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Development of Web-Based Courseware for Van Hiele's Visualization Level

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ABSTRACT :*This study developed web-based courseware applying van Hiele theory in order to offer different levels of content for figure learning for elementary mathematics students.*

In mathematics education, it is difficult to increase educational efficiency by conducting individual learning according to student ability because of the large differences in student levels, in addition to high populations in each classroom. This study provides courseware using van Hiele's visualization levels in order to offer different levels of content. This proposed courseware can improve students' learning achievement by offering differentiated content to learners who need advanced or supplementary learning materials. It also enhances learners' spatial-perception ability by offering various operating activities in figures learning.

Key words: *Courseware, E-learning content, Figure learning, Individual learning, van Hiele theory*

I. INTRODUCTION

Mathematics, like reading, is an important skill in our everyday lives. Mathematical reasoning is something we all do, from simple counting to complex calculations; however, the ability to use these skills varies greatly and difficulties emerging in childhood can persist through to adulthood. A solid grounding in basic numeracy helps children to succeed in other subject areas in the curriculum and develop more advanced mathematical skills that are essential for higher education and employment [1].

The field of geometrical figures is essential to many parts of mathematics textbooks and is closely related to students' lives. Although it acts as a foundation for abstract visualization, which students find difficult, a proper level of teaching is rarely possible and problems, which are not appropriate to the level of the students, are often assigned [2].

A major drawback of traditional instruction is that many teachers "teach to the middle" [3,4], which means that the needs of a growing number of students go unmet. Traditional instruction has a particularly deleterious effect on students with disabilities who often display diverse cognitive abilities, evidence multiple and varied instructional needs, and perform academically below their same-age classmates [5]. These deficits make students with disabilities especially vulnerable to a one-size-fits-all approach to instruction. The net result is that many of these students perform poorly on standardized tests, and have high dropout rates, low graduation rates, and high percentages of unemployment [6]. One solution is what experts refer to as

Differentiated instruction. Differentiated instruction is the process of "ensuring that what a student learns, how he/she learns it, and how the student demonstrates what he/she has learned is a match for that student's readiness level, Interests, and preferred mode of learning" [7].

In order to solve such problems, educational resources at various levels were produced according to the cognitive level of students. Even now, however, problems such as excessive numbers of students per class, superior class recognition due to group formation, excessive amounts of work for teachers, problems in the development of supplementary and night educational programs, etc. are occurring; these make the educational process operations for various levels difficult [8].

In this study, various leveled studies applying van Hiele theory are provided. A web-based courseware applying van Hiele theory was developed in order to support different levels of studies in geometrical figure learning for elementary students.

II. VAN HIELE THEORY

In this chapter, we refer van Hiele theory as theoretical background.

1. The Components of the van Hiele Theory

The three components of the van Hiele model are insight, van Hiele thinking level, and studies level [9]. The learner must undergo five levels in their education experience, and if one cannot pass a certain level, that person may not move on to the next.

Insight is the ability to carry on an assignment even in unfamiliar situations and to perform the situational requests proficiently. It also means being able to thoughtfully and consciously find solutions for certain situations.

If students have insight, it means that they know and understand what they are doing, why they are doing it, and when they will do it. In addition, students who have insight have the ability to use their knowledge when solving problems [10].

1.1 The Geometrical Thinking Level of van Hiele Theory Van Hiele theory classifies students' geometrical study thinking levels into the following five categories [11, 12].

The first level is visualization or the holistic level.

It is the basic level and, rather than looking at a geometrical concept through the components or properties, it is seen as a whole. A geometrical shape, when it comes to physical appearance, is identified not through partial characteristics, but through its shape as a whole. Children who are at this level can identify and copy geometrical terms and shapes; but children of this level cannot identify right angles or parallel lines. Thus, when they see a rectangular box, they identify it as being a square shape, and a triangular ruler as a triangle shape, and a delicious pizza as a circular shape. They are able to understand that the shapes are different from one another, but that is about all they are capable of doing.

Although they can identify squares, rectangles, parallelograms, etc. and other shapes, they are not able to confirm the relationship between the various shapes. In addition, they cannot understand the concept of all squares being rectangles and all rectangles being parallelograms. Children focus on the visual characteristics of the 'geometric' shapes in order to tell them apart.

The second level is the analysis or description level.

In the second level, the classification of geometric concepts begins. Through observation and experimentation, the characteristics of figures are divided. Through these characteristics, the shapes are classified. The fact that figures have parts, and these parts form a geometric figure is identified. Students, however, are not able to make a precise mathematical definition for the figure. In addition, since they do not clearly understand the definition, they are also not able to understand the relationships between the figures' characteristics. Children at this level, for example, recognize that parallelograms have parallel lines and are congruent; however, they merely think that these characteristics are happening at the same time. These children are also not able to identify a quadrangle with congruent parallel lines as a parallelogram. At this level, children can see the similar characteristics of different shapes, but they still are not able to decide upon a 'ranking' among squares, rectangles, and parallelograms

The third level is the informal deduction level.

Children at this level are able to identify the characteristics within one figure. In addition, they understand the relationships among various geometric figures. This is the point where they move on from an experimental geometry into a formal geometry. Deductive inference can become a concrete proof; and, therefore, children can make inferences about the figure's characteristics; and, not only can they identify that some characteristics can result from other characteristics, but they also have the ability to classify figures through their characteristics. They have, for example, the ability to identify squares as a specialized form of the diamond, and understand the inclusive relationship of quadrangles properly. Once they understands inclusive relationships, not only are they able to understand the definition, but they are also be able to carry out formal arguments. Children at this level, however, cannot understand the importance of deduction as a role in common. Inference is used as an experimental or experiential method. Formal proof may be possible, but the theoretical order that brings about the conclusion is not noticed easily; deductive inference is limited and they need to receive help from teachers or textbooks.

The fourth level is the deduction level.

Students who are at the level of formal deduction are able to understand deduction, which is one of the methods of arranging geometrical figures within the postulates. They can understand the roles and relations of undefined terms, postulates, concept arrangements, postulates and proofs, and identify the deduction systems within geometry. Children at this level are not at the stage of merely demonstrating skills by remembering proof processes, but they can also create them themselves. In addition, they can understand the interrelationships between necessary conditions and sufficient conditions; they can distinguish between their propositions and their roles.

Thus, for the definition "a triangle with two equal sides is an isosceles triangle," they are able to prove that "the base angles of an isosceles triangle are equal." These students, during the process of propositional deduction, do not understand the necessity of preciseness, nor do they understand the thinking transition relation when going from one deduction to another.

The fifth level is rigor level.

At this level, children are able to understand the necessity of various abstract deductive inferences that are strict and precise; for example, Hibert's basic geometrical theory. As a result, it is a level where students can grow to understand Euclidean geometry by thinking mathematically in both an abstract and general manner through the specific characteristics of geometry; they can also understand the specific meanings behind it. In addition, they are able to understand the postulate system's characteristics: non-contradiction, independence, and completeness. The fact that "two parallel lines which meet a third straight line result in equal alternative angles" can be proven by 'reduction to absurdity'; and by using these parallel line postulates and sub-organization, they can conclude that "the three angles of a triangle add up to 180°. Children who are at this level exceed the level of high school students and have the ability to study in an academic system. Not only are they be able to compare other systems, but they are also be able to abstractly study various geometries without being provided a concrete shape or diagram. This last level did not receive much interest during the initial research, nor from other researchers as well.

Crowley [9] described some properties of the model. Three are of particular interest to teachers. .

First, students must proceed through the levels in order.

Second, Students move through the levels without skipping any level. Their progress from level to level is more dependent on the content and method of instruction than on age.

Third, for learning to occur, instruction must occur at the level of the student. If instruction is delivered at a higher level than the learner is able to comprehend, the student will have difficulty following the thought processes used.

1.2 Studying Level based on the van Hiele levels

As observed above, it was claimed that there could be no skipping among the thinking levels according to the van Hiele theory, and that things occur in a step by step manner. Students have to pass through one level after another. This progression is not a natural process, however; it is carried out by the support of professionals and organized study programs. According to Crowley [9], the professional support consists of five steps: a quality guidance level, a guided research level, an opinion level, a liberal research level, and a combination level.

2. The Characteristics of the van Hiele Model

If one organizes the characteristics of the study level theory of van Hiele, they are as follows [13].

First, the thinking process is a leveled, discontinuous activity; and therefore, without passing through the low levels, a student cannot move into the higher levels. As a result, for mathematical thinking, all levels must be taken step by step in order for advancement. Thus, without going through the n-1 level, students will not be able to reach the n level.

Second, not all students pass through each level at the same speed. In addition, the time consumed at each level may be shortened through good guidance, or may even be lengthened because of inappropriate guidance. Advancement from one level to another relies much more on educational content and methods than on age and physical maturity.

Third, in a higher level, the actions that were carried out during lower levels become a subject of classification. Things that had been a method of thinking in the previous level may become a subject of thinking in the next level. In addition, a concept that was understood tacitly in the precious level may be more clearly defined in the next level. The first level is one where you can think of objects around you as figures and shapes. The second level is one where you think of figures and shapes as having a geometric characteristic. The third level is one where the figure's characteristics become a subject of thinking, and the characteristics of the figures are identified through the means of proposition. The fourth level is one where methods become a subject of thinking, and the methods are identified through the means of logic.

Last, at the fifth level, logic itself becomes a subject of research.

The basic premise of the van Hiele theory is an idea that systemizes the experience of mathematical thinking processes. In addition, the method of organizing experiences within a particular level is identified as a new experience. The activity is carried out and these processes are repeated as students move to the next level. Mathematical learning guidance must therefore be able to reinvent these cycles [14].

With respect to geometrical guidance, when children are guided properly, they will increase in level; and, if guided inappropriately, their advancement may be delayed. Thus, the importance of providing children with geometric studies that fit their level and uses the appropriate language and guidance is crucial.

Previous studies have suggested reasonability through the concrete examples regarding the theories of van Hiele and teaching-learning resources that can increase the knowledge level of the learning have been developed. Through these studies, the learners can be provided with individualized figure learning that fits their level. Traditional teaching-learning, however, is being carried out only in offline learning; there has not been enough research on the development of teaching-learning resources that considers the knowledge level of the learners. By keeping pace with the changes happening among new teaching and learning styles, online figure learning applied using van Hiele's theories should be provided for each levels.

III. DEVELOPMENT OF COURSEWARE FOR VISUALIZATION LEVEL

In this chapter, we describe development environments, the courseware interface model, and courseware for visualization levels.

1. Development environments

The major development tool is flash; and, in order to process images and interwork Photoshop and database, the PHP web programming language is used.

The developmental direction of this research is as follows.

First, by using the online van Hiele questionnaire, the learner's knowledge skill is accurately diagnosed. Depending on the diagnostic results, leaning that fits the learner's level is ensured within the provided virtual space.

Second, through various games, interest in learning is induced, and motivation is sustained through interaction with the learning system.

Third, the games provided within the virtual space are developed by considering the development of Geometry skills according to van Hiele's theories in order to fit the knowledge level of the learners.

Fourth, game environments that allow learners to personally manipulate shapes are provided in order to increase the spatial sense of the children.

Last, advice that promotes the mindset of the learner should be provided.

2. Developmental of the Courseware Interface

2.1 Log-In of Learners

In the initial screen, the major character visits Figure Land. In order to trigger interest in the learner, this system gives learners a chance to be the main character and sets up a story such that the learner has to bring back several stolen figures.

When those visiting for the first time the learner presses the 'Register' icon, and progresses to the registration screen. When guidelines are followed, an ID and PASSSWORD are created, and learner can immediately start learning.

Previously registered learners insert their ID and PASSWORD and press the 'challenge' button. As shown in Fig. 1, once the button is pressed, information about previously learned content is provided. Through this, the learners can discover learning that appropriately suits their level.

Fig. 1 The result of Logging-in

2.2 Main Menu

The main menu screen provides information for the learner. In the major menu, various buttons are provided including buttons for the Room of Abilities Testing where the learner's level is tested, the Room of Strength where learner can learn, the Room of Bravery, the Room of Wisdom, the Spaceship, and the Completion of Studies. In order to trigger motivation in the learners, learners become the actual characters and are able to feel that they are in the midst of an adventure. Fig. 2 illustrates the main screen.

Those who are visiting for the first time have to start in the Room of Abilities Testing so that they can test their levels. Those who have previously visited will start learning in the room that is compatible with their abilities. In order for learners to enter each room, passwords are needed. By taking the abilities tests, learners can acquire the passwords to rooms that are appropriate to their levels.

Fig. 2 Main Menu

2.3 Diagnosis of the Learner's Level

As shown in Fig. 3, a level test is presented with 20 questions; and, when the presented numbers are clicked, the next question is presented. When the correct answer is clicked, the score increases. The level of the learner is decided depending on this score.

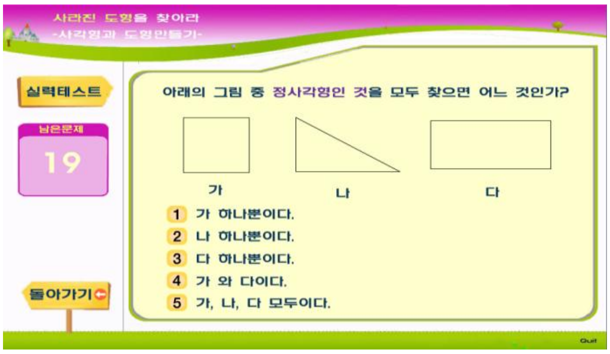

Fig. 3 Level Test

As shown in Fig. 4, depending on the diagnostic test results, passwords that can take learners to the Room of Strength, the Room of Bravery, and the Room of Wisdom can be obtained.

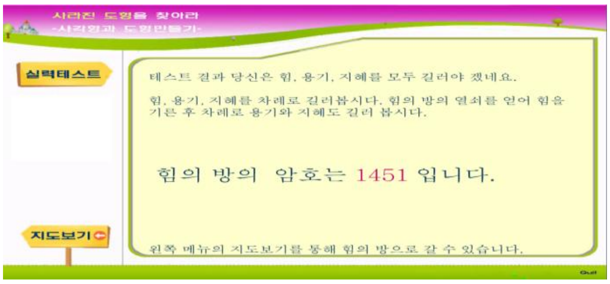

Fig. 4 The result of Level Test

2.4 Figure Learning Games

All the content of figure learning is provided according to the game learning methods for each level and depending upon the learners' levels. When the learning for each level is completed, evaluation is always provided. Depending on the evaluation result, the authority to pass to a higher level of learning is given so that learning for each level can be made appropriately.

3. Courseware for the Visualization Level

We called this room the "Room of Strength". The Room of Strength is formed around four kinds of games. Objects that can be easily seen in our surroundings are used to observe and manipulate as they are recognized as figures. Explanations for each game are as follows.

As displayed in Fig. 5, 'Find the same Shape' is a game that provides cards with objects that can be seen in the surroundings and the learner must find the same shape. When learners see a notebook, they search for a rectangular shape. If the learners see a mountain or shellfish, they search for a triangular shape. If they see a ball, they will recognize it as a circular shape. Thus, learners are tested on their ability to distinguish between different shapes.

Fig. 5 Find the same Shape Game

As displayed in Fig. 6, 'Capture the Shape' is a game where shapes have to be recognized although the cards have been divided into upper and lower parts and moved from left to right during a short amount of time. In this game, as the shapes pass by, the learners have to guess the shapes. This, then, contributes to helping learners visually recognize various shapes.

Fig. 6 Capture the Shape Game

Fig. 7 Complete the Shapes Game

The game called 'Complete the Shapes' is displayed in Fig. 7, Shapes are given before starting the game, and learners observe the shapes. Once the game starts, the shape disappears and the game is accomplished when the shape is found. In order to increase learning efficiency, various given pieces are manipulated by the mouse and the learner is able to confirm them visually. Through the replay button, the earlier shapes can be seen according to the learners' desires.

As shown in Fig. 8, 'Find the Hidden Shape' is a game where triangular, rectangular, and circular shapes have to be found in a picture. As learners search for triangular, rectangular, and circular shapes in the game, they will be able to recognize the fact that many of these shapes exist in their surrounding environment as well.

Fig. 8 Find the Hidden Shape Game

Through the games where shapes are found in surrounding objects or by completing shapes using different pieces, learners will be able to visually recognize figures. As their levels increase through each of the games, learners can find the password for the Room of Strength in order to move to a higher level of learning.

IV. Conclusion

A web-based courseware applying van Hiele's theory of visualization levels was developed.

In this program, game content that fits the level of awareness of learners regarding shapes is developed so that real-time, individual learning can take place. In addition, graphics and animation stimulate learner interests and motivation, cultivate an appropriate attention span and learning attitude, and provide an interactional, teaching-learning environment between the student and educator.

The results of this study are as follows.

First, level learning based on the theories of van Hiele can help enhance effective learning about Geometry as well as increase the level of recognition of shapes.

Second, though the adventure-game style of learning, interest in mathematic can be triggered in the learners.

Third, diverse learning materials should be introduced when learners are learning shapes, since such learning requires spatial perception skills. By providing various operational activities, learners are able to develop spatial perception skills.

Fourth, mathematics in the 4th grade of elementary school deals with content regarding 'learning about shapes' by levels; so, for learners who need additional deep supplementary lessons, more learning opportunities can be provided.

Last, educators will feel less burdened by having to sacrifice time and effort on developing learning for each level.

This study proposes some of the areas that need improvements as well as some agendas in the educational field that need to be improved and secured.

First, web courseware and learning models appropriate to each level of mathematics learning should be developed. In addition, proper learning guidance should be developed as well, in order that the two be applied together.

Second, in order for students to learn according to their personal level, development of web courseware for each level is needed in diverse areas beyond figure learning.

Third, the authors intend to develop courseware for other levels of van Hiele theory, and need to develop an adaption module to supply a course for learners' differentiated learning at proper levels.

Last, in order to verify the accurate effects of the courseware, it is thought that research on the effects on students is needed.

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