

## Web-based Learning in a Geometry Course

### Hsungrow Chan

Associate Professor, Department of Mathematics Education, National Pingtung University of Education  
No.4-18, Minsheng Rd., Pingtung City, Pingtung County 900, Taiwan (R.O.C.)

hchan@mail.npttc.edu.tw

Tel: +886-8-7226141#6200 or 6210

Fax: +886-8-7239860

### Pengheng Tsai

Doctoral Student, Department of Industrial Technology Education, National Kaohsiung Normal University  
No.58, Lane 59, Longsing St., Cianjhen District, Kaohsiung City 806, Taiwan (R.O.C.)

pengheng.tsai@msa.hinet.net

Tel: +886-7-7510048

Fax: +886-7-7510445

### Tien-Yu Huang

Professor, Department of Computer Science, National Pingtung University of Education  
No.4-18, Minsheng Rd., Pingtung City, Pingtung County 900, Taiwan (R.O.C.)

tyhuang@mail.npttc.edu.tw

Tel: +886-8-7226141#3107 or 3110

Fax: +886-8-7215034

### ABSTRACT

This study concerns applying Web-based learning with learner controlled instructional materials in a geometry course. The experimental group learned in a Web-based learning environment, and the control group learned in a classroom. We observed that the learning method accounted for a total variation in learning effect of 19.1% in the 3<sup>rd</sup> grade and 36.5% in the 6<sup>th</sup> grade. The main factor in the difference was attributed to the students' ability to apply information technology. We further found that students need more communication with peers, teachers, and lecture materials when learning via the Internet. We are encouraged that progress in the technological advances of the Internet will make it more convenient and more effective for use in Web-based learning.

### Keywords:

Classroom learning, Geometry curriculum, Learner control, Van Hiele level of geometric thought, Web-based learning

### Introduction

Elementary students in Taiwan usually learn geometric concepts by recitation and through practice. Most of them fail to learn basic geometric concepts and geometric problem-solving, so they obviously don't view themselves as being successful in geometry courses. Some elementary geometry students have a lot of difficulty with ordering properties logically and general definitions. This situation gets worse later in Junior and High School. Taiwan is not alone in this. Much learning of geometric concepts by U.S. students has been by rote; they frequently do not recognize components, properties, and relationships between properties (Clements & Battista, 1992). Many mathematics educators have studied children's geometric conceptions. The three dominant lines of inquiry concerning children's geometric conceptions are based on the theories of Piaget, the van Hiele, and cognitive psychologists (*ibid*). While the Piagetian and cognitive psychology studies were not grounded in educational concerns, the van Hielian research, by contrast, was so-grounded (Clements, Swaminathan, Hannibal, & Sarama, 1999). Thus, this study is based on their work. According to the van Hiele theory, students progress through levels of thought in geometry when aided by instruction (van Hiele, 1986). Thinking on geometric concepts develops from an initial, Gestalt-like visualization through increasingly sophisticated levels: descriptive and analytic, abstract and relational, formal deductive, and mathematically rigorous.

The five van Hiele levels are thought of in the following ways.

1. The visual level: Children identify shapes according to appearance, recognizing them as visual gestalts using visual prototypes, saying, for instance, that a given figure is a circle because "it looks like a moon."
2. The descriptive and analytic level: Students reason about geometric concepts by means of an informal analysis of component parts and attributes.

3. The abstract and relational level: Students order properties logically and begin to appreciate the role of general definitions. They can form abstract definitions and distinguish between the necessity and sufficiency of a set of properties in determining a concept.
4. The formal deductive level: The role of axioms, undefined terms, and theorems is fully understood, and original proofs can be constructed.
5. The mathematically rigorous level: Students can compare various axiomatic systems based on various axioms, and study various geometries in the absence of concrete models.

Helping children move through these levels may be taken as a critical educational goal (van Hiele, 1986). The main aim of geometric education is to change students' geometric conceptions through teaching activities, and move students from one level of van Hiele thinking to the next. Using an elementary geometry curriculum, the first purpose of this study was to find a way to help elementary students use the learning effect to advance their van Hiele levels of geometric thought.

Previous lines of inquiry into children's geometric conceptions have provided useful foundations, but have also left gaps that impede curriculum development and teaching improvements. And as briefly explained above, much learning of geometric concepts by Taiwan students has been by recitation and through practice. We should allow students to explore geometric concepts and shapes, and must provide experiences in informal geometry for students throughout their school years. However, because of limited classroom space, teaching time, and inability to interact, classroom teaching and learning contexts in traditional schools haven't been successful in geometry courses, and students always treat the geometric models as toys. Moreover, instructional control and program control are administered by teachers in classrooms, and interactive activities are few or even nonexistent. So even though teachers perform quite well, no instructional records are preserved and it is impossible for students to review the instructional interactive process.

The concept of learner control, defined as an individual ability to sequence the content while engaged in an instructional activity, is now extended to include allowing students to control the pace of instruction (Mager & Clark, 1963; Gay, 1986; Reiser, 1984). Several studies suggest that learner control of instruction can result in more positive student attitudes, higher levels of student engagement, and less anxiety (Fowler, 1983; Hannafin, 1984). Accordingly, this study involved using the concept of learner control in conducting a Web-based geometry course. However, implementation did entail some risk. Learner-controlled instructional materials may improve students' performance and attitudes toward the subject matter, and increase efficiency, but they also produce large variations in students' performance that may result from instructional tasks, instructional designs or assessment procedures (Hannafin, 1984).

Lepper (1985) suggests that providing learner control increases the relevance of instruction especially if the activity involves the external environment. Through careful combinations of course exposition text, images, expository videos, and 3D virtual geometric objects, the prototypic module strives to simulate instructional activities and geometric mental manipulation action. Our creation of Web-based materials had the ultimate goal of generating complete support for vertical and horizontal integration in the geometry course. Our experimental design embedded the instructional material scaffolding in the Internet, and allowed students to arrange their programs, manipulate 3D virtual geometric objects, and discuss online with teachers and peers. That is, instructional control and program control were returned to students. Here, teachers served as counselors and guides. Hence, the second purpose of this study was to promote the learning effect and level of geometric thought of elementary students with Web-based learning. This study designed and applied Web-based cube and cuboid materials for 3<sup>rd</sup> grade students, and prism, pyramid, cylinder, and cone materials for 6<sup>th</sup> grade students. Upon completion, we used our own test to assess the learning effect and the van Hiele level of geometric thought. We also interviewed the sampled students to determine how thoroughly they grasped the geometric concepts, how well they accepted this different learning method, and their perceptions on using Web-based learning.

## **Method**

### **Participants**

The experimental group, which received Web-based instruction, included thirty-five 3<sup>rd</sup> grade students and thirty-nine 6<sup>th</sup> grade students. The control group, which received classroom instruction, included thirty-four 3<sup>rd</sup> grade students and forty 6<sup>th</sup> grade students. All subjects were from an elementary school in Kaohsiung City, Taiwan.

## Web-based learning environment

This study applied the Web-based learning environment whose structure is shown in Figure 1. The environment is divided into a teachers' management interface, students' learning interface, and system support interface.

Teachers' management interface: Enables teachers to manage all parts of the courses, design Web-based materials, record lecture videos, administer teaching files, and test students.

Students' learning interface: Students logging on to this environment can choose studying the geometry course, controlling the instruction program and content, asynchronous and real-time communication, and taking tests. In particular, they can manipulate 3D virtual geometric objects using a mouse.

System support interface: This provides course management, including page setting, personal e-mail, and discussion and assignment areas so that instruction activities proceed smoothly.

These interfaces are integrated by the database management function which, includes the user, curriculum, Web-based materials, and instruction activities record databases.

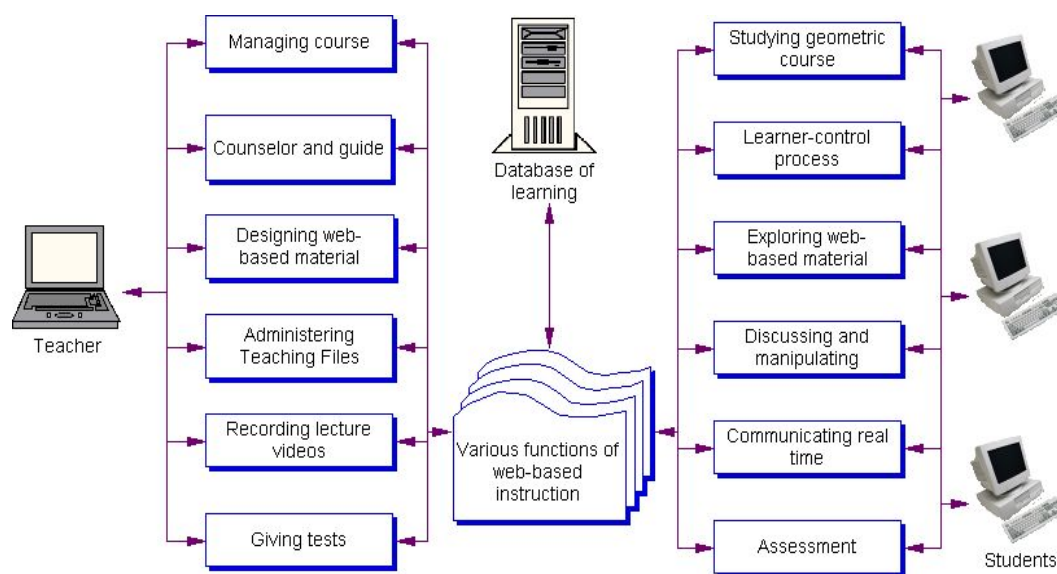


Figure 1 Web-based learning environment

## Achievement tests

The aim of this study was to find a way to help promote learning and van Hiele levels of geometric thought among elementary students. We developed our pre- and post-tests according to the criterion-referenced van Hiele theory of content validity. Each test consisted of three parts:

1. identifying and denominating geometric shapes on level 1;
2. informal analysis of geometric component parts and geometric shape attributes on level 2;
3. forming abstract definitions and distinguishing geometric shapes on level 3.

The Pearson correlation coefficients for the pre- and post-tests were 0.8054 for the 3<sup>rd</sup> grade and 0.736 for the 6<sup>th</sup> grade as alternate-form reliability, and the Cronbach coefficient for the pre- and post-tests were 0.8289 for the 3<sup>rd</sup> grade and 0.8482 for the 6<sup>th</sup> grade, with a 0.05 confidence level.

## Results

### Learning effect

Table 1 shows descriptive statistics for both groups' pre- and post-tests. We found that learning effects in both groups were promoted in the geometry course.

Table 1. Summary of means; SD: the learning effect determined by achievement test

		3 <sup>rd</sup> Grade				6 <sup>th</sup> Grade					
Group	n	Pre-test		Post-test		Group	n	Pre-test		Post-test	
		Means	SD	Means	SD			Means	SD	Means	SD
Ex	35	66.86	10.42	78.03	13.36	Ex	39	46.77	18.99	72.21	23.23
Con	34	71.94	9.96	80	16.89	Con	40	46.98	17.88	61.93	22.54

Ex = experimental group, Con = control group

Table 2. Summary of ANCOVA: the learning effect of different learning methods, \*p<.05

Grade	Sources of variation	Type III Sum of Squares	df	Mean Square	F	Sig.
3 <sup>rd</sup> Grade	Between groups (learning method)	37.061	1	37.061	0.2	0.656
	Error	12214.466	66	185.068		
Eta Squared = 0.003, Observed Power <sup>a</sup> = 0.073, r <sup>2</sup> = 0.191						
6 <sup>th</sup> Grade	Between groups (learning method)	1756.824	1	1756.824	5.136	0.026
	Error	25994.814	76	342.037		
Eta Squared = 0.063, Observed Power <sup>a</sup> = 0.609, r <sup>2</sup> = 0.365						

After removing the influence of the covariance, F = 0.2 for the 3<sup>rd</sup> grade in Table 2 is below the 0.05 significance level, which means there was no significant difference in learning effect between the Web-based and classroom learning environments. Taking a closer look at the strength of association (r<sup>2</sup> = 0.191), we see that learning method accounted for 19.1% of the total variation in learning effect in the 3<sup>rd</sup> grade class, but in the 6<sup>th</sup> grade class, F = 5.136 reached the 0.05 significance level, which means the learning effect in the Web-based learning environment differed significantly from the learning effect in the classroom learning environment. Checking the strength of association (r<sup>2</sup> = 0.365), we see that the learning method accounted for 36.5% of the total variation in learning effect in the 6<sup>th</sup> grade class.

Table 3. van Hiele Level Distribution on Pre-test and Post-test

Test	Level	3 <sup>rd</sup> Grade				6 <sup>th</sup> Grade			
		Ex (n=35), %		Con (n=34), %		Ex (n=39), %		Con (n=40), %	
		Cube	Cuboid	Cube	Cuboid	Prism, Cylinder	Pyramid, Cone	Prism, Cylinder	Pyramid, Cone
Pre-test	*	0	0	0	0	30.8	20.5	42.5	30
	1	48.6	45.7	26.5	44.1	30.8	48.8	30	50
	2	51.4	54.3	70.6	53	35.9	28.2	22.5	15
	3	0	0	2.9	2.9	2.5	2.5	5	5
Post-test	*	0	0	0	0	7.7	5	12.5	12.5
	1	8.6	11.5	2.9	5.9	17.8	28.2	15	30
	2	88.6	85.7	79.4	76.4	41	33.4	62.5	47.5
	3	2.8	2.8	14.7	14.7	33.4	33.4	10	10

\* = unreached Level 1

Table 3 shows that the van Hiele level of geometric thought in both groups was promoted from level 1 to level 2 or level 2 to level 3. The promotion percentage in the 3<sup>rd</sup> grade control group was greater than that of the experimental group, however, in the 6<sup>th</sup> grade, the promotion percentage was greater in the experimental group than in the control group.

### Group interview

Students were questioned in a group interview about the various learning settings, with the interviewer recording the students' answers (I = interviewer). After the interview, the students were asked to make two perspective drawings. Six students from each group were sampled and answers were coded as follows: E = experimental group, C = control group, 3 = 3<sup>rd</sup> grade, 6 = 6<sup>th</sup> grade; score intervals are: 1 = high score, 2 = middle score and 3 = low score, and serial numbers are 1 and 2. Thus, code E312 represents the 2<sup>nd</sup> sample in the high score interval of 3<sup>rd</sup> grade students in the experimental group. Students' verbal statements are given below:



























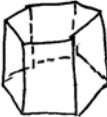





















<b>Experimental group</b>	<b>Control group</b>
<p>I: Just tell me about the activities of the geometry course via the Internet?  E312: I watch the videos and the Web, then I discuss with teacher and classmates in the chat room.  E321: I do the same things, and I think the 3D things in the screen are interesting.  E331: But, sometimes I don't know what to do.  E611: I can receive the reply from teacher by e-mail or bulletin board.  E622: When I click the hyperlink, I can explore the information of the geometry course.  E631: Yes, if I can't understand the geometry course, I can watch the videos again.</p>	<p>I: Just tell me about the activities of the geometry course in the classroom?  C311: Teacher asks us to open the textbook, we go page by page.  C322: And we make some paper models and play with them.  C332: I don't know what teacher says, I forget.  C612: We read and listen to what teacher teaches. After school, I do homework and complete exercises.  C622: At times, we make too much noise, and teacher silences us. But that is not all my fault.  C631: I don't know who I can ask about the geometry problems. Our teacher just teaches all the time.</p>
<p>I: Can you tell me how you play with the 3D animations?  E311: I can rotate and move them with the mouse.  E332: I can find their surfaces, sides and corners.  E612: I can operate them easily with the mouse, their solid shapes are clear.  E632: I have seen 3D things in video games, so I know how to use them.</p>	<p>I: Can you tell me how you play with the paper models?  C312: I can make the paper models and observe them.  C331: The paper models are like building blocks, I can use them to build a house.  C611: Teacher tells us how to make them, I can understand more about geometry.  C632: I can't make the paper models.</p>
<p>I: How do you feel the Internet discussions went?  E311: I can discuss with teacher and classmates in the chat room, and send my questions. I can answer others' questions, too.  E322: I don't worry about making too much noise on the Web, or teacher asking me to be quiet.  E331: I can see what I don't understand while they talk.  E612: It's perfect. I can communicate with teacher and classmates by typing.  E621: And we share our thinking on the bulletin board or by e-mail.  E632: Although I type slowly, everyone can see what I type in the list.</p>	<p>I: How do you feel the classroom discussions went?  C312: I can answer every question teacher asks.  C321: Teacher doesn't notice when I raise my hand most times.  C331: Nobody asks me, and I don't want to reply to any questions.  C612: In my group, they don't listen to me. How can I complete the task?  C621: I don't need to do too much. Jay and Lin usually will do the whole job.  C632: I don't know how to join them, they are too smart.</p>
<p>I: What is the most difficult for you on the Internet?  E312: Nothing at all! I feel it is interesting. Will we have another course?  E321: I don't see a real teacher.  E332: Typing is the most difficult thing for me. I can't keep up with others.  E611: Too many others want me to help them and reply to them. I don't like it.  E622: People saying something dirty in the chat rooms is unlovely.  E631: I can't type fast, because it is hard for me to spell well.</p>	<p>I: What is the most difficult for you in the classroom?  C311: Nothing is difficult for me in the classroom, I do whatever teacher says.  C322: I can't solve some homework exercises of the, and I can't find any help.  C332: The geometry course is the most difficult for me anyway.  C611: I think I don't have enough ability to be the leader of the team.  C622: I can't join discussions. Some people are uncooperative.  C631: Everything is difficult for me. I wish I could understand geometry better.</p>

Interpretation of the students' responses to the questions above helped to explain the quantitative results obtained with the ANCOVA. The group interview results can be classified into three main viewpoints on the Web-based and classroom-based learning settings. The first viewpoint is that students in high score intervals could complete most of the learning objectives and solve problems in both 3<sup>rd</sup> grade and 6<sup>th</sup> grade settings. The second viewpoint is that students in the middle score interval of control groups of both grades hardly gained any help when they faced problems with geometry questions. Students in the middle score interval of the 6<sup>th</sup> grade experimental

group could acquire help from the chat room, bulletin board, or e-mail, but not the 3<sup>rd</sup> grade. The third viewpoint is that the main difficulty students in the low score intervals of both grades' control groups had was in the content of the geometry course. Another difficulty students in the low score intervals of both grades' experimental groups had was inability to use computers and the Internet. In particular, they all complained of slow keying-in and spelling.

### The Perspective drawings

Table 4. Perspective drawings by 3<sup>rd</sup> grade and 6<sup>th</sup> grade students

Code	Cube	Cuboid	Code	Cube	Cuboid
E311			C311		
E312			C312		
E321			C321		
E322			C322		
E331			C331		
E332			C332		
Code	Prism or cylinder	Pyramid or cone	Code	Prism or cylinder	Pyramid or cone
E611			C611		
E612			C612		
E621			C621		
E622			C622		
E631			C631		
E632			C632		

Students need both spatial and drafting ability. From Table 4, we can see that the students with higher van Hiele levels made better drawings. However, while subject C632 had better sketching ability, he couldn't reach level 1 of the van Hiele theory.

## Discussion

The results above show that learning method accounted for a total variation in learning effect of 19.1% in the 3<sup>rd</sup> grade and 36.5% in the 6<sup>th</sup> grade. And the promotion percentage in van Hiele level of geometric thought in the 3<sup>rd</sup> grade control group was greater than the promotion percentage in the experimental group, but the promoted percentage in van Hiele level of geometric thought in the 6<sup>th</sup> grade experimental group was greater than the promotion percentage in the control group. The group interview results explain why learner-control instruction indeed improved students' achievements, but also produced large variations in students' performance. Those variations may come from the instructional task, instructional design, or assessment procedure results. In other words, students in the experimental groups thought that learning in the Web-based learning environment was interesting, helpful, and convenient, but some had difficulty typing and manipulating computers. A few also felt that the lecture video wasn't real. The influence of these problems was more serious than the shortcomings of classroom learning in the 3<sup>rd</sup> grade, however, the reverse was true in the 6<sup>th</sup> grade. That is, the ability to learn with computers and the Internet were the important factors in learner-controlled geometry instruction in the Web-based learning environment. For reasons mentioned above, the 6<sup>th</sup> grade were possessed of better computer skills and experiences than 3<sup>rd</sup> grade, so they could benefit more learning effect than the 3<sup>rd</sup> grade in a geometry course via the Web-based learning environment of learner control.

## Conclusion

The Web-based geometry course in this study was implemented with learner controlled instructional materials. We observed that the 6<sup>th</sup> grade students' ability to learn with computers and the Internet was sufficient to handle problems and promote their van Hiele levels of geometric thought. But this instructional technology seemed to threaten 3<sup>rd</sup> grade students' learning. Our research goals were confined by the 3<sup>rd</sup> grade students' ability to apply information technology. Research into the application of the Internet has been an amazing journey and led to some interesting observations. The evidence from the group interview pointed out that students need more communication with peers, teachers, and lecture materials, but this need wasn't satisfied for students in the control group. However, students in the experimental group could be included in a navigational scheme that reflected a balance between instructional control and program control based on learner control. This balance could let students in the experimental group meet the requirements of curricular discussion. Thus, it will help them to construct their geometric concepts and get greater achievement. We realize that this is but one small step in a long and challenging journey. The ever-growing presence of the Web should facilitate necessary levels of communication to continue our research and development. The technological advances in Internet progress will make it more convenient and more effective for use in Web-based learning.

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