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Developing LEGAMAT on Geometric Distribution: A Teaching Tools for Understanding Mathematics Concept

Desi Cahyaningsih[1], Alya Khairunnisa[1], Azzahra Indah Safitri[1], Nur Kholifah[1], Resti Jumrotin[1], Rondiah Novi Rani[1], Ratu Ilma Indra Putri[1], Novita Sari[1*], Yovika Sukma[1]
[1]Mathematics Education Study Program, Universitas Sriwijaya, Palembang, Indonesia
**Correspondence: novitasari@fkip.unsri.ac.id*

Abstract

The traditional approach to teaching geometric distributions, which focuses on proving theorems, makes it difficult for students to apply the concept in everyday life. Moreover, the content delivered by the teacher is challenging for students to understand. Therefore, developing learning media to increase student interest and understanding of the concept was necessary. In response to these challenges, the researchers developed 'Lempar Gelang Matematika (LEGAMAT)', a set of teaching tools for geometric distributions, accompanied by a student worksheet. Consequently, this study aimed to produce valid and practical teaching tools. This study employed a design research method with two stages: the preliminary stage (preparation and design stage of teaching tools and Student Worksheet) and the formative evaluation stage (evaluation and revision stage). The participants of this research were nine pre-service teachers. The data were collected by walkthrough, observation, and interview. The collected data was analyzed qualitatively. Based on the results of expert judgments and trials at the one-to-one stage, it was found that the set of LEGAMAT teaching tools was valid in media appearance aspects, easiness aspects, aesthetic aspects, and usage requirements aspects. It is practical to be used by students based on the observation in the small group stage. The researchers suggested that further studies continue until the field test stage to determine the effectiveness of the teaching tools. Additionally, they recommended developing other teaching tools related to geometric distribution topics.

Keywords: Design Research; Geometric distribution; LEGAMAT; Teaching Tools

Abstrak

Proses pembelajaran distribusi geometri, yang biasanya terbatas pada pembuktian teorema, membuat siswa sulit ketika konsep tersebut diterapkan dalam kehidupan sehari-hari. Selain itu, materi yang disampaikan oleh guru sulit untuk dipahami oleh siswa. Oleh karena itu, diperlukan pengembangan media pembelajaran untuk menambah minat belajar serta membantu siswa memahami materi pembelajaran

tersebut. Berdasarkan hal tersebut, peneliti mengembangkan media pembelajaran berupa Alat Peraga yaitu *Lempar Gelang Matematika* (LEGAMAT) dengan Lembar Kerja Peserta Didik. Adapun tujuan dari penelitian ini adalah untuk menghasilkan alat peraga yang valid dan praktis. Metode yang digunakan dalam penelitian ini adalah *Design Research* tipe *Development Study* yang terdiri dari dua tahap yaitu tahap pendahuluan (tahap persiapan dan perancangan alat peraga dan Lembar Kerja Peserta Didik) dan tahap evaluasi formatif (tahap evaluasi dan revisi). Adapun subjek dari penelitian ini adalah 9 orang mahasiswa calon guru. Pengumpulan data dilakukan dengan cara *walkthrough*, observasi, dan wawancara. Data yang terkumpul dianalisis secara kualitatif. Berdasarkan hasil expert judgement dan uji coba tahap one-to-one diperoleh hasil bahwa seperangkat ajar LEGAMAT valid baik isi, konstruk, dan bahasa. Seperangkat alat ini praktis digunakan oleh mahasiswa calon guru berdasarkan observasi pada tahap kelompok kecil. Peneliti menyarankan agar peneliti selanjutnya melanjutkan penelitian hingga tahap *field test*, sehingga dapat mengetahui keefektifan perangkat pengajaran dalam proses pembelajaran. Peneliti juga menyarankan untuk mengembangkan perangkat pengajaran lain yang berkaitan dengan topik sebaran geometri.

Kata Kunci: Design Research; Distribusi Geometri; LEGAMAT; Media Pembelajaran

Introduction

Geometric distribution, a subject in mathematics, is a discrete probability distribution representing the probability of the number of successive failures before a success in a Bernoulli trial. Knowledge of probability distributions is essential for understanding geometric distributions (Noto et al., 2017). Students with a good grasp of probability distributions can better understand geometric distributions.

However, students often struggle to understand geometric distributions. Based on previous studies, these problems were caused by many factors. First, understanding probability distributions is considered advanced and requires mastery of calculus and statistics (Noto et al., 2017). Second, the teaching of geometric distributions often focuses on theorem proving, making it difficult for students to apply the concepts in real life (Febrilia, 2017). Third, the conventional, teacher-centered approach to teaching geometric distributions is ineffective, leading to poor student understanding. As a result, many students perceive geometric distributions as complex.

The difficulties students experience are mainly related to the learning process (Noto et al., 2017). Previous studies indicate that students find geometric distributions complex due to boring lecture-based methods (Noto et al., 2017). Consequently, the content delivered by teachers is challenging for students to understand (Abbas et al., 2020). Therefore, it is necessary to develop learning media for students to increase their interest in learning and understanding the subject.

The learning media is a tool that can assist the teaching and learning process to clarify the meaning of ideas and ensure that educational or learning objectives can be achieved effectively and efficiently (Nurrita, 2018). The learning media can potentially improve the students' learning process and concept understanding (Audie, 2019; Ekayani, 2017). The other advantage of using learning media in learning activities is that it makes learning activities more attractive to students so they can develop their motivation to learn (Binangun & Hakim, 2016). One type of learning media is teaching tools.

A teaching tool is a communication tool to deliver the concepts the teacher provides (Telaumbanua, 2020). A teaching tool is a tool that is used to describe or visualize mathematical concepts; therefore, teaching tools are expected to be able to capture the student's attention and increase their interest, motivation in learning, and concept understanding (Nasaruddin, 2018).

Previous studies indicate that teaching tools support understanding abstract concepts by providing concrete objects for intermediate understanding (Rusmawati, 2017). Previous studies have indicated increased student interest and concept understanding in mathematics using teaching tools (Aisyanah & Kurniasari, 2017). The positive effect of using teaching tools was also shown in the results of previous study that the concept understanding of students after using teaching tools was higher than without using teaching tools (Munawar et al., 2020). Furthermore, teaching tools effectively improved students' concept understanding (Audie, 2019; Ekayani, 2017; Umarella et al., 2018). Therefore, using teaching tools in learning activities could make learning effective and efficient to increase students' concept understanding and learning outcomes.

However, previous studies on geometric distribution rarely relate to developing and using teaching tools as a learning medium. Previous studies that focused on geometric distribution, conducted by Yuzan et al., (2019), Desmawati et al., (2017), and Sudarno & Mukid, (2016), primarily addressed specific mathematical applications. Yuzan et al., (2019) discussed the estimation of the parameters of the geometric distribution with the Bayes method, Desmawati et al., (2017) discussed the branching process in the geometric distribution, and Sudarno & Mukid (2016) discussed the modeling of discrete total and time control charts for the generalization of geometric distribution. These studies focused on the application of geometric distribution concepts in mathematics, rarely addressing the development of learning media to help students understand the concept. It is important for students to first understand the concept, so they can apply it to related topics.

Based on these urgencies, the researchers developed teaching tools for geometric distribution, namely "Lempar Gelang Matematika (LEGAMAT)," followed by a Student Worksheet. This study aimed to produce valid and practical teaching tools, which are expected to serve as a reference for developing learning media to enhance students' understanding of geometric distributions.

Method

The method used in this study was a Design Research type development study with two stages: the preliminary stage (preparation and design stage of teaching tools and Student Worksheet) and the formative evaluation stage (evaluation and revision stage) (Tjeerd Plomp, 2007; Zulkardi, 2006). The flow of the formative evaluation stage is shown in Figure 1.

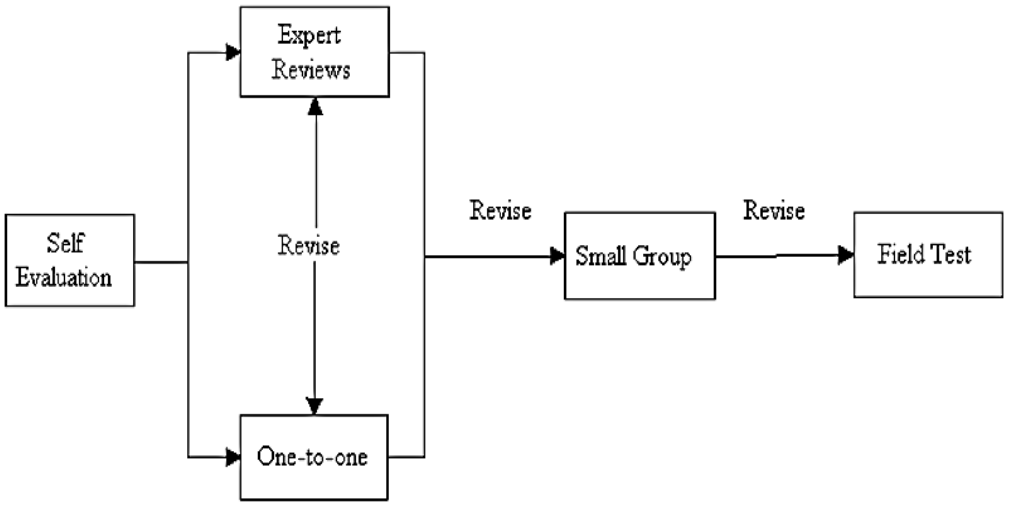


Figure 1. The flow of the formative evaluation stage

Preliminary Stage

In the preliminary stage, the researchers collected information as initial preparation before designing a set of geometric distribution teaching tools. At this stage, tasks included determining the study's time, place, and subject; analyzing students, curriculum, and materials; and designing geometric distribution teaching tools and appropriate Student Worksheets.

Formative Evaluation Stage

The Formative Evaluation Stage consisted of self-evaluation, expert review, one-to-one, and small group.

Self-Evaluation

In the self-evaluation stage, the researchers assessed the suitability of the teaching tools and Student Worksheet designs with the topic covered.

Expert Review

The results of the self-evaluation, or prototype I, of the teaching tools and Student Worksheet were re-evaluated by experts to improve quality. Experts provided suggestions and feedback on the content, construct, and language suitability. These evaluations were used as the basis for revisions, leading to prototype II.

One-to-One

At this one-to-one stage, the researchers tested the teaching tools and Student Worksheet on selected students. These students used the teaching tools and worked on the Student Worksheet, then provided feedback to the researchers. This feedback was used to revise the design.

Small Group

Revisions based on expert feedback and student difficulties during the initial trial were used to create prototype II. Prototype II was then tested on a small group to assess the practicality of the developed teaching tools and Student Worksheet.

The subjects of this research were nine pre-service teachers (hereinafter referred to as students) from a university in Palembang. Data were collected through walkthroughs, observations, and interviews, and were analyzed descriptively. The validity of this set of teaching aids was evaluated through expert assessment and small-scale trial evaluations (Tjeerd Plomp, 2007). Validity included content, construct, and language (Sastri et al., 2018). Content validity ensured conformity with criteria, material suitability, and relevance to learning objectives. Construct validity assessed the match between the product and student characteristics and the appropriateness of concept-building stages. Lastly, language validity ensured the use of clear, unambiguous, and correctly spelled language.

Results

Preliminary Stage

The preliminary stage of the study was to assess and analyze the geometric distribution material that would be applied to the participants of the study. At this stage, the material analyzed was geometric distribution. This material is a special distribution of discrete random variables in mathematical statistics courses. In statistics, a geometric distribution is a discrete probability distribution that defines the likelihood of success in a sequence of independent trials with two potential outcomes. The geometric distribution aids in calculating the chance of success after a certain number of attempts. The initial knowledge that students must have is regarding the axioms of probability and calculus. The research was carried out in odd semesters with the consideration that the research participants had already passed the calculus and probability theory courses. Based on analysis of several studies, it was known that the learning process for specific probability distribution material was limited to proving theorems, so that students had difficulty when the concept was applied in everyday life (Febrilia, 2017). The conventional and teacher-centered learning process of opportunity distribution material makes learning meaningless and students fail to understand the material well (Suryana & Seruni, 2019). Thus, the challenge of teaching probability is how to get students to understand and apply it (Borovcnik & Kapadia, 2021). After carrying out this analysis, the Throwing Mathematical Bracelet (LEGAMAT) was designed for geometric distribution material. The design can be seen in Figure 2.

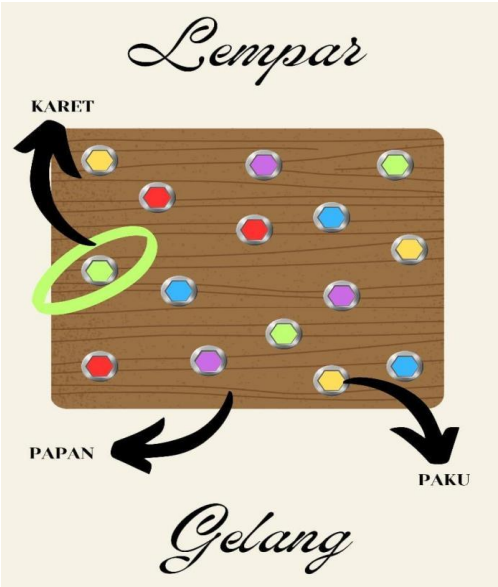


Figure 2. Teaching Tools Design

Tools and materials used in making LEGAMAT, namely boards measuring 80x80 cm, 10 pieces of wood measuring 10x2 cm, plastic bracelets, meters/measuring tools as starting line benchmarks, paint (red, yellow, green, blue, purple, and brown), thinner, and glue. The game rules in this LEGAMAT are not much different from the bracelet-throwing game at the night market, but there are several modifications. First, make a starting line 50 cm from the relief. Second, players take one of the five bracelet colors provided. Third, the player is said to be successful if the bracelet thrown hits a block of wood that is the same color as the bracelet thrown. Finally, record the experimental results on the worksheet provided.

Prototyping Stage

The next phase was the prototyping stage following the formative evaluation flow. The formative evaluation flow included self-evaluation, expert review, one-to-one, and small group stages.

Self-Evaluation

In this stage, researchers prepared the necessary tools and materials, wrote usage instructions, and developed the Student Worksheet to support the teaching tools. The planned materials included plywood boards, bracelets, and nails used as poles for placing the bracelets. Students used the teaching tools by throwing bracelets toward the game board until they successfully landed on the nails. Subsequently, the researchers conducted validation among the research team to improve the inappropriate teaching tool design.

Expert Review

In this stage, the researchers validated the teaching tools with two experts. The reviewers were lecturers from the Mathematics Education Study Program at Sriwijaya University, specializing in learning media development. This stage aimed to obtain feedback and suggestions for improving the teaching tool design. The researchers at this stage suggested changing the materials, which were the nails used as poles on the LEGAMAT teaching tools due to the difficulty in painting. Following the experts' suggestions, researchers replaced the nails with wood to facilitate painting. Figure 3 shows the design of the LEGAMAT teaching tools using wood as a pole for the LEGAMAT teaching tools.

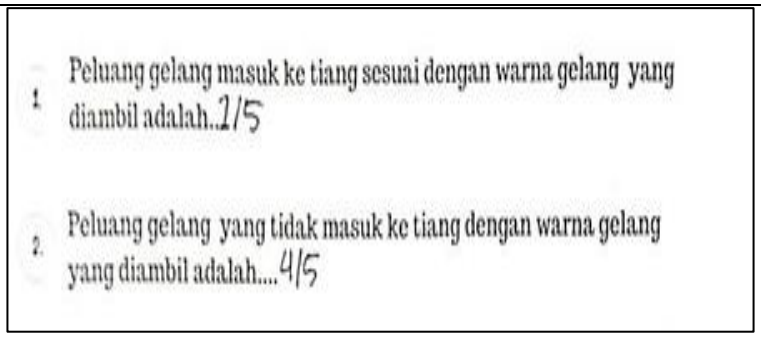
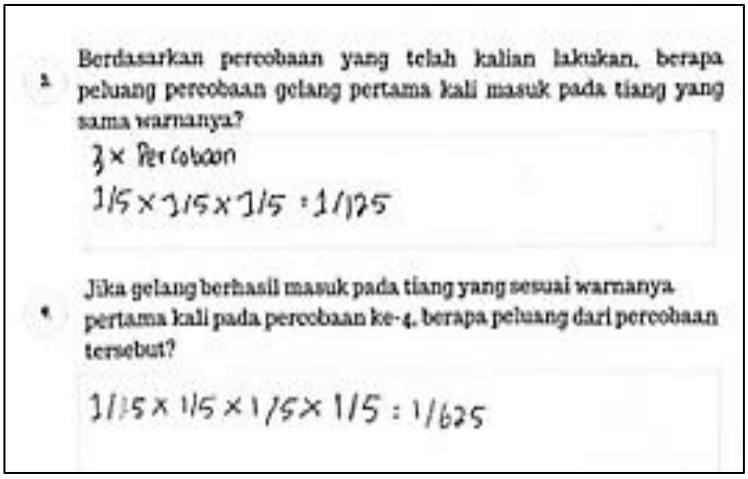
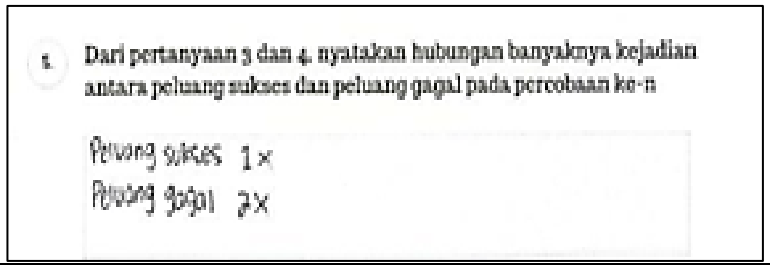
Figure 3. LEGAMAT teaching tools

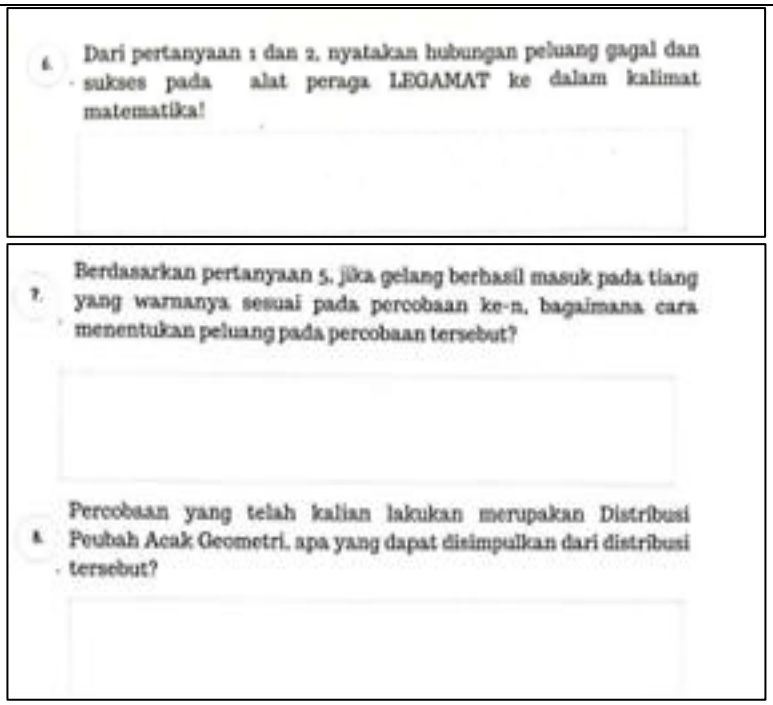
Experts recommended revising phrases in the Student Worksheet, such as 'let's observe,' and suggested adding more questions. Then, the researchers improved the teaching tools based on the feedback from the experts and revised the student worksheets.

One-to-One

Researchers tested the teaching tools with three students in a one-to-one setting. This test aimed to determine the validity of the LEGAMAT teaching tool by evaluating the difficulty based on throwing distance, bracelet size, and pole distance. First, students were asked to throw the bracelet at a pole from a predetermined distance. During the trial, the distance between the students and the teaching tools was one meter. After several unsuccessful trials, researchers reduced the distance to 70 centimeters. The experiment succeeded on the third throw after the distance was changed. Then, the researchers gave the Student Worksheet for students to work on. Table 1 shows the results of students' work on the Student Worksheet at the one-to-one stage.

Table 1. The results of students' work on the Student Worksheet at the one-to-one stage

Example of Student Work Results on Student Worksheet	Description
	Students could solve questions number 1 and 2 properly because they have studied probability theory.
	Students were able to fill in the table according to the instructions given.
	Students were able to solve questions number 3 and 4 with proper attention to the table.
	Students were not able to answer question number 5 correctly.

	Students were unable to answer questions number 6, 7, and 8.

Afterwards, the researchers interviewed students about the difficulty of using the teaching tools. Feedback and suggestions from the one-to-one stage were used to improve the LEGAMAT teaching tools. The summary of the interview results at the one-to-one stage is listed in Table 2.

Table 2. The Interview Results at the One-to-One Stage

Based on the interviews that researchers conducted, the following results were obtained:
1. According to students, LEGAMAT teaching tools were difficult to use with a distance of 1 meter. 2. According to students, when the distance between LEGAMAT and students was reduced, the experiment became easier. 3. The question number 5 was incorrect and questions numbers 6, 7, and 8 were missed because the students did not understand the meaning of the question.

Based on feedback from the one-to-one stage, the researchers adjusted the instructions for using the LEGAMAT teaching tools, including reducing the distance from one meter to 70 centimeters and revising questions 5, 6, 7, and 8 on the Student Worksheet, as students found them unclear (see Table 3 for the revised worksheet).

Table 3. Revised STUDENT WORKSHEET

Before Revision	After Revision
	
	Revision decision: Delete the sentence "*Ayo Amati!*"
	
	Revision decision: Revise questions 5 and 6 to become questions 5, 6, and 7.

Revision decision:
There was a change from question 7 to question 8.

Small Group

In the small group stage, the trial was conducted with four students. Students were given a Student Worksheet containing questions about experiments with the teaching tools, which were then connected to the geometric distribution material. Based on the answers of the four students in the small group, the students were able to answer the questions on the Student Worksheet well. The students answered questions 1, 2, 3, and 4 on the Student Worksheet correctly. However, in question number 5 related to determining the relationship between the number of success and failure probabilities in the experiment and question number 6 related to expressing the relationship between failure and success probabilities based on the experiment into mathematical form, there were still errors in the students' answers.

When answering question 5, most students were able to describe the relationship between the number of successes and failure probabilities in the experiment they conducted with the teaching tools (see Figure 4 for an example of one student's answer). Only student number 1 was still incorrect in describing the relationship. The student did not consider that q was 1-p, so the student wrote the relationship as $q^4 \times p$ (Figure 5).

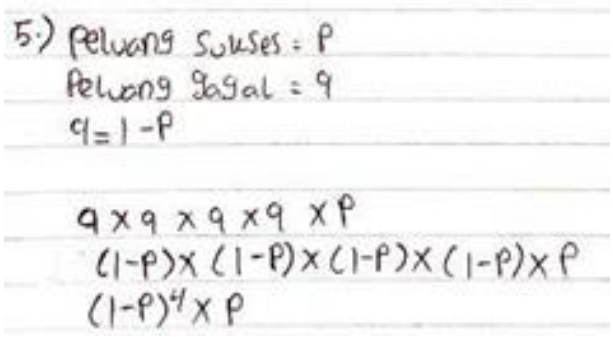


Figure 4. Student answer

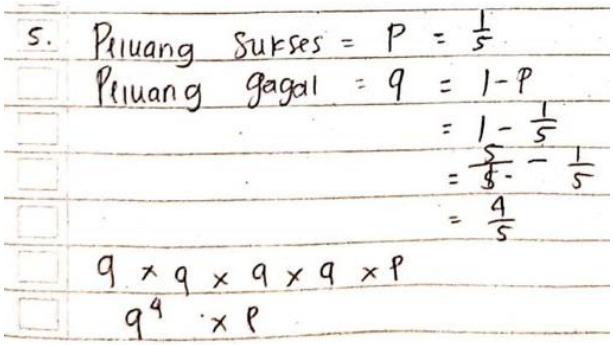


Figure 5. Student answer

Furthermore, question 6 was a continuation of question 5. Due to the incorrect answer to question 5, student number 1 still did not correctly describe the relationship between the number of successes and failure probabilities in the experiment with the teaching tools. Thus, the answer to question 6 also contained an error in writing the relationship in mathematical form (see Figure 6). The correct mathematical form of the relationship between the probabilities of failure and success using the teaching tools is shown in Figure 7.

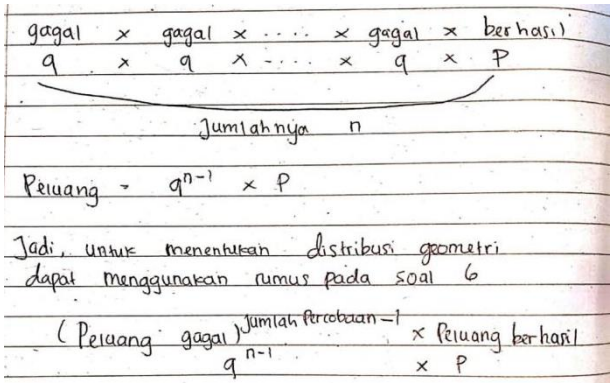


Figure 6. Student answer

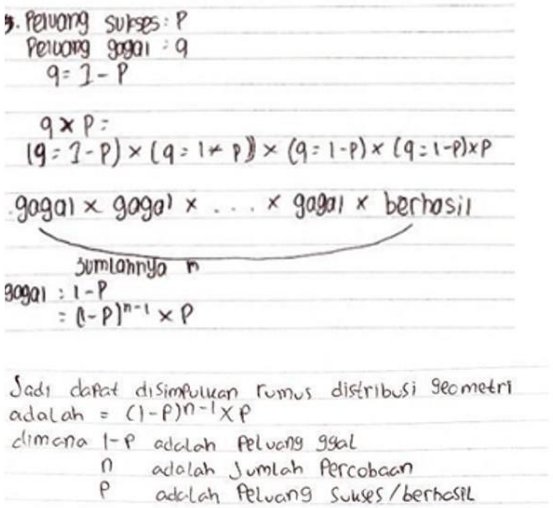


Figure 7. Student answer

However, when interviews were conducted with all students at the small group stage, the researchers revealed that all students understood the concept of geometric distribution. The student number one who was still unable to recognize the relationship $q = 1 - p$ when answering questions number 5 and 6, was actually able to consider the relationship $q = 1 - p$ during the interview. Therefore, from the results of the student worksheets using the LEGAMAT teaching tools, it can be concluded that the students as a whole understood the concept of geometric distribution. This was evident from how students answered the questions in the Student Worksheet, demonstrating their understanding in the cognitive domain. Thus, the researchers concluded that the students were able to understand the concept of geometric distribution.

Furthermore, researchers conducted interviews to confirm again the students' comments on LEGAMAT teaching tools. The students commented that placing the start line of the overlay at 70 centimeters was too far, so it was moved closer to 50 centimeters. According to the four students, they were all very enthusiastic about learning using these teaching tools. Regarding the Student Worksheet, the four students had no comments; they thought the instructions and questions were easy to understand.

Based on the results at the expert review stage and one-to-one stage, it was found that the teaching tools were valid based on the assessment by the validator. The teaching tools are practical for learning geometric distribution, based on the results of the Student Worksheet and interviews with students at the small group stage.

Discussion

Teaching and learning of geometric distribution rarely use teaching tools that are familiar to students. LEGAMAT uses the concept of a throwing bracelet game, often found at night markets, making students more familiar with its use. The concept of throwing bracelets has also been used by Arum et al. (2020) as a learning medium in Natural Science and Indonesian Language topics. The LEGAMAT teaching tools were accompanied by a Student Worksheet designed to help students understand the concept and derive the formula for geometric distribution step by step.

After completing the preliminary stage (preparation and design of teaching tools and Student Worksheet) and the formative evaluation stage (self-evaluation, expert review, one-to-one, and small group), it was found that the LEGAMAT teaching tool was valid based on expert reviews and trials with students at the one-to-one and small group stages. This finding is consistent with previous studies, which found that validity can be assessed based on expert reviews and validator assessments of content, construct, and language, while the practicality of tools and their worksheets can be evaluated based on small group results. Practicality is seen based on the students' comments/suggestions which they understand and can follow the instruction of the learning media used (Akker, 1999; Asmara & Sari, 2021; Saputra et al., 2019).

Moreover, the LEGAMAT teaching tools developed have also been declared practical based on the results of interviews, and tests at the small group stage. Van den Akker stated that practicality is determined by the extent to which users find the developed product attractive and usable under normal conditions (Akker, 1999). Students seemed to be able to use this teaching tool during the implementation in the small group stage. Students become helpful in understanding the geometric distribution material, and students were interested in learning geometric distribution with this LEGAMAT teaching tool.

Conclusion

This study has produced teaching tools and Student Worksheets on geometric distribution materials that are valid and practical. The validity based on evaluation results from the validator and one-to-one stage. The practicality of the teaching tools and Student Worksheets is evident from the small group stage, where students effectively used the tools and completed the worksheets. This helped them

understand the material, and they showed interest in using the LEGAMAT teaching tools to learn geometric distribution concepts.

This research had a limited scope, focusing on a small sample group tested during the one-to-one and small group stTherefore, the researchers suggested for further researchers to continue the research until the field test stage, thus it could determine the effectiveness of the teaching tools in the learning process. Researchers also suggested to develop other teaching tools related to geometric distribution topics.

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