



GEOGEBRA APPLETS DESIGN AND DEVELOPMENT FOR JUNIOR HIGH SCHOOL STUDENTS TO LEARN QUADRILATERAL MATHEMATICS CONCEPTS

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Abstract

This design and development research was motivated by the rapid expansion and use of GeoGebra by mathematics educators (teachers and lecturers) in Indonesia. One of GeoGebra features is GeoGebra Applet that can be used, modified, and/or developed by educators for dynamic and interactive mathematics teaching and learning. At the time of research project, there is no GeoGebra Applets closely linked and aligned to the Indonesia national curriculum. The availability would be benefit for mathematics teaching and learning aligned to this curriculum. This research proceeds through seven steps of the Need, Capability, and Analysis (NCA) Model of Design and Development: 1) User Need Analysis; 2) Researcher as Developer Capability; 3) GeoGebra Applets Design; 4) GeoGebra Applets Development; 5) Experts Judgements; 6) Field testing in its Natural Setting Environment; and 7) the Prototype. The field testing was conducted with 8th grade students in a junior high school. The field testing shows that the developed Quadrilateral GeoGebra Applets can work as expected in its purposed natural setting environment.

Keywords: GeoGebra, Applet, Design and Development, Junior High School

Abstrak

Riset desain dan pengembangan ini dimotivasi oleh pesatnya perkembangan dan penggunaan GeoGebra oleh para pendidik (guru dan dosen) matematika di Indonesia. Salah satu fitur dari GeoGebra adalah ketersediaan applet GeoGebra yang dapat digunakan, dimodifikasi dan dikembangkan oleh para pendidik untuk pembelajaran matematika yang dinamis dan interaktif. Pada saat riset dilaksanakan, belum tersedia Applet GeoGebra yang terkait dan mengacu pada kurikulum nasional Indonesia. Ketersediaan Applet GeoGebra yang terkait dan mengacu pada kurikulum nasional akan memberi manfaat lebih bagi proses pengajaran dan pembelajaran matematika. Riset ini dilakukan melalui tujuh tahapan model NCA (Need, Capability, and Analysis) Desain and Pengembangan: 1) Analisis Kebutuhan; 2) Analisis Kapasitas Peneliti sebagai Pengembang; 3) Desain Applet GeoGebra; 4) Pengembangan Applet GeoGebra; 5) Uji Ahli; 6) Uji lapangan di tempat alami produk akan digunakan; dan 7) Purwarupa. Uji lapangan dilakukan pada para siswa kelas VIII salah satu sekolah menengah. Uji lapangan menunjukkan bahwa Applet GeoGebra Quadrilateral yang dikembangkan dapat berfungsi dengan baik di tempat alami produk tersebut akan digunakan.

Kata kunci: GeoGebra, Applet, Desain dan Pengembangan, Sekolah Menengah Pertama

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Technology developments rapidly bring new challenges in education. New technology has capability to make change in education. Many people already use and explore the new and existing technology for greater benefit of education. Putra (2012) in his book stated that *it's not chalk and talk anymore, but (more) to school approach to developing student's digital literacy*. Long before, in year 2002, UNESCO has advocated the use of technology in education. This trend is still continuing until today, as recently Leung (2016), Oktaviyanthi and Supriyani (2015), Loong (2014) and Saadati (2014) exploring the use of technology in regard to learning and education. Specifically, Fathurrohman and

Porter (2012) advocate the use of technology for mathematics teachers. Recently in year 2017 they explain the teachers' real and perceived of technology availability for teaching and learning, while Hatlevik, Throndsen, Loi and Gudmundsdottir (2018) explain the students believe and their actual achievements in regard to ICT experiences. Vongkulluksn, Xie, and Bowman (2017) argues on teacher belief as one of important factors in technology integration. Karadeniz and Thompson (2018) proposed the use of calculator, and Wares (2018) argues on the use of dynamic geometry, while in particular, Martinovski (2013), Quinlan (2016), Segal, Stupel, & Oxman (2016), States & Odom (2016) promoting GeoGebra as a tool for technology use in mathematics teaching and learning.

One of mathematics concepts is geometry. Atiah in Hoherwarter and Jones (2007) said it is important to learn geometry and algebraic geometry. Geometry concepts and the ideas of geometry have been introduced to students since their study in elementary school level, for example for the introduction of line, plane and space. However, many geometry concepts and ideas in high school level presented in the abstract concept for students, not in concrete as before. This is one of the reasons why the students still get some difficulty when learn geometry. Quadrilateral is a mathematics concept in geometry for junior high school level. Quadrilateral topic consists of concept and definitions of abstract geometry that is required to solve problems related with geometry use in daily life. It is acknowledged that the students' cognitive development at the stage of junior high school age is the formal-operational stage. At this stage, the student should have the capacity to use abstract principles, so that students must be able to learn abstract learning materials such as Quadrilateral. Kabaca (2017) provided classroom note for understanding geometry, however it is not enough for this case.

Computer programs can be used as an alternative-effective solution. One of the computer programs that can be freely used is GeoGebra. GeoGebra is Non-Commercial Free Software for use by mathematics educators (teachers and lecturers) in Indonesia. The use of GeoGebra in mathematics teaching and learning enable students to draw geometry objects in fast and specific. Enable to animate and manipulate visual to understand geometry concept, evaluating, to study geometry object (Syahbana, 2016). Many researches show positive effects of teaching and learning with GeoGebra, such as Zengin, Y (2017) and Hähkiöniemi, M., (2017).

GeoGebra software can be installed on a personal computers, android devices, and direct use on the web anytime and anywhere. In addition, the '.ggb' file extension, as outcomes of the learning process using GeoGebra, can be stored and disseminated for the next session of learning. This output file is commonly called the GeoGebra Applet. This is one of features in GeoGebra that can be used, modified, and/or developed by educators for dynamic and interactive mathematics teaching and learning.

The Indonesia national curriculum, called year 2013 curriculum, mandates the essence of scientific approach in teaching and learning, including for mathematics. Through a scientific approach (observing, questioning, associating, experimenting, and networking stages), the students are directed to establish the ability to thinking scientifically that emphasizes inductive reasoning rather than deductive, and guiding the students to research, instead of being told. At the time of research project, checked through available

publications, there is no GeoGebra Applets closely linked and aligned to the Indonesia national curriculum in accordance to the mandated approach. The availability would be benefit for mathematics teaching and learning and the implementation of the national curriculum. In addition, various discovery learning activities can be carried out, by using the GeoGebra Applet. For that reason, there is a need to develop GeoGebra Applet closely linked and aligned to the Indonesia national curriculum, in this case is to facilitate the mathematics teaching and learning in quadrilateral concept, in accordance to the scientific approach.

METHOD

The method used is Design and Development. One crucial component of this research involves mixture of data gathering techniques as it relates to the design and development of GeoGebra Applets. Design and development research can be defined as the systematic study of design, development, and evaluation processes with the aim of establishing an empirical basis for the creation of instructional and non-instructional tools and new or enhanced models that govern their development (Ross, Morrison, Hannafin, Young, et al, 2008, p. 751). This research is closely related to mixed methods as explained in the following:

Design and development research tends to be complex methodologically. This is typically because of the complexities of real-life situations and of the design and development process themselves. This research tends to employ either mixed-method or multiple method approach (Ross, Morrison, Hannafin, Young, et al, 2008, p. 751)

Other authors also have proposed their definition, design, steps and/or approach in relate to this method of research, including Tim Puslitjaknov (2008), Sugiyono (2010), Borg & Gall in Sukmadinata (2011), Putra (2012), and Fathurrohman (2014). In particular Fathurrohman (2014) advocates the Need, Capability, and Analysis (NCA) Model of Design and Development. This model proposed that the developed product is intersection between user need and researcher capabilities as illustrated in the following diagram.

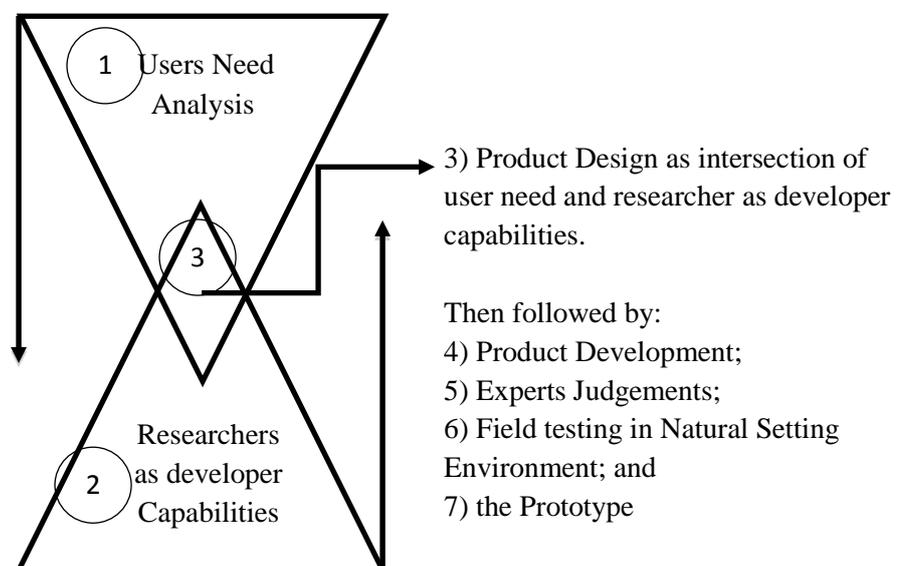


Figure 1. Concept of Need, Capability, and Analysis (NCA) Model of Design and Development
Adapted from Fathurrohman (2014)

Need, Capability, and Analysis (NCA) Model of Design and Development consists of seven steps of 1) User Need Analysis; 2) Researcher as Developer Capability; 3) Product Design; 4) Product Development; 5) Experts Judgements; 6) Field testing in its Natural Setting Environment; and 7) the Prototype. The focus of research was investigation of what types of GeoGebra Applets required in mathematics teaching and learning for quadrilateral, how to develop the Applets that can be used in mathematics learning, and the measure of GeoGebra Applet usability and the students' responses on it. The data is obtained from several instruments consist of: 1) User needs analysis questionnaire. 2) Teacher interview guidance to know the topics mostly problematic for students and teachers when they learned quadrilateral. 3) Expert judgments questionnaire for assistance in product development. 4) Questionnaire to measure the GeoGebra Applet useability in natural setting environment and the students' responses.

RESULTS AND DISCUSSION

Quadrilateral GeoGebra Applets scientifically designed and developed based on observation of users need and identification of researchers as developer capabilities. The intersection of these components is the proposed product to be developed.

1. Users Need Analysis

Users need questionnaire was distributed to 262 8th grade of a junior high school students who have studied the quadrilateral. The analysis resulted to selected topics and the way GeoGebra Applet to be used during mathematics teaching and learning in accordance to Indonesia national curriculum. The result is GeoGebra Applet development focused on: 1) the properties of quadrilateral. 2) Rotation symmetry of quadrilateral. 3) Fold symmetry of quadrilateral 4) Circumference of quadrilateral and 5) Area of quadrilateral. In addition, there are several topics of Quadrilateral, to be identified that GeoGebra Applets is required to learn the topics. User need analysis resulted to the following figure in which the GeoGebra Applet will be designed and developed in regard to top three topics.

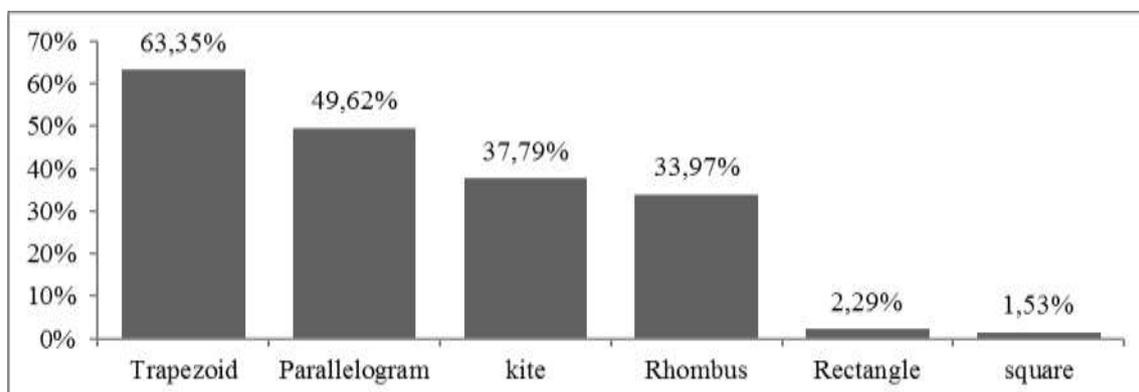


Figure 2. Ordered list of mathematics topics (need analysis)

Students preferred ways to learn using ICT also considered making sure the easy and user-friendly use of the applet. Following is result of this result can be seen in Figure 3.

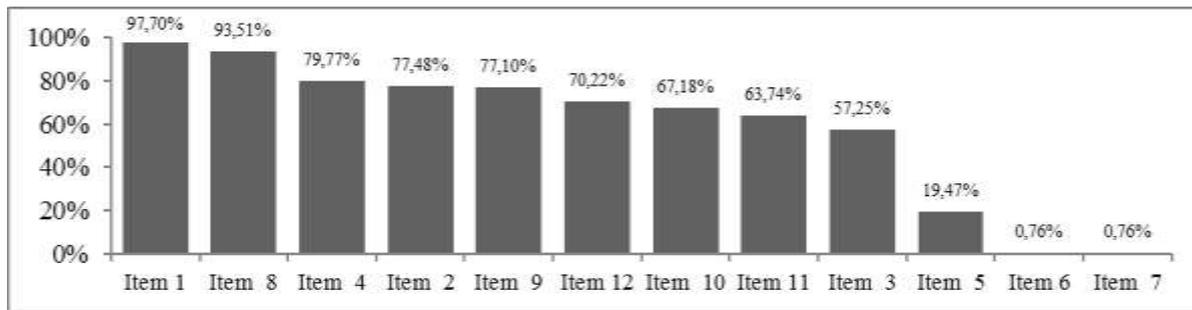


Figure 3. Ordered list of preferred computer use in learning (need analysis)

Legends:

Item 1: The use of computer in learning activities

Item 8: With animation

Item 4: Attractive mathematics learning using a computer program to be more attractive

Item 2: Frequently use of computers

Item 9: With Compact Disc

Item 12: Not in static (prefer to dynamic geometry)

Item 10: Prefer Compact Disk that contains animations for mathematics learning

Item 11: Quadrilateral concept was difficult

Item 3: Just using the textbook was boring

Item 5: math teacher gives assignments using a computer

Item 6: the use of software program in class

Item 7: teacher using the software program for presentation

2. Researchers as Developers Capability

As a basis for the development of GeoGebra Applet, the ability of researchers has an important role. The ability of researchers in using GeoGebra program can be measured by the extent to which the GeoGebra Applet could be developed. In this case, researchers are well aware of GeoGebra software since year 2012 and before. The researchers also part of Indonesia GeoGebra Institute since 2012. By the year of 2012 to present, researchers already familiar with various GeoGebra Applet, how to use GeoGebra by studying the usability of various toolbars available on the main menu and sub menu, re-create existing GeoGebra Applet by following the steps provided in the course of construction protocol of GeoGebra, and make some new GeoGebra Applet on a certain subject and then the steps to produce clearly articulated and packaged in distributable form. Until now, researchers continue to gain knowledge about GeoGebra in line with GeoGebra Applet development.

3. GeoGebra Applets Design

Considering user needs (step 1) and researcher as developer capabilities (step 2), researchers take the top three needs of students preferred learn with GeoGebra. GeoGebra Applet development will be aligned with the three highest requirements needed by the students: 1) Students require to use the computers in learning activities (97.70%). 2) Students need to use animation as favorite animated in learning mathematics (93.51%). 3) Students need to interested mathematics learning like using a computer program (79.77%).

For above reasons, seven pieces of GeoGebra Applet will be prepared: 1) Properties of

Quadrilateral Applet. 2) Rotation Symmetry of Quadrilateral Applet 3) Fold Symmetry of Quadrilateral Applet 4) circumference of Quadrilateral Applet 5) Trapezoid Parallelogram Area Applet 6) Parallelogram Area Applet and 7) Kite Area Applet. The applet will be narrative with text, illustrations, and animations adapted to year 2013 curriculum using a scientific approach.

In addition, it is required by the scientific aspect in design and development method that the proposed GeoGebra Applets will become scientific contribution to the body of knowledge. For that reason, researchers have observed other applets that may similar to the proposed applets to be designed and developed. Result of observations aims to claim that the GeoGebra Applet to be developed is not same yet as those already available, and to see if the GeoGebra Applet that has been available, there are still some shortcomings that can be improved and developed into better GeoGebra Applet. Observations carried out on 30 GeoGebra Applets that available on site www.geogebra.org.

Table 1. List of current available Quadrilateral GeoGebra Applets

No.	Owner	Applet Title
1	FHHO	Area of a parallelogram
2	Jed Butler	Trapezoids and Triangles
3	User4973	Mid segment of a Trapezoid
4	Catherine E.	Area of a Kite
5	Catherine E.	Area of Trapezoid
6	Jed B.	Trapezoid Transformation
7	Irina B.	Line Symmetries and the Quadrilaterals
8	Jed B.	Kite Transformed into Rectangle
9	Azulzaile2	Mengira luas trapezium
10	Bagus A. S.	2.3 OK
11	Irina B.	Properties of Parallelograms
12	Sonom	Find The Area
13	Edward K.	Area of A Parallelogram
14	DK. Jordan	Properties of parallelograms
15	DRT	Properties: parallelogram
16	DRT	Properties: Kite
17	Aleksandra	Površina trapeza (1.)
18	Kiokemeister	Finding the Area of a Kite
19	DRT	Area of a Kite
20	Catheagen	Properties of Trapezoids
21	Rikeylee	Quadrilateral Characteristics
22	Renata R.	Il Trapezio, Caratteristiche E Area Della Superficie
23	Sulaeman	Segiempat dan Titik Tengahnya
24	Budiana	Kite
25	Irena Š.	Area of Trapezoid – Mid segment
26	Blewis	Fake Square
27	GeoGebra Tube Team	Classifying Quadrilaterals
28	Anthony	Area of Parallelograms
29	Anthony	Constructing Quadrilaterals by Four Sides
30	Anthony	Exterior Angles of Polygons

Based on observation of pre-research 30 GeoGebra applets of quadrilateral, it can be claimed that the product to be developed is not similar, and not available to be substitute with the existing

product. For that reason, the design and development steps proceed to step of development. The existing GeoGebra applet is not in some way suitable as expected, because they are linked and aligned to the Indonesia national curriculum. Following is the details can be seen in Figure 4.

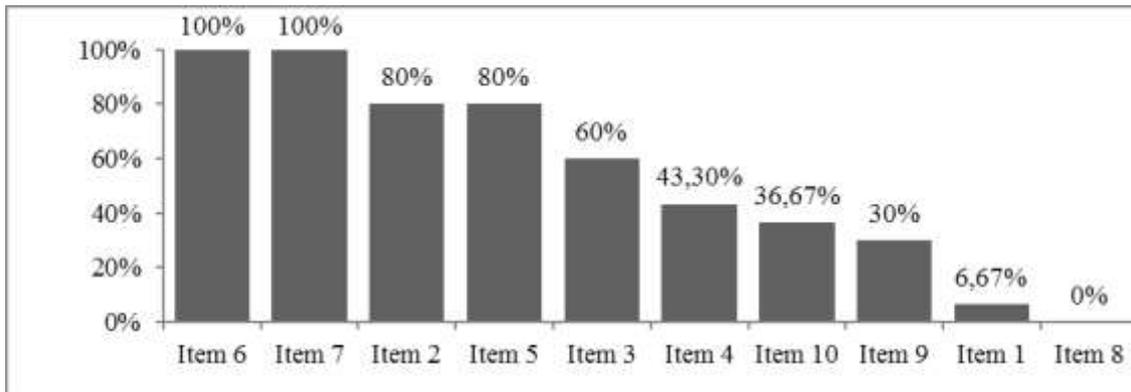


Figure 4. Observation Result of pre-research available Geogebra Applets of Quadrilateral

Remarks:

Item 6: Images and text appropriately placed

Item 7: Picture and its components are made consistent

Item 2: Text can be read clearly

Item 5: The animation is displayed in accordance with the submitted materials

Item 3: The information presented clear

Item 4: Applets along with a description

Item 10: The concepts was presented covers the concepts being discussed

Item 9: The concepts was described clear

Item 1: Applet was Used Indonesian

Item 8: Applet was adapted to the 2013 Indonesia National curriculum

Observations result show, all images and text on the applet has been placed appropriately and all component was made consistent. From the language aspect, 80% of the text can be read clearly and 60% of the information presented clearly though only 6.67% Applets that use Indonesian. It remains an obstacle for main user that junior high school seventh grade student who partially still pretty much has the vocabulary in a foreign language yet. From the display aspect, 80% of the animation is displayed in accordance with the submitted concepts but unfortunately only 43.3% Applets are complemented by an explanation. From the material aspect, only 30% of the Applet which describes the concepts clearly and 36.67% coverage which describes the concepts being discussed. None of the 30 Applets are available that are tailored to the 2013 curriculum.

Therefore, based on the observation of the researchers claim that the absence of the GeoGebra Applet on the subject of rectangles as researchers develop. Strongly stated that the applet is mostly in English, not in Bahasa Indonesia so it was not relevant for use for general junior high school students audiences.

4. GeoGebra Applets Development

After completing identification intersection between users need analysis and researchers as

developed capabilities and observing the existing products that may similar to make sure that the proposed product to be developed will be make contribution to body of knowledge, then author proceed to the next step of product development. Result of this step is as following

Product identity:

- a. Storage : Flashdrive or Compact Disc (CD)
- b. Learning topics : quadrilateral concept
- c. Fonts : Serif, Sans Sheriff, Kristen ITC
- d. contents : a. GeoGebra Introduction
b. GeoGebra program Installer
c. Java program
d. Installer,
e. Java & GeoGebra installer tutorial,
f. Seven (7) GeoGebra Applets



Figure 5. Front Cover of GeoGebra Applet Prototype in CD-R

5. Experts Judgements

After the previous steps, GeoGebra Applet testing by three experts. It showed that questionnaire result of educational aspect, the indicators obtain average percentage of 93.75% with a very good interpretation. The questionnaire results of media aspect, the indicators obtain average percentage of 82.50% with a very good interpretation. The questionnaire results of mathematics aspect, the indicators obtain average percentage of 76.47% with a good interpretation. Thus, based on the three experts' judgments, GeoGebra Applets is proper to be tested on the field testing in its natural setting environment. The environment where the product to be used in the future.

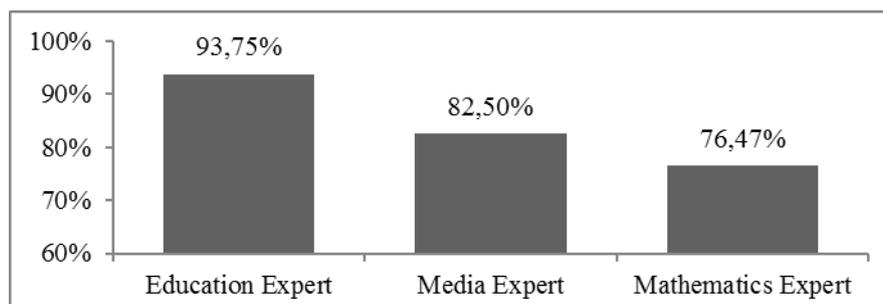


Figure 6. GeoGebra Applets quality (experts judgement results).

6. Field Testing in Natural Setting Environment

The designed and developed GeoGebra Applets field tested to 15 of eighth grade students of a junior high school level. The natural setting environment of the product is junior high school. This testing aimed to measure the GeoGebra Applet usability and user response.



Figure 7. Start Layout of GeoGebra Applet

As an example, the students will start with the Home Form (7.a), that has “GeoGebra Introduction” button, to continue to Introduction to GeoGebra Information Form (7.b). From the frontpage, the students also can continue to List of Applet Page Form (7.c), then proceed to seven applets provided in this package, for example, “Parallelogram Area Investigation Applet” Form (7.d). Then the GeoGebra applet is ready to use to learn for this selected topic.

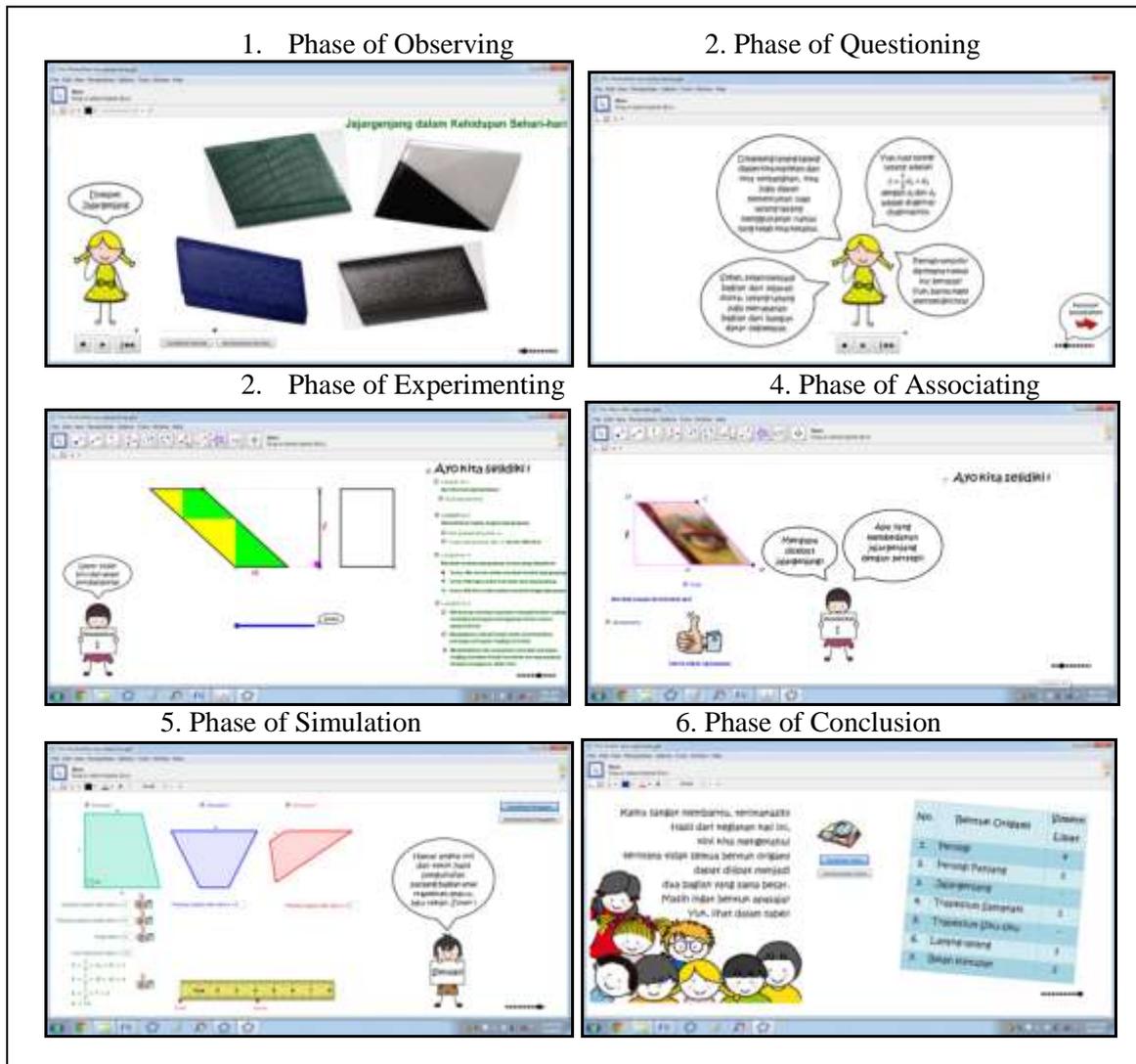


Figure 8. The applets linked and aligned to the six phases of scientific learning processes

The designed and developed GeoGebra Applets are linked and aligned to the Indonesia national curriculum. There are six phases of scientific learning, as illustrated in Figure 8, accommodated by these applets. Enclosed questionnaire used to measure GeoGebra Applet use abilities while open questionnaire used to gather the users' response on it.

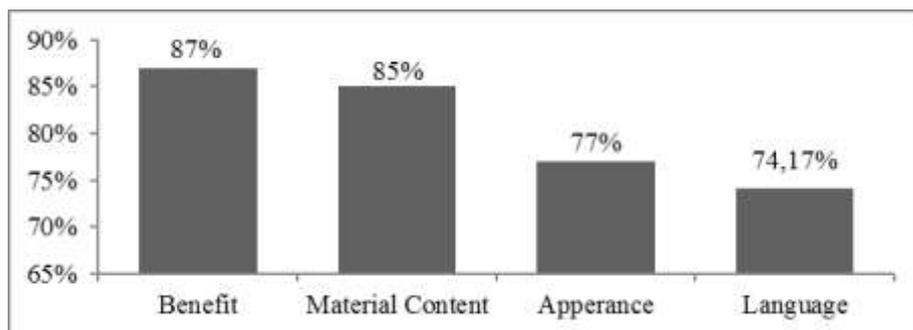


Figure 9. Students' responses to the GeoGebra Applets

Based on questionnaire results, the students give a very high response to the three aspects of GeoGebra Applet of usability category: benefit aspect, material content aspect and appearance aspect. Viewed from all aspects, the indicators obtain average percentage of 81.56% with a very good interpretation that means the GeoGebra Applet in terms of benefit, material content, appearance and language overall very good.

Open questionnaire data results show that questionnaire average results of responses students each item indicate there are 3 (three) main things that get the highest positive response of students, namely 1) the clarity presentation of the material content, 2) the attractiveness of the illustrations 3) comprehension of quadrilateral. The results of students' opinions each item questionnaire is presented in the following diagram.

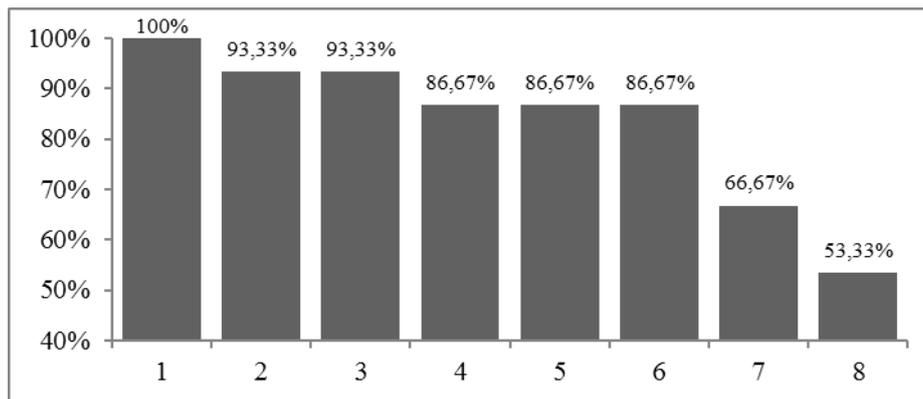


Figure 10. Student Responses to GeoGebra Applets Use

Legends:

- 1: Clarity presentation of material content in GeoGebra Applet by 100%
- 2: the attractive illustrations in GeoGebra Applet by 93.33%
- 3: Quadrilateral comprehension using GeoGebra Applets by 93.33%
- 4: The attractive mathematics learning using GeoGebra Applet by 86.67%
- 5: GeoGebra Applet ability of adds mathematics insight by 86.67%
- 6: GeoGebra Applet ability of mathematics curiosity encourage by 86.67%
- 7: GeoGebra Applet repair by 66.67%
- 8: Clarity appearance of GeoGebra Applet by 53.33%

It can be concluded that the GeoGebra Applet use abilities especially in terms of benefit, material content, appearance and language is very good. The students' response of the GeoGebra Applet also gets positive responses, especially in the clarity presentation of the material content, the attractive illustration and comprehension of quadrilateral material. The final GeoGebra Applet product is ready to be defined as the prototype.

7. The Final Prototype

The final GeoGebra Applet product could also be regarded as a prototype or working product. The prototype of GeoGebra Applet as follow.

- a. Storage : CD/DVD-R, Flashdrive, and to be available for online download
- b. Material : quadrilateral concept

- c. Fonts: Serif and Sans Sheriff
- d. Contents : GeoGebra Introduction,
GeoGebra program Installer,
Java program Installer,
Java & GeoGebra installer tutorial,
Seven GeoGebra Applets

The entire contents of the GeoGebra Applets prototype are packaged into a CD/DVD-R and a folder in Flashdrive, and to be available for online download for use by students to learn Quadrilateral in accordance to Indonesia National Curriculum.

CONCLUSION

The GeoGebra Applets of Quadrilateral, closely linked and aligned to Indonesia National Curriculum successfully designed and developed. The field testing shows that the prototype can work as expected in its natural setting environment.

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