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APPLYING VAN HIELE'S THEORY TO POLYHEDRONS MODULE

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Abstract: Various students' ability on understanding geometry leads to the poorest of learning in the class. A learning module is one of the ways to deal with diversity. Furthermore, the experts trust that van Hiele's theory of learning is effective in geometry learning, such as polyhedrons. This article describes how to design a learning module that implements van Hiele's theory of geometry learning. This article tells the validity of the module as well. The module was developed by Plomp's model. Based on preliminary research step, the module was designed into five sections. Following van Hiele's theory of geometry learning, each section of the module contains five learning activities, these are the inquiry phase, guided-orientation phase, explication phase, free-orientation phase, and integration phase. In the inquiry phase, students meet with cases related to their daily life, such as gifts pack for boxes, material cloth for tents, the volume of an aquarium, or volume of solid chocolate. Then, guided-orientation phase offers some activities which build up polyhedron concepts. This phase is fraught with processes such as observing, copying pictures, drawing geometry objects, calculating, cutting, folding, or finding a formula. In explication phase, students construct concepts from the previous phase. This phase contains explanations about the polyhedron concepts that presented in fill-in-blank statements. The second last phase is free orientation, which serves a chance to students for doing other complex tasks or applying the concepts in tasks. The tasks are directly related to the concepts that students gained from explication. The last is integration which students play games related to the concepts or solve problems without a clue. Based on expert validation, the module was confirmed as a valid learning resource.

Keywords: learning module, polyhedrons, van Hiele's theory

INTRODUCTION

Students meet geometry since they are in elementary school. It is undeniable that geometry is close to daily life. Every day they face with geometric figures, such as circle, cube, cuboid, pyramid, etc. The implementation of geometry in daily life makes it be a crucial subject. Geometry is a natural place where students establish their reasoning skills (NCTM, 2000). According to Jones (2002), geometry plays a vital role in many aspects. Furthermore, teaching geometry well leads to a great achievement in mathematics.

Based on Wu (1996), students take quite a long time to deal with geometric figures before they understand them. Many researches reported that students encounter difficulty in geometry (Usiskin, 1982). According to the data of final examination on 2016 in junior high schools in Surakarta, students' absorption on geometry and measurement

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was the lowest among the others. The data shows that students' absorption on geometry and measurement was 50.39%, while students' absorption on the number; algebra; and statistics and probability were 56.80%; 53.42%; and 53.12% respectively. This means the teaching and learning of geometry in school still worst enough. Some studies were done to analyze why geometry become one of the subjects where students have a quite disappointing achievement. According to Hiele (1999), there is a misconception on the teaching of geometry in the schools then this leads to misunderstandings. In geometry, students' thinking is directed to formal deductive thinking, students study axioms, definitions, proofs, and theorems meaningless in geometry (Abdullah & Zakaria, 2013b). Furthermore Abdullah and Zakaria (2013b) said that geometry teaching in school rules out its importance in students' life.

Based on observation in one of junior high school in Surakarta, a teacher taught geometry traditionally. The teacher used the chalk-and-talk method with the teacher-centered approach. The concepts of geometry were delivered by lecturing. Based on Rahmawati et. al (2013), conventional learning starts with teacher's explanation, presents samples, and ends up with giving exercises. This ruins the development of students' knowledge and potency. As a fundamental concept that should be skilled by students (Abdullah & Zakaria, 2013b), geometry learning has to be understood meaningfully. It is claimed that van Hiele's theory is an effective way to learn geometry (Havinger & Vojkuvkova, 2014; Mostofa, Javad, & Reza, 2017). Moreover, learning geometry based on van Hiele's instruction leads to great influence for learning outcome (Yazdani, 2007). According to van Hiele, there are five phases to supports students on geometry, they are information, directed orientation, explication, free orientation, and integration (Howse & Howse, 2014). The information or inquiry phase is the beginning phase where students explore and discover certain geometric structure (Hiele, 1999). This phase contains dialogue between teacher and students in order to inquire into students' prior knowledge (Howse & Howse, 2014). The second phase is guided orientation phase where students and teacher explore sets of carefully sequenced activities (Breyfogle & Lynch, 2010). In the next phase, excplication phase, students share their explicit views and understanding about the previous activities. Then, on the free orientation phase, teacher asks students to solve problems related to geometric concepts (Breyfogle & Lynch, 2010). The last phase is integration, where students pull together what they have learned from all previous phases (Hiele, 1999).

It is also interesting to note that based on the observation, this school use students' book, developed by the ministry of education, called Buku Sekolah Elektronik (BSE). According to Ahyan, Zulkardi, and Darmawijoyo (2014), BSE offer problems on mathematics language, not on context. This is not in accordance with the current curriculum, Curriculum 2013, where invited students to build habits in their daily life so that they would have noble characters (Prihantoro, 2015). In fact, though the government offers BSE, learning resources could be developed to support the implementation of the curriculum. One of learning resource that could be offered is a module of learning. This

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allows students to learn independently because students have different ways to solve problems and could not gain the same outcome at the same time (Nasution, 2005).

Based on the exposure above, it is needed to develop a module that implements van Hiele's theory as a learning resource on geometry. In general, this research designed a learning module that implements van Hiele's theory of geometry learning.

APPROACH & RESEARCH METHOD

Pursuant to the research purpose to describe how to design a learning module that implements van Hiele's theory of geometry learning, this research was research and development. The Plomp model was used to develop this module. Started by preliminary research phase, development phase, and ended up with assessment phase (Plomp, 2014). On the preliminary research phase, curriculum on the grade VIII (especially on the polyhedrons section), students' condition, and the existing learning resources were analysed. According to the first phase result, a polyhedron module was designed and van Hiele's theory was implemented on the module. On the assessment phase, validation of the polyhedron module was conducted.

RESULTS AND DISCUSSION

a. Preliminary research phase

In the first step, preliminary research phase, curriculum and geometry materials in the junior high school were identified. One of junior high school in Surakarta, SMP Muhammadiyah 7, still used *Kurikulum Tingkat Satuan Pendidikan* (KTSP) or school-based curriculum for the second and third grade, while the first grade used Curriculum 2013. The latter curriculum points out on building students' characters, fostering students' skill based on their interests and needs, not to mention developing a thematic learning approach (Putra, 2014). The teacher used BSE and a commercial worksheet as learning resources. While commercial worksheet teacher used was less contextual and did not emphasize students' interests and needs (Prastowo, 2013). Besides, BSE teacher-utilized used abstract problems (Ahyan et al., 2014) that were less daily life.

Identification was done on of polyhedrons material on the second grade of junior high school. Then, by analyzing the learning objectives of the polyhedron material, it yielded that there were 15 objectives of learning in polyhedrons material. They were: 1) designing nets of cube and cuboid based on concrete object, 2) finding the formula of surface area of cube and cuboid, 3) calculating the surface area of cube and cuboid, 4) identifying nets of prism and pyramid and finding the formula of their surface area, 5) finding conditions so that the formula of surface area of prism and pyramid can be calculated, 6) finding pattern to derive the volume of cube and cuboid, 7) calculating the volume od cube and cuboid, 8) finding pattern to derive the volume of prims and pyramid, 9) calculating the volume od cube and cuboid, 10)

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determining the relation among space diagonal, face diagonal, and diagonal planes of polyhedrons, 11) determining the length of space diagonal and face diagonal, and also the area of diagonal planes, 12) solving problems related to cube, cuboid, prism, and pyramid, 13) evaluating the surface area of combination of polyhedrons, 14) evaluating the volume od combination of polyhedrons, and 15) solving problems related to space diagonal, face diagonal, and diagonal planes. According to the identification phase, this research developed module with 5 sections for learning polyhedron. The first section was cube and cuboid, and their surface area, the second was prism and pyramid, and their surface area. The next section was the volume of cube and cuboid. The fourth section was the volume of prism and pyramid. The last section was getting to know more about polyhedrons. These sections were written on the cover of the module. The cover od polyhedron module was given on Figure 1 as follows.

Figure 1. The cover of the polyhedron module

Besides, learning objectives were given in detail on the second page. This was intended that students could know what they would learn further. On each section, the beginning was section title and it was followed by the learning objective of the section. In line with Purwanto, Rahadi, and Lasmono (2007), a module has contained learning objective in order to clarify the direction of learning activities and to emphasize them.

b. Implementing van Hiele's theory on polyhedron module

Each section on the polyhedron module was arranged based on van Hiele's theory. It contained five phase of van Hiele learning processes, namely inquiry phase,

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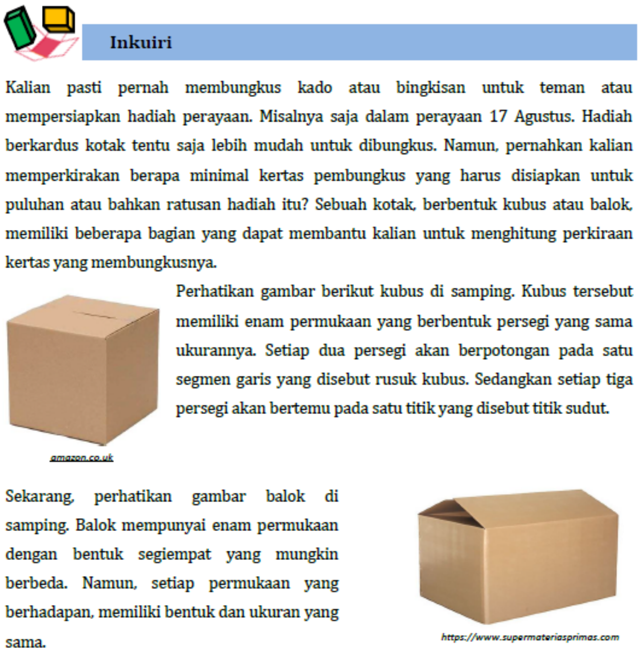
guided orientation phase, explication phase, free orientation phase, and integration. This van Hiele's theory was integrated on every steps for learning polyhedrons.

At first, students met with ***inkuiri***. It was the inquiry phase on the van Hiele's theory. In this part, students acquainted with the preliminaries concept of polyhedron. The main activity on this phase was the introduction of polyhedron concepts through the relationship of information with concrete objects, context, and information related to the concept (Abdullah & Zakaria, 2013b). In this module, on the first module section (cube and cuboid, and their surface area), students met with context about wrapping box (Alcocer, n.d.). The example of ***Inkuiri*** can be seen on Figure 2 as follows.



Inkuiri

Kalian pasti pernah membungkus kado atau bingkisan untuk teman atau mempersiapkan hadiah perayaan. Misalnya saja dalam perayaan 17 Agustus. Hadiah berkardus kotak tentu saja lebih mudah untuk dibungkus. Namun, pernahkan kalian memperkirakan berapa minimal kertas pembungkus yang harus disiapkan untuk puluhan atau bahkan ratusan hadiah itu? Sebuah kotak, berbentuk kubus atau balok, memiliki beberapa bagian yang dapat membantu kalian untuk menghitung perkiraan kertas yang membungkusnya.

Perhatikan gambar berikut kubus di samping. Kubus tersebut memiliki enam permukaan yang berbentuk persegi yang sama ukurannya. Setiap dua persegi akan berpotongan pada satu segmen garis yang disebut rusuk kubus. Sedangkan setiap tiga persegi akan bertemu pada satu titik yang disebut titik sudut.

amazon.co.uk

Sekarang, perhatikan gambar balok di samping. Balok mempunyai enam permukaan dengan bentuk segiempat yang mungkin berbeda. Namun, setiap permukaan yang berhadapan, memiliki bentuk dan ukuran yang sama.

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Figure 2. The inquiry phase on the section of cube and cuboid, and their surface area

Students usually meet this problem when they want to give gitfs. They have to estimate how many wrapping papers that they should buy. This preface made students acquainted with the characteristic of cube and cuboid, not to mention its surface area. Besides, on the other section, this module offered some other context, such as cloth for making a tent on the section of the surface area of prism and pyramid; the volume of an aquarium as a context of cuboid volume; and the volume of solid chocolate as a context on prism volume.

The second phase was ***Orientasi Terbimbing***, it was guided orientation on the van Hiele's phase. According to Hiele (1999), this phase was like playing a game "feel and find the shape". Further, the activity in this phase was arranged so that concepts or characteristics could be found gradually by students. In this module, this phase was activities in order to build polyhedron concept for students, that contained observing, copying pictures, drawing geometric objects, calculating, cutting patterns,

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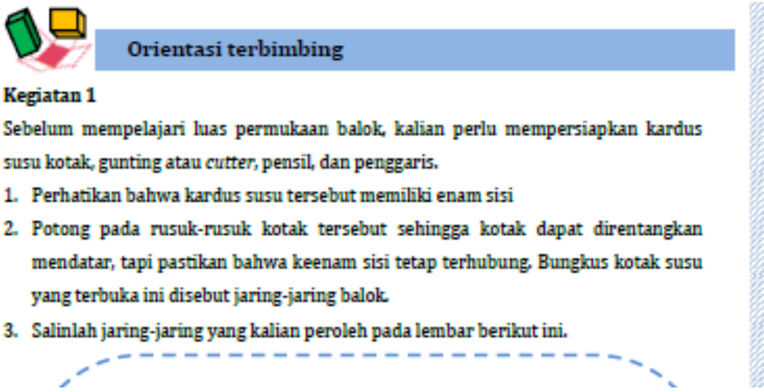
and folding. The example of guided orientation phase could be seen on Figure 3 below.



Orientasi terbimbing

Kegiatan 1

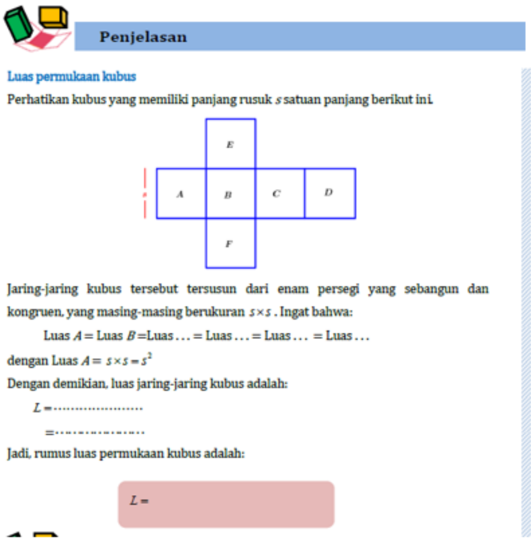
Sebelum mempelajari luas permukaan balok, kalian perlu mempersiapkan kardus susu kotak, gunting atau *cutter*, pensil, dan penggaris.

1. Perhatikan bahwa kardus susu tersebut memiliki enam sisi
2. Potong pada rusuk-rusuk kotak tersebut sehingga kotak dapat direntangkan mendatar, tapi pastikan bahwa keenam sisi tetap terhubung. Bungkus kotak susu yang terbuka ini disebut jaring-jaring balok.
3. Salinlah jaring-jaring yang kalian peroleh pada lembar berikut ini.

Figure 3. The guided orientation phase on the section of cube and cuboid, and their surface area

This module gave a chance for students to directly explore a cuboid by using an old box of milk. They have to cut some edges in order to make a net of cuboid. Then they were asked to draw other nets of the cuboid. By using a net, students directly explored how to find surface area of cuboid. As explained by Siew, Chong, and Abdullah (2013), in this phase, students investigated geometric objects based on guided activities so that they could find the characteristics of the geometric object.

The next phase was ***Penjelasan***. In this explication phase, students were expected to realize the properties of geometric objects properly. The activities used in this phase were explanation related to the previous phase. Based on Siew, Chong, and Abdullah (2013), they arranged the learning so that teachers introduced the properties of geometric objects inaccurate and appropriate language. In this module, students worked on fill-in-the-blank statements to find the properties of polyhedron. By this steps, students could understand the concepts clearly. Figure 4 shows an example of this step.



Penjelasan

Luas permukaan kubus

Perhatikan kubus yang memiliki panjang rusuk s satuan panjang berikut ini.

Jaring-jaring kubus tersebut tersusun dari enam persegi yang sebangun dan kongruen, yang masing-masing berukuran $s \times s$. Ingat bahwa:

Luas A = Luas B =Luas ... = Luas ... = Luas ... = Luas ...

dengan Luas $A = s \times s = s^2$

Dengan demikian, luas jaring-jaring kubus adalah:

L = ...

= ....

Jadi, rumus luas permukaan kubus adalah:

L =

Figure 4. The explication phase on the section of cube and cuboid, and their surface area

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By observing a cube net, students have to complete the given task (fill-in-blank-task) in order to find the surface area of the cube.

The second last phase of van Hiele's theory was free orientation. This module offered ***Orientasi bebas***, where students met with a challenge to complete task related geometric shapes (Breyfogle & Lynch, 2010). Moreover, Siew, Chong, and Abdullah (2013) stated that students worked on more complex tasks. In this module, students were asked to complete tasks directly related to the previous phase; to solve the problem (that given on ***Inkuiri***); or to solve guided tasks (or tasks with some clues). One example is given in Figure 5 below.

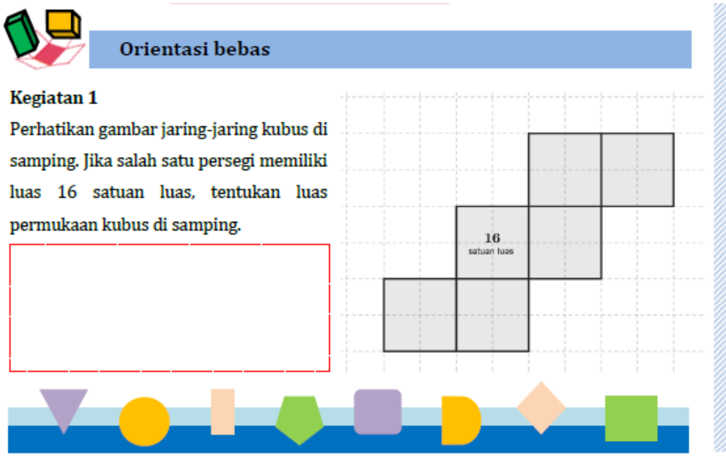

Figure 5. The free orientation phase on the section of cube and cuboid, and their surface area

By students' understanding on the previous phases that a cube has 6 congruent faces, they could evaluate the surface area of the given net. The net was never given before. In accordance with Siew, Chong, and Abdullah (2013), students explored new geometric shapes on the free orientation phase.

The final phase of van Hiele's phase was integration. This module offered ***Integrasi,*** students framed an overview of all they studied (Mason, 1998; Siew et al., 2013; Abdullah & Zakaria, 2013a). In this module, students met with a challenging task integrated by using games or giving task without a clue. The example of integration phase can be seen as follows.

ISBN: 978-602-361-102-7

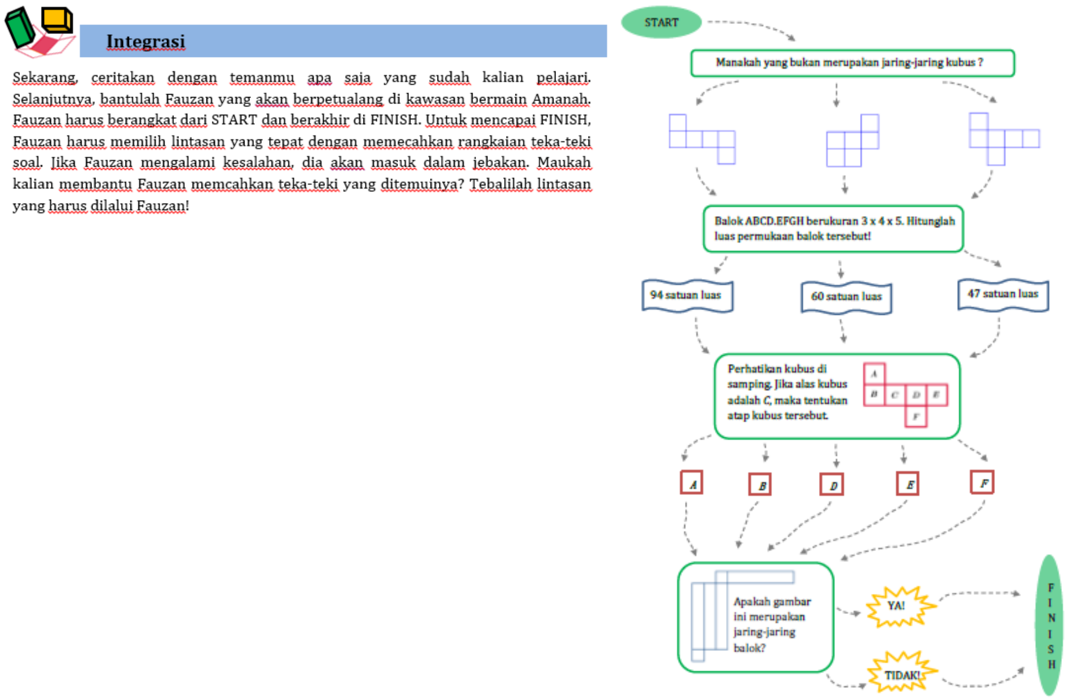

Figure 6. The integration phase on the section of cube and cuboid, and their surface area

It can be seen from the Figure 5 that the module asked students to discuss overview what they studied. Then they had to finish the game in order to deepen their understanding. By this steps, students were expected to develop a network and relation of geometric properties (Mason, 1998).

According to Depdiknas (2008), a module has to contain some criteria, from self-instruction, self-contained, stand-alone, adaptive, and user-friendly. This module was self-instruction. By using this module, students could do self-studying. This module contained complete instructions so that they study independently. Besides, the key answers of exercise were presented at the end of the section in order to give chance for students checking their answer. In the case of contents, this module constructed according to syllabi and geometric materials in the school. The development phase started with preliminary research where curriculum was studied in detail. This means the module had a self-contained criterion.

The module developed independently so that students did not require other sources to study polyhedron. This implies that this polyhedron module was stand-alone. Further, because this module was developed in accordance with van Hiele's theory, this module was adaptive following geometry theory. Besides, contextual problems were presented to start the learning. This module also completed with some figures designed by GeoGebra, a dynamic software that claimed effective for mathematics learning (Preiner, 2008). To meet with the last criterion of a good module, this module offered games related to the material. Besides, it wrote with languange that easy to understand for junior high school students. It also used friendly terms, such as ***Mari berlatih*!** (it means "Let's practice") instead of

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"Exercises", and ***Ayo cek jawabanmu!*** (it means "Let's check your answers") instead of "Answer key".

Based on the validation of two experts, this module was valid for learning source. Some improvement has to do in some parts. These are on the positions of geometric figures and tables; and the arrangement of sentences.

CONCLUSION

This was a research and development study in developing a polyhedron module based on van Hiele's theory. This module consisted of five sections, they were: 1) cube and cuboid, and their surface area; 2) prism and pyramid, and their surface area; 3) volume of cube and cuboid; 4) volume of prism and pyramid; and 5) getting to know more about polyhedrons. Each section contained van Hiele's learning activities, started with the inquiry phase, guided-orientation phase, explication phase, free-orientation phase, and ended up with the integration phase. In the inquiry phase, students met with cases related to their daily life. Then guided-orientation phase offered some activities which build up polyhedron concepts. In explication phase, students constructed concepts from the previous phase. The fourth phase was free orientation, which serves a chance to students for doing other complex tasks or applying the concepts in tasks. The last was integration which students play games related to the concepts or solve problems without a clue. This module also met with good criteria, these were self-instruction, self-contained, stand-alone, adaptive, and user friendly. Based on expert validation, the module was confirmed as a valid learning resource with some improvement in some parts.

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