Simulator I (Yang, Yin, & Chen, 2014). Learning spatial ability through origami. Using digital environments to enhance learning effectiveness. This study design and developing technology integrated into learning origami – WOOS II. The main purpose of the study is to investigate the effect of technology integrated into learning origami of one straight cut on elementary school students' spatial abilities.

2. Literature Review

2.1 Spatial abilities

National Council of Teachers of Mathematics encourage students to understand mathematical concepts through origami (NCTM, 2000). Students will use spatial abilities when they observed symmetry of geometric or folding paper from two-dimensional to three-dimensional. Spatial ability is the capacity to recognition, remember, conversion the spatial relations among object (McVey, 2001). Thurstone(1938) mentioned that spatial ability is to remember an image in the mind and move or rotate the image. Spatial abilities can be subdivided into "spatial orientation" and "spatial visualization" (Linn & Petersen, 1985). "Spatial orientation" is the ability to understand the spatial relationship between the objects. Spatial visualization is the ability to think about objects in two-dimensional or three-dimensional figures.

Ambrose and Falkner (2002) using a simple triangle, square space to develop elementary students' spatial concept. In Zhang and Wu study (2009), using the cube counting exercise to observe the graphics from two-dimensional to three-dimensional.

Boakes, Norma J. (2009) found that teaching origami will affect the student's spatial ability and knowledge of geometry. Because it’s easy to obtain paper, while folding paper or rotate the paper also training spatial abilities.

2.2 The use of origami

Students learning origami can enhance different abilities, such as thinking more flexible, a higher EQ, strong execution, strong inferential ability. Sternberg(1989) mentioned that the repeatable process of folding paper can improve students’ concept of origami and mathematics.

In the elementary school mathematics curriculum that students use origami to learn geometric course. In Taiwanese elementary school mathematics curriculum, using folding paper to teach the student how to learn the symmetry, angle bisector, the Pythagorean Theorem. The folding process requires the use of hand-eye coordination and hands-on practice, which is more attractive for the students. Pope (2002) integrated origami in mathematics teaching that allows students observe the characteristic of geometric polygons. Yang and Yin (2015) use the characteristics of symmetry to enhance the concept of student graphic reasoning. Simple action of folding paper and intuitive learning can increase students’ interest in learning.

2.3 The origami of one straight cut

The origami of one straight cut means that folding paper and then give one straight cut. Different folding and cutting process, it will produce different geometry. In Taiwan elementary mathematics curriculum, through folding paper to learning axis of symmetry. For example, origami or cutting paper. He (2005) using the process of folding paper to teaching student to learn symmetry principle. When the student cut the different axis of symmetry pattern, there will be a different shape. In Wang and Tzeng (2015) study, discover that the permutation of the paper cutting will fold as triangle or square.

If you want to cut off a geometry with one straight cut, according to Erik Demaine (1998) mentioned The Fold-And-Cut Problem, the geometry on paper can cut off by one straight cut. Students need to use space orientation when they are doing one straight cut. Observed the axis of symmetry pattern. Think of the way of paper folding and use the ability of mental rotation to think what the cutting pattern shape is. This activity can improve students’ spatial ability, concept of symmetry and inferential ability.

On the training spatial ability, there are different materials. The origami is one of them. In fact, there are many origami digital simulator (Origami Club, 2002; Miyazaki, 1996; David, 2008; Let’s fold, 2015; Joel, 2012; Make-a-Flake, 2016). The origami digitized can break the restrictions of paper thickness. Give the student repeated practice environment. The main purpose of the study is to investigate the effect of technology integrated into learning origami of one straight cut on elementary school students’ spatial abilities.

3. Methodology

A quasi-experimental design is adopted as the methodology. The participants included 40 six-grade students, using technology integrated into learning origami of one straight cut. Technology integrated into learning origami of one straight cut include *Hands-on learning activities* and *operating Web of Origami Simulator II* (WOOS II) at computer classroom. Each session is 40 minutes. First teaching session is writing origami of one straight cut pre-test. Second teaching session is *Hands-on learning activities*. Third teaching session is *operating WOOS II*. Fourth teaching session is *Hands-on learning activities*. Fifth teaching session is *operating WOOS II*. Sixth teaching session is writing origami of one straight cut post-test. Table 1 is experimental design.

Table 1. Experimental design

Group	Pre-test	Intervene	Post-test
Experiment group	O_1	X	O_2

X: Technology integrated into learning origami of one straight cut
O_1: Origami of one straight cut pre-test
O_2: Origami of one straight cut post-test

3.1 Materials

3.1.1 Origami of one straight cut teaching materials

Origami of one straight cut is mean folding paper and give one straight cut. The origami of one straight cut base on paper fold as triangle or rectangle (figure 1). We can fold paper and give one straight cut, then we will get L-shaped paper or V-shaped paper. Origami of one straight question is based on L-shaped paper and V-shaped paper. Left of Figure 1 is use L-shaped paper mirrored to T-shaped. Right of Figure 1 is use V-shaped paper symmetrical to W-shaped.

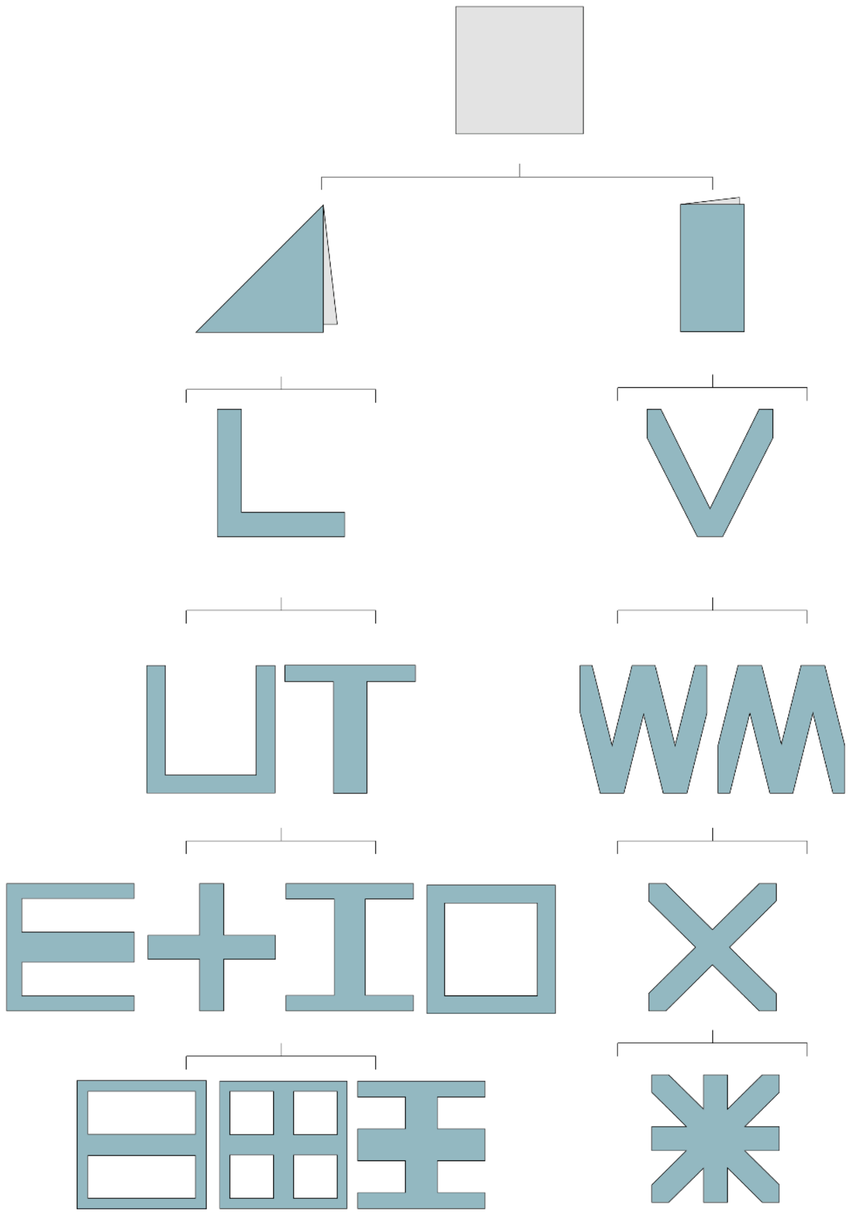

Figure 1. the basic of origami of one straight cut

L-shaped paper each step look figure 2. First found the symmetric line of L-shaped. Fold the paper to triangle and then cut a one straight cut we will get L-shaped paper. This is the basic of one straight cut. According to the shape, student can observe the axis of symmetric and cut off the geometry. Student must be know well with line symmetry relationship when they doing origami of one straight cut.

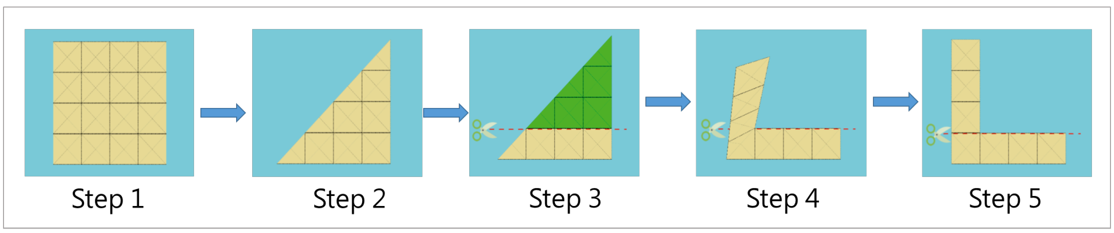

Figure 2. L-shaped paper steps

Another example is T-shaped paper (figure 3). First we should find the T-shaped paper symmetry line. We could found that T-shaped paper is a bilateral symmetry graphics. Fold the paper left to right, we can found that L-shaped at the top of T-shaped. And then we can fold and cut the paper, unfold the paper we will get the T-shaped paper. The key of this example is symmetry axis of paper folding.

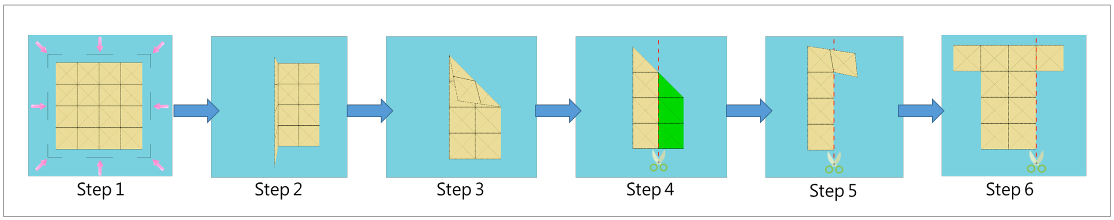

Figure 3. T-shaped paper steps

Demonstration by the two example, we can find that L-shaped paper can extend the U-shaped or T-shaped. And U-shaped and T-shaped can be continue extend. Such as the U-shaped duplicate the symmetrical, and you can create an E-shaped.

3.1.2 Web of Origami Simulator II (WOOS II)

WOOS II using the Unity game engine for the development platform. Combined with origami animation, drag and click on operation. WOOS II designed basic on Origami of one straight cut teaching materials, spatial ability and Taiwan's grade 1-9 curriculum guidelines (Taiwan Ministry of Education, 2008). WOOS II contains 8 levels and the levels are progressively distributed from easy to difficult. The detail can be described as the following levels. Level 1: student needs to observed symmetrical characteristics; Level 2: the relational of symmetrical and one straight cut; Level 3: using different folding, observed difference of shape; Level 4: using same folding and different cutting angle, observed difference of shape; Level 5: find geometric properties through one straight cut; Level 6: the basic of one straight; Level 7: learn to use origami to paper to complete shapes; Level 8: observed the one straight properties through animation.

User interface see Figure 4. There are four areas.
A area (Subject area): A area is Subject area. This area provides the description of topic. Students must understand the subject according the topic.
B area (Tool area): B area is Tool area. WOOS II provides ruler, protractor, and scissors to help students learn.
C area (Operate area): C area is Operate area. The main operating object is placed in this area. Students use mouse to operate object.
D area (Answer area): D area is Answer area. Students submit answer at this area.

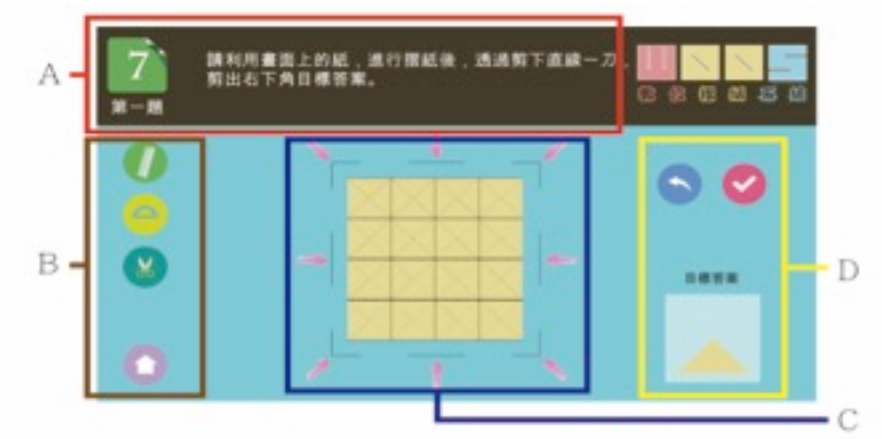

Figure 4. WOOS II user interface

3.1.3 Hands-on learning activities

Hands-on learning activities mainly use the actual folding and cutting, it makes students understand with basic of origami of one straight cut. The content based on origami of one straight cut teaching material. There has three parts in hands-on learning activity, “Find symmetrical of the shape”, “The paper folding and cut”, and “Origami of one straight cut”. Hands-on learning activities according to Taiwan Ministry of Education Indicators (2008). Learning sheet refer to the following table.

Table 2. Hands-on learning activities

Content	Learning sheet unit
Find symmetrical of the shape	1-1~1-4、2-1
The paper folding and cut	1-5、2-2
Origami of one straight cut	2-3~2-4

Learning sheet 1 contains five topics, perfect score is 100 points, each topic is 20 points. Learning sheet 1 material contains four geometry shapes and 10 pieces of paper. Learning sheet 2 contains four topics, perfect score is 100 points, each topic is 25 points. Learning sheet 2 material contains six geometry shapes and 10 pieces of paper. Hands-on learning activities took 2 teaching sessions (40 minute each). The learning activities are explained as follows:

1. Find symmetrical of the shape:
This topic let students use the geometry paper such as triangle, squares. Students can observe whether the graphic symmetrical. To know whether the graphics have same angle or edges.

2. The paper folding and cut:
This topic let student draw the graphic on the paper, fold the paper to find the symmetry line. Practice how to cut paper with one straight cut. The example contains L-shaped paper. Students can extend in following course.

3. Origami of one straight cut:
This topic let student to observe the graphic. First, student should find the symmetric line of the graphic, overlap all the lines together, and cut off the shape. With L-shaped paper, we can extend other shape like T-shaped or E-shaped.

3.1.4 Origami of one straight cut test

Origami of one straight cut test is bases on Taiwan Ministry of Education Indicators (2008). Origami of one straight cut test contained four topics, perfect score is 100 points, each topic has five questions, and each question is 5 point. First topic is to observe the meaning of symmetric graphic. Second topic is the graphic of one straight cut. Third topic is true/false item, this topic in order to understand students' the performance of spatial ability. Fourth topic is the geometric shape of one straight cut, in order to understand students' performance of inferential ability. Test time took thirty minutes.

4. Results

In order to understand the effect of technology integrated into learning origami of one straight cut on elementary school students' spatial abilities. Use *t-test* analysis origami of one straight cut pre-test and post-test. The origami of one straight cut test perfect score is 100 points. Table 3 shows the result of origami of one straight cut test:

Table 3. Origami of one straight cut test *t-test* analysis

	n	Mean	SD	t	df	p
Pre-test	40	70.00	12.810	-2.238	39	.031*
Post-test	40	74.25	14.031			

* $p<.05$; ** $p<0.01$

According to the result of *t-test*, the experiment group pre-test average was 70 (perfect score = 100), Standard Deviation is 12.810, post-test average was 74.25, Standard Deviation 14.031. After lesson the effect were significantly to the benefit of them. t=-2.238, $p<0.05$.

In order to understand the correlation between spatial ability achievement and technology integrated into learning origami of one straight cut teaching materiel. Following table 4 and table 5 is the result using Pearson correlation analysis. "Technology integrated into learning origami of one straight cut" is the average of "hands-on learning activities" with WOOS II.

Table 4. Means and standard deviations for tests

	Mean	SD
Hands-on learning activities	92.40	7.89693
WOOSII	88.38	5.42743
Technology integrated into learning origami of one straight cut	90.39	5.68421
Post-test	74.25	14.03064

Table 5. the result of correlation analysis

	Post-test	Hands-on learning activities	WOOSII	Technology integrated into learning origami of one straight cut
Post-test	-			
Hands-on learning activities	.276	-		
WOOSII	.526**	.437**	-	
Technology integrated into learning origami of one straight cut	.443**	.903**	.781**	-

*** = p<0.01; * = p<0.05*

Table 5 shows that the average of hands-on learning activities was 92.4, the average of WOOS II was 88.38, technology integrated into learning origami of one straight cut were 90.39, the average of post-test was 74.25. The correlation coefficient of post-test and hands-on learning activities were 0.276($p=0.084$), the correlation coefficient of post-test and WOOS II were 0.526($p<0.01$), the correlation coefficient of post-test and Technology integrated into learning origami of one straight cut were 0.443($p<0.01$). The correlation coefficient of hands-on learning activities and WOOS II were 0.437($p<0.01$).

The results about post-test achievement revealed that there was a statistically significant change in spatial ability achievement scores. It shows that technology integrated into learning origami of one straight cut can improve students' spatial ability effectively. And the result shows that the correlation coefficient of post-test and WOOS II were positive. The better operation in WOOS II, students had a better score at spatial ability.

5. Discussion

After the result of analysis, shows that there was a statistically significant change in spatial ability achievement scores. The better operation in WOOS II, students had a better score at spatial ability.

This is the first contact with the students and origami of one straight cut, origami is still a new area (Chen, 2006). The student understand the concept of symmetry have no trouble on hands-on learning activities. They need some time to learn WOOS II operation. The student learning faster through teacher's demonstration.

The students seek answers to others without thinking when the student feel impatient. This causes the students cannot understand the concept. But students can learn faster with teacher's demonstration at hands-on learning activities. When operating WOOS II, some students feel confused about graph rotation or the process of origami. It must be demonstration many times to the students.

There were some students can find the different solution during WOOS II. The students try to share the different solution to others. For example, square-shaped paper can be as two L-shaped, the students will tell others the difference. Such interaction provides a better influence.

Overall, students can learn with teacher's demonstration at hands-on learning activities. Students could practice origami of one straight cut through operating WOOS II. Students learning symmetry, spatial orientation and spatial visualization through technology integrated into learning origami of one straight cut.

6. Conclusion

This study design and developing technology integrated into learning origami, which contains hands-on learning activities and WOOS II. Technology integrated into learning origami have variability and the limit of one straight cut, hands-on learning activities and digital learning can train students' spatial abilities and symmetric concepts.

The result of technology integrated into learning origami shows that students can learn the basic of one straight cut with teacher's demonstration, and practice with WOOS II. Technology integrated into learning origami could enhance students' ability. Origami is the geometry most use tool for learning. Also train students' hand-eye-brain coordination.

The technology integrated into learning origami which contains hands-on learning activities, and also contains digital origami simulator. Digital origami simulator is currently less used by researchers. Technology integrated into learning origami let student be able to promote coordination through the hands-on learning activities, also practice with digital environment, and improve learning efficiency.

In summary, the technology integrated into learning origami contains hands-on learning activities and WOOS II. Hands-on learning activities can impression through actual operation, and practice with digital learning, reduce waste of resources. Therefore, WOOS II is a system which can enhance students' spatial ability and the knowledge of symmetry.

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