EUCLIDA: 3D Augmented Reality Card for Learning Numeracy about Geometry

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Abstract **– Students consider that spatial geometry is tough, they require equipped mastery of concepts and visualized 2D object. This study is addressed to develop and evaluate EUCLIDA card integrated with AR using 4D model. The EUCLIDA card was claimed to satisfy the valid standard, because it achieves a percentage of 90%, from the appraisal data of two specialists and one practitioner. Moreover, EUCLIDA card also fulfills the utility aspects, because it obtained a percentage of 93% based on the outcome of learning activities observed and gained 97% from the student feedback survey on operating EUCLIDA card. It can be concluded that the EUCLIDA card is considered valid and useful.**

Keywords **– AR, spatial geometry, mathematics.**

1. Introduction

Mastery of mathematics and technology currently is essential for every human being in encountering the challenges in the future. Technology is entirely integrated into the learning curriculum, because of the paradigm shift in the 21st century. Consequently, contextual learning becomes more concrete by using technology-based media [1]. Thus, student should be accustomed for utilizing technology to practice the mathematical problem.

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Moreover, students currently encounter the real-life context problems in learning, encouraging students to visualize problems, represent mathematics model and apply students' experience to solve every problem [2]. Hence, teachers should train all students to overcome this challenge by involving technology assistance in learning mathematics.

PISA reports that the achievement of Indonesia in mathematics ranked 38th in the period 2000 and 2003 by generating the average of 393 and 395. Indonesia also placed 50th in 2006 by reaching the score at 393, while decline that occurs caused Indonesia to obtain score of 382 ranking 64th from 65 countries in 2012. This case reveals that Indonesia needs to fix the students' mathematics learning in order to compete other countries [3]. This is consistent with TIMSS report that Indonesia still has achievements under the international standard, indicated by the number 397 out of the total score of 500. Indonesian students only contribute the higher score in comprehension level, compared to application and reasoning problems [4].

The preliminary data obtained from interviews of all lecturers at mathematics education program at the State University of Jakarta, confirm that geometry course asked students to implement good spatial skill in visualizing the abstract object and comprehending the material learned. Another supporting data from the questionnaire distributed to 30 students resulted in percentage of 89.7% who claimed that they find out the difficulties in visualizing three-dimensional material. In addition, the results indicate that students who really enjoyed the use of technology for learning content mathematics reached a total of 90%. Hence, augmented reality in the form of animation which is integrated into the EUCLIDA card is designed for students to understand geometry easily and visualize abstract objects better.

Some transformations of mathematics learning in this era encourage teachers to design the interesting and meaningful learning by implementing augmented reality.

Augmented reality absolutely assists students to grasp three-dimensional object clearly, student can identify all side of object [5]. Subsequently, practice utilizing augmented reality encourage students to do hands-on lesson by interpreting information, making them into connection, and applying some concept related to the real-life context [6]. This is confirmed by the existing literature that technology significantly contributes to students' comprehension in learning concepts [7]. Another study demonstrates that using augmented reality creates the meaningful learning by presenting the real object through animation display [8]. The augmented reality also effectively enhances student learning outcome rather than only the use of textbook or certain strategy [9].

Nowadays, Augmented Reality in instruction has received attention from pedagogical institutions and scholars. The benefits of Augmented Reality contain encouraging learner motivation, comprehension, and involvement [10], degrading learners' cognitive load [11]. Moreover, AR makes student comprehension of concept better. Some literatures have selected AR as a tool for providing virtual object, but the instruction and cognition acquisition are obstacles encountered when applying AR in learning context [10].

2. Method

This study selects the 4D model by Thiagarajan to produce the EUCLIDA media. A 4D model includes 4 stages. They refer to define, design, develop, and disseminate. However, the development of this media is restricted only 3 phases. This limitation eradicates the distribution stage, because it takes a long time, therewith it will be explored in further studies. The defining phase in this study seeks to determine several criteria required in learning. The components inspected at this phase are learner characteristics, the concept of lesson, learning targets, and tasks covered. The secondary phase is media design following the specs reached from the previous phase. This phase generates an early draft that is utilized to build a real media. Further development is carried out to acquire media validation results from two expert validators and one practitioner, followed by testing on a limited scale. Validation test was appraised by two education specialists and practical validation was evaluated by one lecturer. The development is addressed to make this media better based on instruction from validators and data from media application appraisals.

The equipment in this research was an attestation questionnaire to determine the eligibility level of the EUCLIDA card from the validator. The EUCLIDA card attributes assessed in the inspection incorporate content, function, form, and appearance.

In addition, supervisors used a learning observation questionnaire purposed at assigning the practicality of utilizing this medium on a restricted scale. The components of the appraisal criteria comprised in the survey consist of preliminary, primary, and closing activities. The next instrument contains a learners acceptance survey that is utilized to evaluate the function of EUCLIDA card based on the student's viewpoint. Students appraised several features including the appearance of content, shape, and language. All the previously mentioned instruments adapted Likert scale. Thus, the quantified variables are translated into criteria items [12]. The chosen appraisal score in the format below.

Table 1 The Appraisal Format

Score	Interpretation
1	Highly compatible
2	Compatible
3	Fairly compatible
4	Not compatible

The result obtained from examining EUCLIDA card is separated into two classifications, quantitative and qualitative. Qualitative data contains reviews and recommendations, which is generated by evaluation of the education specialists, practitioners, observers, and users. Subsequently, quantitative data is gained from the amount of the validator examination scores and application tests throughout data assembly. The supposed data from this study is the level of validity of EUCLIDA card and the level of its utility. Data on the validity level of EUCLIDA card are gained from expert validators and practitioners, whereas empirical results are attained from supervisors who observe the learning activities in class when students operate the EUCLIDA card. After the data is assembled, then the outcome is analyzed qualitatively and quantitatively. Qualitative analysis is addressed to depict EUCLIDA card, while quantitative analysis is taken to determine the level of validity and practicality of the EUCLIDA card. The validity of the EUCLIDA card was attained from a survey, which was analyzed by counting the formula below [13].

$$V = \frac{\sum X}{N} \, x \, 100\%$$

Explanation:
V : Value
$\sum X$: Total Point
N : Maximum Point

The quality report of EUCLIDA card adjusted to the validity point of reference in Table 2 below.

Table 2 The Category of Validity Result

Score Range	Category	Description
86% − 100%	Strongly Valid	No revision
70% − 85%	Fairly Valid	Small revision
60% − 69%	Less Valid	Partial revision
00% − 59%	Invalid	Total revision

The utility of the EUCLIDA card is conducted by analyzing data of an observational survey appraised by 2 supervisors of learning activities by running the media and the survey form on student answers to the utilization of the EUCLIDA card. The outcome of the survey form is analyzed by applying the formula as follows [14].

$$A = \frac{TSEV}{S - max} \; x \; 100\%$$

Explanation:
A : Application
$TSEV$: Total Point Empiric Validator
N : Maximum Point

The report of the empirical rate of EUCLIDA card adopt the standard in Table 3.

Table 3 The Category of Practicality Result

Percentage	Criteria	Interpretation
86% − 100%	Strongly Practical	No revision
70% − 85%	Fairly Practical	Small revision
60% − 69%	Less Practical	Partial revision
00% − 59%	Impractical	Total revision

3. Result

This section reports information about the product development process through the defining stage, the design stage, and the development stage.

The Defining Stage

The defining phase seeks to explore the necessary information associated with EUCLIDA card. This phase contains a preliminary analysis consisting of student features, the assignments, and the concept of lesson. The preliminary analysis is intended to probe the fundamental problem in EUCLIDA construction.

Student inspection is taken to assign student features including academic achievement, age, motivation for the lesson being studied. In terms of student analysis, the seventh-grade students are at concrete operational period [15]. Furthermore, student cannot be divorced from tangible items in learning process, because they still depend on reason to capture lesson in its entirely [16]. The usage of tangible items in teaching material contributes in generating the productive, interactive, and constructive condition. Therefore, the knowledge transmission can be running smoothly, and students' motivation gets better [17].

Task analysis is necessary conducted to construct the series of student activities. Task analysis is also organized based on the core competency and primary competency, which indicates the substance of subject matter integrated in the EUCLIDA card. The essence competency of learning mathematic number three for grade seven is capturing accurate knowledge through the process of monitoring and posing questions based on their curiosity. Moreover, the primary competency refers to: 1) KD 3.7 generalizes the surface area and volume of various curved side shapes and (2) KD 4.7 solves the contextual problems associated with the surface area and volume of curved geometric shapes, particularly combinations of some curved geometric shapes. This phase defines the substances that are integrated into the EUCLIDA card. In addition, the concept analysis is addressed to elect the EUCLIDA card content. Learning purpose is outlined to master and apply their knowledge about spatial geometry in contextual problems. Thus, learning activities must be designed into 3 steps, namely: 1) students find the concept of spatial geometry by operating EUCLIDA card in order to promote student mindset growth 2) students master the concept, and 3) and students train their capability by repeated practice.

The construction of EUCLIDA card begins with identifying and analyzing the curriculum utilized in the spatial geometry textbook. The subsequent phase is conducted by interviewing mathematics teachers. The analysis reports that the integrated curriculum in high school textbooks is suitable with the objectives of learning spatial geometry. Moreover, this research distributes the survey form to 30 students to achieve the data analysis about the potential of several media options that can be used in learning spatial geometry. The initial data reveals that the largest portion is hold by animation with a percentage of 60%, followed by video with 57% and the smallest is 3D objects with a percentage of around 47%. The percentage of every media choice is presented in Figure 3 below.

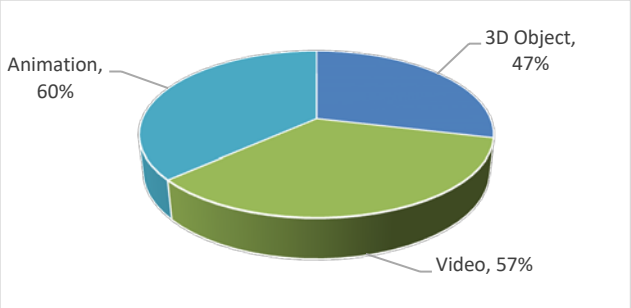


Figure 1 The Percentage of Learning Media Options

Some media display analysis is accustomed with the learning objectives. The outcomes of survey form distribution indicated that Augmented Reality (AR) becomes the most fascinating media option for 60% students. The preference of media that get the second highest score after AR is in the form of game about 57% and worksheet generates the lowest percentage of 27%. The proportion of media display options are outlined in the following figure.

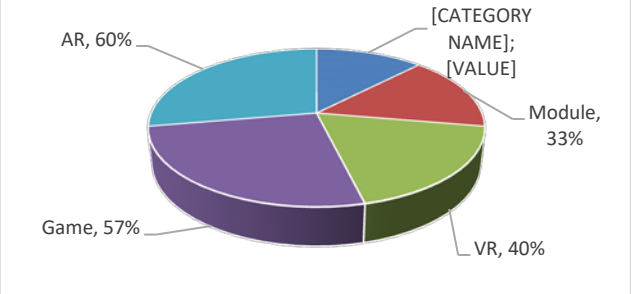


Figure 2. The Percentage of Learning Media Display

The Design Stage

The design phase includes determining the media, shape, and main appearance of EUCLIDA card. This phase transforms the learning objectives into several steps of media utilization to reach the learning goals. This phase selects the media materials utilized, based on technology. In addition, the media is designed in the form of cards that are integrated with Augmented Reality for the purpose of discovering the concept of spatial geometry. The initial draft of the EUCLIDA card is successfully produced in this stage, after it obtains an approval from an education expert. This initial draft provides guidance in generating the valid and practical product. The developed product named EUCLIDA, which is a set of cards containing two-dimensional geometric images and their script. Cards are integrated with Augmented Reality, which each two-dimensional image on a card will change into a three-dimensional geometry when scanned by phone.

The creation of this media is addressed to recognize the spatial geometry section entirely, find the concept of surface area and volume, and solve the contextual problems using the accurate and well-ordered way.

After conducting a needs analysis, the researcher proceeded to the planning stage. There are three steps taken to build EUCLIDA card design. First, arrange material animations using the Adobe Animated 2020 application and the Blender application. Next, create the card design using the Affinity Design application. Lastly, create Augmented Reality using the Assemblr application. Several users are required to install the Assemblr application for applying EUCLIDA card. The design of EUCLIDA card is provided below.

Figure 3 EUCLIDA Card Front Display

Figure 4 EUCLIDA Card Back View

The Development Stage

The development phase is addressed to create the EUCLIDA card based on the validation outcome. The development phase includes appraisal activities from several specialists and trials on a limited scale. In this research, EUCLIDA card is tested to verify the media criteria of content, utility, and appearance. Validation exam is taken by proving that the created EUCLIDA card was valid, and it gained some reviews and advice for refinement. EUCLIDA card is appraised by two mathematics lecturers at Universitas Negeri Jakarta and one mathematics teacher. The outcome of media validation gained is presented below.

Table 4 The Appraisal Outcome

The component criteria	Average
EUCLIDA Card Content	
EUCLIDA card promotes learners to study mathematics	3.67
EUCLIDA card helps learners to get fully comprehension and mastery of the concept	4.00
The activities present chances for students to work positively with EUCLIDA card	4.00
The activities taken in the operation of EUCLIDA card are suitable with the learning goals to be reached	3.00
EUCLIDA card does not present ambiguity	3.00
EUCLIDA Card Utility	
EUCLIDA card encourage learners to achieve learning objectives	3.67
EUCLIDA card possesses the potency to be a supporting device in institutions	3.00
EUCLIDA card promotes learners to be more enthusiastic in studying	4.00
EUCLIDA Card Appearance	
EUCLIDA card has an interesting design	4.00
EUCLIDA card has a compatible format	4.00
Average Point	3.67

The average validation value of EUCLIDA card is 3.84. The obtaining validity reaches 90%, it means it can be characterized as strongly valid. Nonetheless, two experts and one practitioner present reviews that can be taken into justification for improvement. The EUCLIDA card appraisal taken on a restricted scale in this research is beneficial for assigning the level of media utility. EUCLIDA card can be simply utilized and encourage learners to recognize the concept. The level of EUCLIDA utility was determined based on the outcome of student learning activities observation conducted by two observers and student responses to the usage of media. The outcome of students learning activities observation is provided in Table 5 below.

Table 5 The Learning Activities Observation Outcome

The component criteria	Average
Preliminary activities	
The teacher gives an apperception that is adjusted to the lesson to be learned	4.00
The teacher reveals the learning goals	4.00
The teacher delivers learning motivation	3.50
The teacher instructs learners to create small groups	4.00
Main activities	
The teacher sets up EUCLIDA used	3.50
The teacher delivers an explanation about the way to use EUCLIDA card	3.50
Learners contributes operating EUCLIDA card in learning	4.00
Learners are fascinated in utilizing EUCLIDA card	4.00
EUCLIDA card promotes learners to study mathematics	4.00
The teacher directs students' discussion	3.50
The teacher gives directions if learners obtain the difficulty situation	3.50
The teacher allows students to discuss their findings in front of class	3.00
Closing Activities	
The teacher builds reflection activities	4.00
The teacher provides reinforcement or verification	3.50
The teacher allows students to deliver learning inferences	4.00
Learners write conclusions from today's instruction	4.00
Average Point	3.75

The result of learning activities observation states that the obtained average point is 3.75, therefore the percentage gained from the observation survey form on learning activities is about 93%, which describe that EUCLIDA card is relatively easy for the teacher to apply. The outcome of the practicality test of the EUCLIDA card obtained from the student response survey form on the use of this media during learning took place can be seen in Table 6 below.

Table 6 The User Feedback Survey Result

The component criteria	Average
Material displays of EUCLIDA card	
EUCLIDA card is simple for me to implement	3.80
The problem presentation on EUCLIDA card encourages me to comprehend and master the concept of spatial geometry	4.00
I'm fascinated in learning spatial geometry through EUCLIDA card because its format is attractive	3.88
EUCLIDA card encourages me to probe the concept further	4.00
EUCLIDA card encourages me to be enthusiastic in learning	3.75
EUCLIDA card encourages me to learn mathematics	4.00
Language and design of EUCLIDA card	
The command and information performed are easy to comprehend	4.00
The format of EUCLIDA card is attractive	3.75
Average Score	3.89

The student feedback survey output on the usage of the EUCLIDA obtained an average value of 3.89. The percentage generated from this survey outcome is 97%, meaning that the learner response is strongly positive towards EUCLIDA card produced. Based on the learning activities observation and user feedback, it means that EUCLIDA card is classified as strongly practical. EUCLIDA using the Assemblr application generate some animations for mathematics content is integrated with Augmented Reality application.

The development of material animations and Augmented Reality cards paid attention to the position of objects and the point of falling light against the marker. The EUCLIDA is scanned using the Assemblr application on a smartphone, an animation of material appears as shown in figure below.

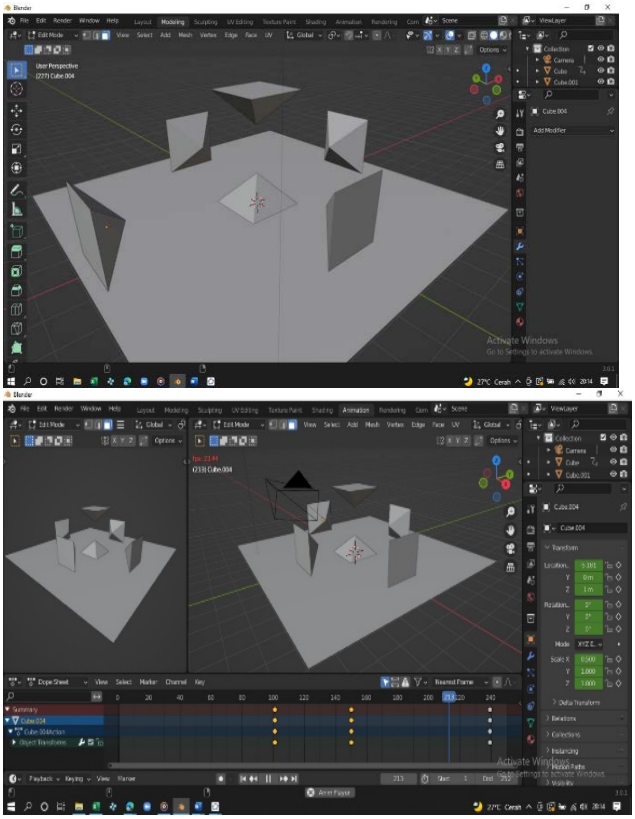
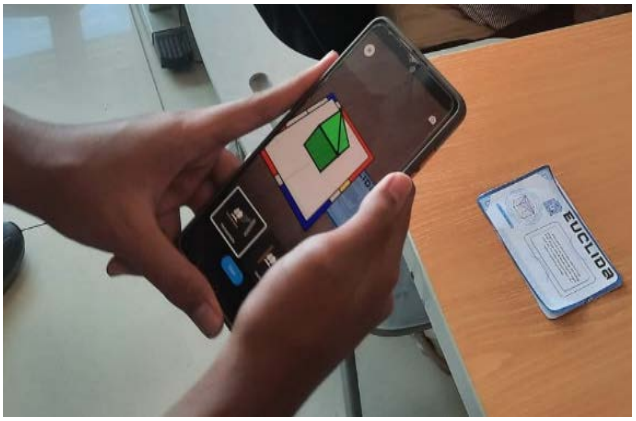


Figure 5 Material Animation Design



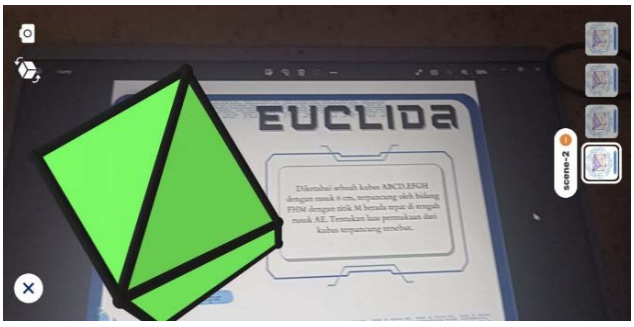


Figure 6 EUCLIDA Card Animation

4. Discussion

The validation appraisal data and the application of EUCLIDA card on a restricted scale show that it is strongly valid and useful. The EUCLIDA card caters the valid criteria, in which it achieves a percentage of 90% based on the output of two education specialists and one practitioner. Validators also present reviews and recommendations for getting the EUCLIDA card in the form of application. The EUCLIDA card also fulfills the utility aspects. It is indicated by reaching the percentage of learning observation around 93%, followed by the student feedback survey form output on the operation of the EUCLIDA card that is 97%. Two expert validators and one practitioner comment that the appearance of the EUCLIDA card developed is strongly appealing and the operation of EUCLIDA card in mathematics learning is simple.

Furthermore,
learners also deliver positive feedbacks on the survey form regarding the operation of the EUCLIDA card. Students states that EUCLIDA card encourages them to identify all spatial geometry section and master the concept of surface area and volume in the meaningful learning atmosphere.

The EUCLIDA card encourage learners to easily identify all side of spatial geometry and discover the concept of the surface area and volume. Augmented Reality transform two-dimensional images into three-dimensional spatial geometry forms, thereby learners completely absorb mathematics materials [18]. This result approves that abstract mathematical content can be constructed into real objects with the help of technology [19], [20], [21]. The EUCLIDA also integrated with Augmented Reality can display the large object that is impossible to present in classroom and allow small objects to be performed [22]. This result is consistent with the current research that Augmented Reality encourages learners to discover the concept of the mathematics lesson by themselves [23]. The EUCLIDA card also gets student engagement better. The attractive media particularly technology-based, encourages students to be enthusiastic in learning mathematics and changes their own mindset about mathematics being difficult. This is confirmed by current research of Augmented Reality that allows student to actively participate in meaningful learning and promotes students to explore their curiosity and experience about they learned [24]. Furthermore, AR not only promotes students to grasp the mathematical concept, but several existing literatures also state that AR can enhance the students' engagement and create the enjoyable learning situation [17], [25], [26], [27].

The implication of EUCLIDA card application in mathematics lessons can allow students to experience the concept formation and probe the investigation by using their own knowledge and experience. Several activities are designed on the EUCLIDA card, thereby students can identify the spatial geometry in the form of three-dimensional format and solve the contextual problems about the topic of surface area and volume. Moreover, the utility of the EUCLIDA card promote learners to be more enthusiastic toward mathematics lesson. The EUCLIDA card also allows students to have a discussion with each other, train their elaboration ability, develop students' thinking process, and construct the interactive learning. The EUCLIDA cards integrated with Augmented Reality application has a potency to be further investigated in other mathematics topics and its appliance for many schools in Indonesia.

5. Conclusion

EUCLIDA cards integrated with AR application is valid and practical to operate. EUCLIDA cards can properly be applied in mathematics learning, because students easily operate this card to identify 3D spatial geometry and visualize the concept of the surface area and volume by scanning the AR assistance. Even EUCLIDA is only for the specific mathematics topic. Nevertheless, this media can be developed for other topics in further investigation. The development of EUCLIDA card integrated with Augmented Reality application can be adjusted with the supporting device utilized, to get the easy access for all students.

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