

MANIPULATIVE LEARNING MEDIA BASED ON STEM (SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS) TO IMPROVE STUDENT LEARNING OUTCOMES

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Abstract:

This study aimed to develop manipulative learning media based on STEM (Science, Technology, Engineering, and Mathematics) called Magic Hours on clock and corner material. Research and development model used by using the procedure of Analysis, Design, Development, Implementation, and Evaluation (ADDIE). The population of this study was all 4th grade students from elementary school in Kediri. Due to the Covid-19 pandemic situation and study from home policy, manipulative media was tested on 13 fourth grade elementary school students in Kediri who came from the same village to reduce students' mobility from one place to another. Data collection techniques are collecting through expert validation, teacher questionnaires, student questionnaires, test, observation, and interviews. The instruments are test (description questions) and non-test instruments (material validation sheets, design validation sheets, practicality assessment sheets, questionnaire validation sheet, and questionnaires). The result shows that the learning media are valid, practical, and effective. Learning media have feasible criteria with an assessment score of 88.46% from media experts and 86.67% from material experts. In the practicality test, learning media obtained a percentage of 86.67% with practical criteria. The result of a one-sample t-test on student test scores indicates that the average mathematics score test is significantly more than Minimum Completeness Criteria.

Keywords: Angle and Clock, Manipulative Learning Media, STEM

MEDIA PEMBELAJARAN MANIPULATIF BERBASIS STEM (SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS) UNTUK MENINGKATKAN HASIL BELAJAR SISWA

Abstrak:

Penelitian ini bertujuan untuk mengembangkan media pembelajaran manipulative berbasis STEM (*Science, Technology, Engineering, and Mathematics*) pada materi jam dan sudut untuk siswa kelas IV Sekolah Dasar yang bernama Magic Hours. Jenis penelitian ini adalah penelitian pengembangan (*Research and Development*) dengan mengadopsi prosedur *Analysis, Design, Development, Implementation, dan Evaluation (ADDIE)*. Populasi penelitian ini adalah seluruh siswa kelas 4 Sekolah Dasar di Kota Kediri.

Adanya pandemi Covid-19 dan kebijakan belajar dari rumah, media manipulatif berbasis STEM diujibakan kepada 13 siswa Sekolah Dasar di Kediri yang berasal dari desa yang sama untuk mengurangi mobilitas siswa. Teknik pengumpulan data dilakukan melalui validasi ahli, angket guru, angket siswa, observasi, dan wawancara tak terstruktur. Instrumen yang digunakan meliputi instrumen tes (soal uraian) dan instrumen non tes berupa lembar validasi dan angket uji coba. Hasil penelitian menunjukkan bahwa media pembelajaran telah memenuhi kriteria valid, praktis dan efektif digunakan sebagai media pembelajaran untuk meningkatkan hasil belajar siswa. Media pembelajaran telah memenuhi kriteria-kriteria layak dengan skor penilaian 88,46% dari ahli media dan 86,67% dari ahli materi. Dalam uji kepraktisan, media pembelajaran memperoleh persentase sebesar 86,67% dengan kriteria praktis. Hasil analisis efektifitas media diuji dengan one sample t-test yang menunjukkan hasil rata-rata tes siswa lebih dari ketuntasan minimal.

Kata Kunci: Jam dan Sudut, Media Pembelajaran Manipulatif, STEM

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INTRODUCTION

Mathematics is one component that has a significant role in the world of education. In Indonesia, mathematics is taught at the educational's level start from kindergarten to college. According to Mahmudah, Ahyan, & Rasidi (2018), mathematics needs to be learned because mathematics means solving problems in everyday life, thinking logically, clearly, critically, and acts a basics science to study others. However, several problems occur in learning mathematics, including the lack of maximum use of media in the learning process and the complexity of the material delivered by the teacher who impacts poor understanding of students. Therefore, innovative solutions are needed by teachers so that initially complicated learning mathematics becomes easy and can reduce fear or laziness in learning with students. One alternative solution that teachers can apply is the use of interested and varied learning media.

The media plays a significant role in the learning process. Using manipulative media can help students understand and prove abstract mathematics ideas, solve mathematics problems, and make mathematics

learning more interesting, challenging, and motivating (Burns, 2007; Larbi & Mavis, 2016; Yensi, 2020).

Others, the use of manipulative media can increase students and teachers activity in the classroom, motivation, learning outcomes, student's understanding of a mathematical concept, attitude toward mathematics, help students to concrete abstract ideas and make student's confident and support higher-order thinking skills (Anggoro, 2019; Cope, 2015; Frei, 2008; Hidayah, Isnarto, Masrukan, & Asikin, 2020; Indarwati, Ima, & Diana, 2017; Isnaniah & Imamuddin, 2020; Latri, Nonci, & Juhari, 2019; Palupi, 2019; Putra, 2020; Syam, Akib, & Syamsuddin, 2019; Ulyani & Qohar, 2020).

Based on the preliminary interview mathematics teacher results at MIN 2 Kediri, mathematics learning at MIN 2 Kediri was collaborative learning, with drawing learning media, whiteboard media, and worksheet supporting books and textbooks. However, the application of learning media in schools has not been maximizing. Teachers consider that manipulative media is important in learning mathematics, but manipulative media is difficult to apply in practice, especially when students learn from home. In addition, there is no manipulative media that combines several learning materials. The existing manipulative media are differentiated based on learning material such as science learning media, social studies learning media, mathematics learning media, and others.

The obstacle experienced by teachers in teaching mathematics is the lowest understanding of students about mathematics. It is due to not applying the concept of the interrelationship between science, for example, using STEM-based learning media. Based on these problems, the authors provide alternative solutions in developing mathematics learning media to improve student understanding. In this media, pictures and teaching aid are available to practice so that students have experience as a concept teaching process.

One of the manipulative media that combines several subjects is manipulative media based on STEM. NSF (National Science Foundation) introduced STEM as an acronym of "Science, Technology, Engineering & Mathematics" (Sanders, 2009). STEM is a learning approach that combines two or more STEM components in a learning process (Becker, Kurt, & Park, Kyungsuk, 2011). The purpose of STEM education for all students is to apply and practice the basics content of STEM in the situations they encounter/find in life to become STEM literacy skills (Suwarman, Astuti, & Endah, 2015). Several research results in media based on STEM show that media based on STEM can positively impact student's participating attitudes toward science, student's

motivation, provide engineering experience, and gain affective, cognitive, and psychomotor competency better than conventional class (Karahana, Bilici, & Unal, 2015; Susanti, Hasanah, & Khirzin, 2018; Suwarman, Astuti, & Endah, 2015).

Another research result about mathematics media on hours and angle material stated that media can influence student mathematics learning outcomes (Binangun & Hakim, 2016). This research also succeeded in making students interested in being better built to participate in mathematics learning activities and attention to learning and student understanding of subject matter. From the results of this study, researchers developed learning media on clock and angle that was modified by the existence of flat angles, electrical circuits, and lights as applied from learning based on Science, Technology, Engineering, and Mathematics (STEM). Based on those backgrounds described above, researchers are interested in developing manipulative learning media based on STEM (Science, Technology, Engineering, and Mathematics) to improve student learning outcomes called "Magic Hours".

METHODS

This research is a Research and Development (R&D) study with a final product in manipulative learning media based on STEM called "Magic Hours". R&D aims to develop and test the feasibility of the product (Sugiyono, 2008). This study developed the product by applying the ADDIE development model consisting of five development steps: analysis, design, development, implementation, and evaluation (Mulyatiningsih, 2012).

The analysis phase includes identifying the problems in mathematics teaching and learning activities in elementary and Madrasah Ibtidaiyah in Kediri. The next stage is the design phase that includes analysis of learning objectives, planning time for product development, identification of media specifications, calculation of electricity sources, resistance, and voltage so that the indicator lights on the media can function, as well as the allocation of funds for making media. The next stage is the development stage that includes developing the product into the final product, validating the product, developing a manual for how to manufacture and using the media, and revising the product if necessary. The fourth stage is the product trial phase to determine the practicality and effectiveness of the product based on the questionnaire and test. Magic Hours was the manipulative media that helped students to learn angle and clock material in the fourth grade of elementary school. In order to

reduce student mobility from one place to another during the Covid-19 Pandemic situation, manipulative media called Magic Hours was tested on 13 fourth grade elementary school students from several elementary schools in Kediri who came from the same village. The last step is product evaluation and review of product strengths and weaknesses.

Data collection techniques were carried out through material expert validation, media expert validation, student response questionnaire validation, practicality assessment sheets by the teacher, student questionnaire, observation, and interview. Instruments used in this study include a test (in the form of five descriptive questions) and a non-test in the form of a validation sheet and student questionnaire responses. Furthermore, qualitative data is the results of the validator's suggestion on the validation sheet and quantitative data in the form of the validation results, the practicality of the teacher's questionnaire, student questionnaire, and the results of the trial test were analyzed to determine the criteria of validity, practicality, and effectiveness of the media. According to Nieveen (1999), there are three aspects to determine the feasibility of a product, including validity, practicality, and effectiveness. To measure validity, a validation sheet is used with the rating scale in table 1.

Table 1. The Grading Scale for Validation Sheet

Rating Scale	Score
Very Not Good	1
Not Good	2
Good Enough	3
Good	4
Very Good	5

To measure the practicality of the product, the practicality questionnaire was used that was filled out by the practitioner (teacher). Meanwhile, to measure the product's effectiveness, the student questionnaire sheet and test were used with the rating scale in table 2.

Table 2. The Grading Scales for Teacher Questionnaire Sheet and Student Questionnaire

Item	Item Value				
	Strongly Agree	Agree	Neither Agree Nor Disagree	Disagree	Strongly Disagree
Favorable	5	4	3	2	1
Unfavorable	1	2	3	4	5

Data obtained from validation sheets and questionnaires were analyzed as a whole using the following formula (Arikunto, 2006):

$$p = \frac{\sum x}{\sum x_i} \times 100\% \quad (1)$$

With :

- p : The percentage of the subject testing evaluation result
- $\sum x$: The total number of respondents answers in all given by the test subjects
- $\sum x_i$: The maximum number of scores in all aspects of assessment

Data that have been analyzed and then classified into the categories in table 3. (Sugiyono, 2008):

Table 3. The Descriptive Eligibility Criteria

Percentage (%)	Validity Criteria	Significance
90-100	Very Decent	No Revision Needed
75-89	Decent	No Revision Needed
65-74	Decent Enough	Revision Needed
55-64	Not Decent	Revision Needed
0-54	Very Not Decent	Total Revision

The product's effectiveness is also measured through the completeness of student learning outcomes after participating in learning by applying the manipulative learning media that is Magic Hours. In addition, student test scores were have tested for normality using the Lilliefors test. If the test score data normality distributed, a one-sample t-test performed using the following formula:

$$t = \frac{\bar{x} - \mu_0}{s / \sqrt{n}} \quad (2)$$

RESULTS AND DISCUSSION

Based on the research and development of the ADDIE model conducted in 5 stages, the following results can be obtained:

1. Analysis

The analysis was made product specifications that could help fourth-grade elementary school students to solve problems and optimize their abilities, skills, and creativity in thinking. The necessity was students like activities that combine knowledge and skills to reduce conventional learning model, students like different learning activities one of which is by using learning media that can

show the interrelation between subjects studied so the solution made a manipulative learning media based on STEM that can be held and operated independently by students and allows students to learn several subjects at one time. According to Yensi (2020), manipulative learning media made mathematics more attractive and easier to understand because students direct practice the media and increase student interest in learning mathematics. Another research stated that the use of manipulative media in learning mathematics can increase students' interest and motivation in learning (Packenham & Westenskow, 2013; Ulyani & Qohar, 2020).

2. Design

Based on the necessary analysis, it can be concluded that we need learning media that support learning activities. STEM-based learning media are expected to turn students into characters who can solve problems, become logical thinkers, master technology, and connect their own culture with learning (Gallant, 2010). Designing media can be held by exploring learning material, creating a learning media design, making a guidebook, making a demo video, and arranging questions to evaluate learning. On exploring learning material, clock and angles are selected because this is considered very difficult and close to students' life. The next process was creating learning media design, namely the corner clock and flat fractional angles to show what angles formed when a clock last. To show steps of making, developing, and using the learning media, a guidebook and a demo video were made. The final process of this stage was arranged questions as evaluation. The questions are adjusted to basic competencies, learning objectives, indicators of achievement competencies adapted to the curriculum used in schools.

3. Development

In this stage, media is developed and validated by media experts and material experts then revised to be the final product. Learning media consist of two types, namely the corner clock and flat fractional angles. The corner clock consists of a clock and time pointer, while the fractional flat angles measure the magnitude of the angle formed by both hands.



Figure 1. Angles Corner Clock



Figure 2. $\frac{1}{6}$ Fractional Flat Circles

The two hands of clocks would form the desired angle, and then the indicator light would light up as a form of distortion of each type of angle shown.



Figure 3. The Clock Shows an Obtuse Angle



Figure 4. The Clock Shows a Right Angle

Then the fractional flat will show the large-angle formed by the two hands of clocks by trying various sizes of existing fractional circle flats.



Figure 5. Use Clock Angles along with Flat Circle Fraction

On media validation, three aspects were assessed: function of media illustration, media display, and media use. This process stated that the average value of the two validators was 88.5%, with a decent criterion and no revision. Based on these data, it can be concluded that the manipulative learning media

Magic Hours are appropriate to be used for learning activities. On the other process of material validation, six aspects assessed which are: suitability of the media CC and BC, suitability of the media with BC, suitability of the indicator, suitability of the media with the abilities and experience of students, interactivity of media, and suitability media with the allocation of learning time. This process stated that the average value of the two validators was 86.67% with the reasonable criteria, and there were no revisions. Therefore, it can conclude that the manipulative learning media Magic Hours have the eligibility criteria for learning. After the validation process, the expert gives several descriptive suggestions. The following suggestions are that media should be equipped with a storage box to make it safer, use more affordable materials and use the contrast light theme.

4. Implementation

Products that have been revised then tested. To determine the effectiveness of media MCC (Minimum Completeness Criteria) that is 74 was used. The normality of data assumption was tested using the Liliefors test. If the data shows normality distribution, the data is analyzed using the One-Sample t-test. Based on calculations, the Liliefors value was 0.1942, while the Liliefors table with a significance level of 0.05 was 0.2337. Based on this calculation, it can see that the Liliefors value is smaller than the Liliefors table of value, which means that the student mathematical test scores have normality distribution. Therefore, the One-Sample t-test can be performed. Based on this test, the p-value is smaller than the 0.05 significance level, meaning that the average value of student math tests is more than 74.

The effectiveness aspect of the product was also measured through a student response questionnaire. The student response questionnaire contained 30 statements consisting of 15 favorable and 15 unfavorable questions. From the data analysis, it founded that the percentage of effectiveness of instructional media was 75.69% with effectiveness criteria.

Based on the observations when learning, before the media is applied, students tend to be passive in learning, and then after using the media, students are more active and enthusiastic about learning. Based on the explanations, it can be concluded descriptively that the media effectively increases student interest in learning to increase student understanding of mathematical concepts and impact student learning outcomes. Those results align with previous research that manipulative media can improve students learning outcomes and

motivation (Juma'atin, 2018; Ulyani & Qohar, 2020). In addition, by using manipulative media based on STEM, students can actively conduct scientific investigation to solve and find the solution of problems (NRC, 2012; Kelley & Knowles, 2016). Another aspect was media practicalities. The practicality of the product was measure through a teacher response questionnaire. The results obtained that the practicality percentage was 86.67%. So, it concluded that the manipulative learning media Magic Hours was easy to use in learning mathematics.

5. Evaluation

The weakness of this media was that the media unable to show various angles, especially the small angles. To show more various angle needs more Fractional Flat Circles too. Researchers used this evaluation as a reference for developing products that are more complete and more perfect.

CONCLUSION

Magic Hours is a manipulative learning media based on STEM that achieves decent criteria with an assessment score of 88.46% from media experts and 86.67% from material experts. In the implementation, it is obtained that an average score of students understanding tests was significantly more than the Minimum Completeness Criteria of 74. It means that manipulative learning media can be said to be effective for improving student learning outcomes. Besides, student questionnaire responses containing questions about the use of instructional media showed results of 75.69%, which is means effective as one of the learning media. The practicality of the media measured through a questionnaire by educational practitioners or teachers gets 86.67% which means it is worthy of learning media. So the manipulative learning media Magic Hours can be declared feasible, practical, and effective for improving student learning outcomes.

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