Development of Pop-up Book Mathematics Learning Media on Polyhedron Topics

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Abstract. One of the difficulties of students studying the polyhedron topics is the visualization of the objects so that a learning media that can help and motivate students in learning polyhedron is needed. This research aims to develop a mathematics learning media in the form of a pop-up book to help students learn the material of polyhedron. This research is a development research that uses the Borge & Gall method, which consisted of several procedures as follows: (1) analysis of the to-be-developed product; (2) first product development; (3) validation and revision; (4) large-scale field tests; and (5) the final product. The subjects of this research were 30 students of 8th grade Sunan Kalijaga Malang Junior High School. The pop-up book media developed was declared as valid and received an excellent response from students. Teachers are advised to use a pop-up book media in polyhedron learning.

1. Introduction
Nowadays, the ability of Indonesian students in mathematics still needs to be improved. In 2015, Indonesia participated in the Program for International Students Assessment (PISA). According to the OECD (2015), Indonesia was ranked 63 out of 70 countries in mathematics, with a score of 386. PISA stated that Indonesia was still low in the mastery of mathematics.

In mathematics learning, student interest is vital to support the progress of learning. Khairani [1] stated that interest indicated the ability to provide stimulus encouraging us to pay attention to someone, something, or an activity, or something that could influence experiences stimulated by the activity itself. Various research showed that interest has a role in achieving the success of various science and elements of life.

According to Nurdin [2], successful learning can be achieved by increasing student interest in learning by using a learning media. The development of the mathematics learning process by utilizing the existing technological developments is needed. It can be in the form of a mathematics learning media that allows students to understand mathematical concepts, solve problems, and achieve the mathematics learning objectives.

Geometry is an important part of mathematics and had been identified as a basic mathematical skill [3]. Geometry is important for students because it is also being applied in other parts of mathematics. For example, geometry is being applied in other subjects such as technical drawing and drawing geometry. According to Susilo [4], there are two learning geometry objectives, namely to develop logical thinking skill and to develop spatial intuition, which refers to how a person perceives space and areas in the real world. However, several difficulties are being faced in studying geometry, especially
in the material of polyhedron, such as lack of student evidence, background knowledge, reasoning skill in geometry, geometric understanding language, visualization skill, and teaching methods unavailability of teaching materials, gender differences [5].

The results of the study show that learning media can motivate students to learn mathematics [6], improve math skills [7] and thought processes [8]. Learning that involves physical activities can be beneficial for learning mathematics [9]. Overcoming students' difficulties in visualizing a polyhedron needs a learning media that can help students visualize the object; one of the alternatives that can be considered is the Pop-Up Book media.

Pop-Up media is a folded sheet of paper on which a two-dimensional or three-dimensional structure comes up when opened [10]. Pop-Up contains pieces of paper that come up, moves, or rotates when opened and fully folded when the book is closed, as well as two- or three-dimensional objects [11]. Pop-ups are intrinsically three-dimensional and physically interactive, triggering users to engage with the books in various ways [12].

The polyhedron being described in this media are cubes, blocks, prisms, and pyramids. According to Susilo [4], students who use pop-up media can obtain more learning experiences than students who don't use the media. Pop-up books can help students learn geometry, especially on the material of polyhedron [13]. This is in line with the opinion of Anggraini [14], which stated that pop-up books were used not only for children but also for illustrations in a broader range such as medicine, geometry, and astronomy. In addition to providing unique visualizations, pop-up books can also stimulate students in learning, develop learning capacity, and facilitate students in understanding the material. Thus, through the development of pop-up book learning media, students are expected to understand mathematics more efficiently. Students' interest in learning, especially in the material of polyhedron, is expected to improve. Apart from assisting students' learning, pop-up books also give positive impressions to the teacher. Teachers are interested in using a pop-up book because it enables them to provide a pleasant learning environment that improves student motivation and concept understanding and helps teachers explain materials and manage the class [15]. Based on this background, it is necessary to conduct development research with the title of "Development of Pop-Up Book Mathematics Learning Media on Polyhedron Topics."

2. Method
This research is development research. The product in this research is a learning media, namely The Pop-Up Book of Polyhedron. In assisting the learning process, this media is equipped with student worksheets. This development's procedure is by Borg and Gall [16], which has been simplified. The method includes the following: (1) analysis of the to-be-developed product; (2) first product development; (3) validation and revision; (4) large-scale field tests; and (5) the final product.

This research subjects were 30 students of the 8th grade class of Sunan Kalijaga Malang Junior High School. In determining the media's validity, the scores obtained in the validation questionnaire were matched with table 1. Practicality was determined through the trials (tests) on students. The media was practical when the test result showed that the media could be used with only a few or no revision at all. Meanwhile, the media prototype, the product of observation during the trial, and suggestions from validators and media users became data that qualitatively be analyzed.

| Percentage          | Criteria         |
|---------------------|------------------|
| 85.01% − 100.00%    | Very Valid       |
| 70.01% − 85.00%     | Valid            |
| 50.01% − 70.00%     | Less Valid       |
| 1.00% − 50.00%      | Invalid          |

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The student response questionnaire consists of two aspects that have indicators on each element. The first aspect is the presentation of the material. There are five indicators in the first aspect: the ease of use of the media, the media's benefits, the impression on the media, the impression on mathematics after using the media, and the motivation that arises after using the media. The second aspect is the language and appearance. There are two indicators in the second aspect: the easy to understand language and an attractive appearance. Each indicator is rated from 1 to 4, each representing very bad, bad, good, and very good criteria. Analysis of the student response questionnaire data was done by calculating the percentage of the total score obtained divided by the maximum score and then multiplied by 100%. The result of the percentage of student response questionnaires was matched with the average percentage criteria, according to Arikunto [18], as shown in table 2 below.

| Percentage          | Criteria    |
|---------------------|-------------|
| 75.01% – 100%       | Very Good   |
| 50.01% – 75.00%     | Good        |
| 25.01% – 50.00%     | Bad         |
| 1.00% – 25%         | Very Bad    |

3. Research result and discussion

3.1. Product requirements analysis
The product requirements analysis activity was carried out through a literature review and test on junior high school students in Malang City. The literature review was related to the importance of the followings: (1) learning geometry, especially on polyhedron material; (2) difficulties in learning geometry, especially on polyhedron material; (3) the importance of developing media that can be applied on learning processes; and (4) the effectiveness of pop-up books that had been developed in previous researches.

3.2. Product development
The product being made was a pop-up math book and Student Worksheets. The pop-up book media was created to overcome difficulties faced by students in visualizing polyhedron. A student worksheet was made to support the student learning process in finding the surface area of polyhedron. The pop-up book's starting page consisted of a cover, instructions for using media, and materials.

On the next page, there are materials for each of the polyhedron that contains three-dimensional pop-ups and examples of objects in everyday life that resemble the polyhedron. An example of this material is shown in figure 1 for the material cube.
Furthermore, several nets of polyhedron are provided. The traps are formed from paper, and one of the sides is attached to the pop-up book allowing students to arrange these nets into a polyhedron. Some of the material in this section is shown in figure 2.

![Figure 1](image1.png)

**Figure 1.** Cube material.

![Figure 2](image2.png)

**Figure 2.** Nets of geometry (3D shape).

3.3. Validation and revision

Two validators validated pop-up book learning media on the material of polyhedron in this research. The first validator was a lecturer in mathematics education at the State University of Malang and the second validator was a mathematics teacher of grade VII at Sunan Kalijaga Malang Junior High School.
Table 3. Media validation result

| Assessed criteria                                      | Average score |
|-------------------------------------------------------|---------------|
| Contents                                              |               |
| Media effectiveness                                   | 3             |
| The interactions made possible by the use of the media | 4             |
| Conformity with material                              | 3             |
| Media clarity                                         | 3             |
| Shape and Appearance                                  |               |
| Media appearance                                      | 3.5           |
| Media proportionality                                 | 3.5           |
| Validity score                                        | 3.33 = 83%    |

Based on table 3, it can be seen that the validity score obtained was 83%. It indicates that the learning media is valid. In the media expert test, revisions were made to the media being developed. The media revision was on the pop-up book media instructions and the student worksheets. Based on the validator's suggestion, the instructions for using the pop-up media were still not appropriate enough with the media's explanation. Besides, the instructions for using pop-up media must be integrated with student worksheets.

Based on the validator's suggestion, several information needed to be added to the student worksheets, including the basic competency, learning objectives and indicators, and several guidance steps. Besides, there was a use of the word "congruent" that has not been studied by grade VII students.

3.4. Large scale field testing

Based on the result of the media validity test, it can be concluded that the media can be said to be valid and ready to be tested. The trial (testing) was conducted to assess student responses to the media that had been developed. In this trial, students were given questionnaires and were asked to rate the media. The assessment was based on two aspects: material presentation and aspect of language and appearance. The result of the student response questionnaire analysis can be seen in table 4.

Based on table 4, it can be seen that the validity score obtained was 92.5%. It shows that the students' response to the pop-up learning media that had been developed can be said to be very good. It means that the media is appropriate and effective to use.

Table 4. Student response questionnaire result.

| Assessed criteria                                      | Average score |
|-------------------------------------------------------|---------------|
| Presentation of Material                              |               |
| Ease of use of media                                  | 4             |
| Usefulness of the media                               | 3.9           |
| Interest in learning after using media                 | 3.8           |
| Positive attitude towards mathematics after using media| 3.2           |
| Motivation towards mathematics after using the media   | 3.3           |
| Language and Display                                  |               |
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Based on the validation result, it can be seen that the pop-up learning media for this polyhedron material is valid, according to the criteria of [17]. The validation of media experts showed an average score of 83%. Based on the result of the student response questionnaire, it can be seen that the students' response to the pop-up learning media that had been developed was very good, by the criteria of [18]. The result of the students' response questionnaire showed that an average score of 92.5% was obtained.

Based on the students' response questionnaire, this pop-up book media helped students study the material of polyhedron. This is in line with the findings of [4, 11], which stated that pop-up learning media could help improve student understanding and learning outcomes. Besides, from the students' response questionnaire, it was found that this media fostered a positive attitude and motivation towards learning mathematics. This is in line with the research findings that students who were accompanied by a learning media in learning mathematics showed a positive attitude towards mathematics [19-21].

Based on the students' response questionnaires, it can be said that this pop-up media is good at motivating students to learn mathematics. This is in line with the opinion of [22-23], which stated that pop-up learning media make students active in the learning process, and it was flexible because the media could be used anywhere and anytime, improving student motivation to learn mathematics. Concrete experiences or activities are very valuable for students [24].

Based on the analysis and trial use of media that have been developed, the advantages of this media are as follows: (1) effective and attractive to students; (2) designed as a practical book to carry anywhere and can last a long time if always appropriately maintained; (3) low production cost. At the same time, the disadvantages of this media are in the process of creating this media. The creation of polyhedron, especially block and cube, requires a quite complicated technique and takes a long time. In addition, the pop-up book was made manually (by drawing the nets, then cuts and sticks them manually), resulting in a less precise geometry.

4. Conclusion
The development research had succeeded in producing a pop-up book media on polyhedron learning material. The media produced is valid, with a validity percentage of 83%. In addition, the student response was very good, with a percentage of 92%. This research also showed that the media could support students' learning activities and motivated students to learn the material. The development research results suggest using a mathematics pop-up book as a medium for learning mathematics, especially in the material of polyhedron at schools. In addition, the arrangement of polyhedron pop-ups should be designed using a computer and printed so that the pop-up shapes that are going to be made can be more precise and even more attractive. After the implementation of this development research, there are limitations to this media development, namely the pop-up book is only limited to cubes and blocks. Based on these limitations, researchers are advised to develop pop-up books on other polyhedron materials or on other mathematical materials.

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