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The Impact of MLM-STEM on Temperature and Heat Material in Students' Critical Thinking Skills

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Abstract: This study aims to measure the effectiveness of MLM-STEM on temperature and heat materials on students' critical thinking skills. The research method used in this study is a quantitative method with a quasi-experimental design. Research data were analyzed using normalized average gain, t-test, and effect size. Based on the analysis conducted, it is known that (1) the critical thinking skills in the experimental class are in the high category, while in the control class they are in the moderate category, (2) the critical thinking skills of the experimental class students using MLM-STEM are higher than the control class using electronic textbooks, (3) there is a significant difference between the improvement of critical thinking skills in the experimental class and the control class, and (4) students respond positively to the use of MLM-STEM in learning. Therefore, it can be said that MLM-STEM is a solution to improve students' critical thinking skills.

Keywords: multimedia learning modules, STEM, critical thinking.

Abstrak: *Penelitian ini bertujuan untuk mengukur efetktivitas dari MLM-STEM pada materi suhu dan kalor terhadap keterampilan berpikir kritis siswa. Metode penelitian yang digunakan pada penelitian ini adalah metode kuantitatif dengan desain quasi eksperimental. Data penelitian dianalisis menggunakan rata-rata gain yang dinormalisasi, uji-t, dan effect size. Berdasarkan analisis yang dilakukan diketahui bahwa (1) keterampilan berpikir kritis pada kelas eksperimen berkategori tinggi, sedangkan pada kelas kontrol berkategori sedang, (2) keterampilan berpikir kritis siswa kelas eksperimen yang menggunakan MLM-STEM lebih tinggi dibandingkan dengan kelas kontrol yang menggunakan buku ajar elektronik, (3) terdapat perbedaan yang signifikan antara peningkatan keterampilan berpikir kritis kelas eksperimen dan kelas kontrol, dan (4) siswa memberi respon positif terhadap penggunaan MLM-STEM dalam pembelajaran. Sehingga dapat dikatakan bahwa MLM-STEM menjadi solusi untuk meningkatkan kemampuan berpikir kritis siswa*

Kata kunci: *modul pembelajaran multimedia, STEM, berpikir kritis.*

▪ INTRODUCTION

In the current 21st century, science and technology are developing very rapidly and have an impact on life, one of which is the field of education (Basak and Wotto 2018; Darmaji et al. 2019). So that through education it is expected to be able to create human resources who master science and innovation in facing challenges in the future. Where in facing these challenges, individuals are required to think fundamentally, consistently, efficiently, and master different abilities and be able to solve problems. One way to face future challenges is to train critical thinking skills, where critical thinking skills are individual intellectual thinking skills including reflective thinking, and entry which is focused on making decisions about what to do (Bharati & Lestari, 2019; Sujanem et al. ., 2020).

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Critical thinking is a process that involves seeking knowledge through reasoning, problem-solving, and decision-making skills that will enable us to achieve the desired results more efficiently (Saiz & Rivas, 2011). critical thinking is reasonable and reflective thinking that focuses on deciding what to believe or do. Meanwhile, according to Scriven in Fisher (2009), critical thinking is a skilled and active interpretation and evaluation of observation and communication, information and argumentation. Critical thinking skills are very important because they enable students to solve problems effectively in both social, scientific and practical fields (Snyder & Snyder, 2008). Critical thinking skills are developed into indicators of critical thinking skills which consist of five major groups, namely basic clarification, basic support, interference, further clarification, and strategies and tactics (Ennis, 1996). Critical thinking skills can be trained by giving argumentative assignments about common problems that occur (Saiz & Rivas, 2011). So developing critical thinking skills is needed to be able to analyze, synthesize, and construct a concept to solve problems (Perez et al., 2017). However, based on a preliminary study at a high school in the city of Klaten, it was found that students' critical thinking skills were still not optimally trained in learning. This is evidenced by the fact that students are still passive and act as recipients of information that follow the teacher's instructions. In addition, students still do not understand the material being taught which is indicated by the low student learning outcomes. Some research results show low students' critical thinking skills, such as that carried out by Christi et al., (2020) which shows that the critical thinking skills of class X students at SMA N 1 Jiwan are still low and learning physics is a boring and difficult subject to understand. In addition, research conducted by Ansori et al., (2017) also shows that students' critical and cognitive thinking abilities in physics learning at SMA Muhammadiyah 1 Temanggung are still low and their ability to solve problems is still not optimal.

Various ways have been created to meet this demand, one of which is Science, Technology, Engineering, and Mathematics (STEM) based learning. STEM is a term used to refer to cross-disciplinary teaching and approaches, namely Science, Technology, Engineering, and Mathematics. The integration of this STEM angle can improve student learning outcomes (Pangesti et al., 2017; Bashooir & Supahar, 2018). STEM-based education aims to improve the ability to adapt, think critically, solve problems, self-management and communicate. STEM-based learning is coordinated to encourage students to explore effectively, create thinking skills, and form critical thinking. STEM-based education is believed to play a major role in improving the skills of 21st century students, one of which is critical thinking skills (Gürler, 2021). STEM learning students do not only memorize concepts, but rather how students get them and understand the concepts and their relation to application in life (Pertiwi, 2017; Lestari et al., 2018).

Physics learning that is related to STEM aspects provides opportunities for students to understand physics concepts combined with technology, engineering and mathematics through discussion, practicum and project creation. Activities carried out during the learning process can attract students' interest and have implications for improving learning outcomes and students' critical thinking abilities, so teaching materials are needed that are relevant to the learning process. One form of teaching materials that can be used is a module. Modules are a set of teaching materials that are presented systematically so that students can learn without a teacher, arranged in a systematic and

interesting manner which includes material content, methods and evaluations that can be used independently (Sukardi, 2018; Warsono, et al., 2020).

Multimedia Learning Modules (MLM) is a digital learning module that is associated with various types of media, such as text media, images, videos, animations, and simulations that are presented in various forms of representation (Li, 2014; Darmaji et al., 2019). This has a positive impact in the form of conveying a lot of information to users so that learning activities become more effective, increasing student understanding and motivation (Lee, 2012; Sadaghani, 2012). MLM is made in the form of multimedia presentations in the form of graphics, text, video, narration, animation and audio features that are embodied in various forms of representation (Setiyadi et al., 2019). MLM is an interactive multimedia module that is equipped with controls or facilities operated by the user, so that the user can choose what is needed to continue the learning process further (Moore, 2018; Putri et al., 2018). Multimedia Learning Modules (MLM) are introductory media that aim to motivate students to actively participate and be able to prepare and have initial knowledge before learning activities begin (Chen et al., 2010; Sadaghiani, 2012). MLM is used as a learning tool to reduce the limitations of using textbooks which are less effective where students only read books without taking more important information. The use of MLM is also more flexible because students can freely access it anywhere and anytime without the help of a teacher. Representation in MLM is able to clarify and improve students' understanding of abstract learning concepts.

STEM-based Multimedia Learning Modules (MLM) are interactive modules designed to train students in problem solving by utilizing technology that is integrated with STEM learning (Fadlina et al., 2021). The use of the STEM approach in the form of MLM can improve students' creative thinking abilities, critical thinking, conceptual understanding, and student learning outcomes (Zulaiha & Kusuma, 2020; Almuharomah et al., 2019; Fadlina et al., 2021). In addition, STEM-based teaching materials, especially modules, have a more effective influence on student learning outcomes in terms of knowledge, skills and attitudes (Izzah et al., 2021). Based on research results (Fadlina et al., 2021), it was found that the use of STEM-based modules can improve critical thinking skills and student learning outcomes in motion systems material. Another study conducted by (Almuharomah et al., 2019) also showed that the use of STEM-based physics modules on vibration and wave material can improve creative thinking skills with an N-gain of 0.92 in the high category.

▪ METHOD

Research Design

This study uses a quantitative approach with quasi-experimental methods. The research design used was The Matching-Only Pretest-Posttes Control Group Design (Fraenkel, Wallen, & Hyun, 2012). In this study, two classes were used, namely an experimental class that used MLM-STEM and a control class that used electronic textbooks from schools or the ministry of education and culture. The selection of the experimental class and the control class was made randomly from 7 science classes. The data obtained is in the form of quantitative data obtained from the pretest and posttest conducted in the experimental group and the control group. This study measures students' critical thinking skills with five indicators based on Ennis (2011), namely: elementary clarification, basic support, interference, advanced clarification, and strategy and tactics.

The model design in this study is presented in table 1.

Table 1. Research design

Group	Pretest	Perlakuan	Posttest
Experiment	O_1	X	O_2
Control	O_3	Y	O_4

Information:
O_1 : Pretest critical thinking skills and cognitive experimental class.
O_2 : Posttest of critical thinking and cognitive skills of the experimental class
O_3 : Pretest critical thinking skills and cognitive control class.
O_4 : Posttest critical thinking skills and cognitive control class
X : The use of STEM-based MLM in physics learning on Temperature and Heat for high school students.
Y : Using physics teaching materials commonly used in schools at the high school level

Participants

The participants in this study were class IX students majoring in Science at SMA Muhammadiyah 1 Klaten, Central Java. This research was conducted in two groups as research subjects with a total of 72 students. Two groups were randomly selected consisting of an experimental group of 38 students and a control group of 34 students. The sample selection technique used was purposive sampling. Sugiyono (2016) states that purposive sampling is a sampling technique based on certain considerations, both from experts and based on certain objectives.

Treatments

The implementation of MLM-STEM was carried out in two class XI majoring in Science at SMA Muhammadiyah 1 Klaten. The experimental class uses MLM-STEM which is accessed via students' cellphones and PCs, and the control class uses electronic textbooks published by the Ministry of Education and Culture. The material studied by the two groups is temperature and heat with sub-materials on temperature and expansion, heat, and heat transfer.

Before being treated with the use of MLM-STEM and electronic books in the learning process, a pretest was carried out in the experimental group and the control group to determine students' initial abilities regarding the material being studied. Furthermore, different treatment was given to the two groups, namely the experimental group was given MLM-STEM which could be accessed using cellphones and PCs via the link provided by the teacher, and the control group was given electronic books as learning resources. After being given treatment in both classes, a post-test was carried out to find out the increase in students' critical thinking skills in each group, and the effectiveness of MLM-STEM and electronic books to improve critical thinking skills.

Research Instruments

The research instrument used to measure students' critical thinking skills is 10 essay questions with five indicators of critical thinking according to Ennis (2011), namely basic clarification, basic support, interference, further clarification, and strategies and tactics.

While the student response instrument used a questionnaire containing statements along with two answer choices, namely "Yes" and "No". The student perception questionnaire consists of 22 statements which are divided into six aspects, namely: (1) happy learning with three statements, (2) easy to understand subject matter with five statements, (3) motivated to learn with three statements, (4) confident and curiosity with four statements, (5) mutual respect with three statements, and (6) the use of MLM-STEM with seven statements. The student response instrument was developed and adapted based on Wilkinson's (2004) instrument.

Data Analysis

Data on students' critical thinking skills test results were obtained from the pre-test and post-test which were then analyzed using normalized gain calculations. interpreted by Hake (1999). Data on learning outcomes using MLM-STEM were compared to electronic textbooks using parametric independent t tests and effect sizes. Meanwhile, student perception data were analyzed descriptively (Sugiyono, 2016).

Pilot Tests

The critical thinking skill instrument was tested on 72 students in one of the senior high schools in Klaten Regency. The validity and reliability of the questions were measured using the Rasch Model. The results of the validity of the questions used the Item fit order calculation method with three criteria, namely Outfit MNSQ, Outfit ZSTD and Pt. Measure Corr (Bonee et al., 2014; Bond & Fox, 2015; Sumintono & Widhiarso, 2015). Based on the Item fit order method, it was found that each test item was valid and feasible to use, and did not need to be changed. The reliability test uses the Rasch Model with the output summary statistics method with three criteria, namely person reliability, item reliability, and Cronbach alpha. Personal reliability. The value of item reliability and personal reliability for critical thinking is 0.91 in the very good category and 0.53 in the weak category, respectively. While the Cronbach Alpha value is 0.75 and is included in the good category. The results of this analysis can be concluded that the consistency of student answers is in the weak category, the quality of the items in the very good category, and the interaction of students and the items as a whole is in the good category.

▪ RESULT AND DISSCUSSION

Effectiveness of MLM-STEM

This research was conducted to find learning strategies that can solve the problem of low students' critical thinking skills, especially in high schools in Klaten Regency. The chosen strategy is to design MLM-STEM that can be accessed via cellphones and PCs. The data obtained from this study were in the form of pretest and posttest quantitative data from the experimental group using MLM-STEM and the control group using electronic books. Then based on these data, the normalized gain values for each group are calculated. The results of the normalized gain calculation for the critical thinking skills test for the experimental group (E_G) and the control group (C_G) are shown in table 2.

Table 2. Calculation results of n-gain critical thinking ability

Group	Pretest	Posttest	G	Category
Experiment (E_G)	10.91	40.14	0.71	High

Control (C_G)	10.65	31.53	0.51	Medium

Based on table 2, it shows that students in the experimental group who use MLM-STEM in learning have a higher increase in critical thinking skills, namely with a value of <g> 0.71 and are in the "High" category compared to the control group who use electronic textbooks in learning with value <g> 0.51 and categorized as "Medium". These results are in line with previous research, namely the use of electronic learning modules with a STEM approach to improve student learning outcomes and critical thinking skills (Puspitasari, 2019; Conradty, Sotiriu and Bogner, 2020; Izzah, et.al., 2021).

According to Ennis (2011), critical thinking skills consist of five aspects, namely basic clarification, basic support, inference, further clarification, and strategies and tactics. Each group has a different average <g> increase in each critical thinking indicator. The average value of normalized gain for each aspect of critical thinking skills in the experimental group and the control group is shown in table 3.

Table 3. Improved aspects of critical thinking skills

Indicator	Experiment Group		Control Group	
	g	Category	g	Category
elementary clarification	0.65	Medium	0.48	Medium
basic support	0.80	High	0.51	Medium
Inference	0.59	Medium	0.36	Medium
advanced clarification	0.70	High	0.45	Medium
strategies and tactics	0.91	High	0.89	High

In table 3 it can be seen that students who use MLM-STEM experience an average increase in critical thinking skills in every aspect compared to students who use electronic textbooks. Based on table 3, the strategy and tactics indicator obtained the highest increase in score compared to other indicators both in the experimental group with a <g> value of 0.91 and in the control group with a <g> value of 0.89. Meanwhile, the inference indicator experienced the lowest increase compared to other indicators, namely 0.59 in the experimental group and 0.36 in the control group.

To find out whether there is a significant difference between the increase in critical thinking skills in the experimental group and the control group, prerequisite tests are carried out, namely the normality test and homogeneity test. Test the normality of increasing critical thinking skills by using the IBM SPSS Statistics 26 program with the Kolmogorov-Smirnov method. The normality test results obtained a significance value (sig) in the control group of 0.159 and in the experimental group of 0.200. This result means that the significance value of the control class and the experimental class is more than 0.05 (sig. > 0.05), which means that the <g> increase data for each group is normally distributed.

Homogeneity test was carried out to find out whether the data in the experimental group and control group were homogeneous or not. Homogeneity testing in this study used the Levene test method. The homogeneity test of increasing <g> critical thinking skills was carried out using the IBM SPSS Statistics 26 program. The homogeneity test results obtained that the significance value (sig) in the data <g> the control group and the

experimental group was 0.258. The significance value is more than 0.05 (sig > 0.05), which means that the control class and experimental class data are homogeneous.

The t' test was carried out to find out the significant difference between the average increase in the critical thinking skills of the experimental group students who used MLM-STEM in learning and the control class which only had electronic books. The t-test was carried out using the IBM SPSS Statistics 26 program. The t-test results for the experimental group and control group data showed that the significance value (sig) of the data for improving critical thinking skills was 0.00. The significance value is lower than 0.05. This means that there is a significant difference between the data on increasing <g> critical thinking skills in the experimental group using MLM-STEM and the control group using electronic textbooks.

From the t test it can be seen that there is a significant difference between the increase in critical thinking skills of the experimental group and the control group. Then it is necessary to measure the magnitude of the difference in the increase in critical thinking skills between the experimental group and the control group to see the effectiveness of MLM-STEM in improving students' critical thinking skills. The magnitude of the difference in the increase in critical thinking skills between the group using MLM-STEM (M_E) and the group using electronic textbooks (M_C) was carried out by an effect size test. The results of the effect size test are shown in table 4.

Table 4. Result of effect size test data on increasing critical thinking ability

M_E	M_C	SD_E	SD_C	SD_{Pooled}	d	Category
0,71	0,51	0,12	0,13	0,12	1,64	High

In table 4 it is known that Cohen's d value is 1.64 which is included in the high category. This means that the use of MLM-STEM in learning is more effective with a high category for improving critical thinking skills compared to electronic textbooks. In table 4 it is known that the Cohen's d value is 1.64 which is included in the high category. This means that the use of MLM-STEM in learning is more effective with a high category to improve critical thinking skills compared to electronic textbooks. This is because MLM-STEM materials on temperature and heat contain images, animations, and simulations that can help students to learn independently and improve students' critical thinking skills.

Based on the results of statistical and non-statistical analysis, it was shown that students in the experimental group who used MLM-STEM in learning had a higher increase in critical thinking skills compared to the control group who used electronic textbooks in learning. In line with research conducted by Khalil and Osman (2017), modules that are integrated with the STEM approach can train students in 21st century skills, such as critical thinking and creative thinking. In addition, Mustafa, Arsyad and Helmi (2020) found that the use of STEM-based physics modules in learning can improve students' critical thinking skills more than using the usual learning modules provided in schools.

According to constructivism theory, the educational process must actively involve students to build knowledge through interactions with objects, phenomena, the environment, and experience (Suparlan, 2019; Suparno, 1997). In this theory, the learning process must be student-centered and the teacher acts as a facilitator. STEM-based

learning provides opportunities for students to build knowledge and improve understanding and ability to solve problems and think critically (Pangesti, et.eal., 2017; Pertiwi, 2017). So that teaching materials are needed that are relevant and integrate STEM learning such as modules. In addition, based on the theory of dual coding according to Paivio explains that learning based on a combination of verbal (text and sound) and visual (images, diagrams and animation) is more effective in mastering new material than just using one of them (Kanellopoulou, Kermanidis, & Giannakoulopoulos, 2019). Therefore, teaching materials that combine verbal and visual are better than teaching materials that only use verbal or visual.

Multimedia Learning Modules (MLM) are digital learning modules connected to multimedia in the form of text, images, videos, animations and simulations presented in various forms of representation. This has a positive impact in the form of conveying a lot of information to users so that learning activities become more effective, increasing student understanding and motivation. These results are also in line with previous research (Khalil & Osman 2017; Mustafa, Arsyad & Helmi, 2020; Agustina, Akhdinirwanto, & Fatmaryanti, 2021; Kurniawati, Andra, & District, 2021) which explains that electronic physics modules can improve critical thinking skills, creative thinking skills, and students' cognitive outcomes are more effective than using regular learning modules. The use of MLM-STEM is more effective in increasing critical thinking skills because MLM-STEM has learning activities, sample questions, and assignments that train critical thinking skills. In addition, MLM-STEM contains videos, animations and simulations that can improve students' understanding of concepts (Sujanem, 2012; Kurniawati & Nita, 2018). MLM-STEM which contains simulations and navigation that can be run and controlled by the user can facilitate interactive and dynamic students, making it easier to transfer information to students and add insight and domain knowledge to students.

Students' Perceptions

Analysis of students' perceptions of MLM based on the STEM approach was carried out to find out students' perceptions of the learning that has been done using this module. Students' perceptions of the use of MLM-STEM were obtained by distributing questionnaires to students who had used MLM-STEM in the learning process. The results of students' perceptions of MLM-STEM are shown in Figure 1.

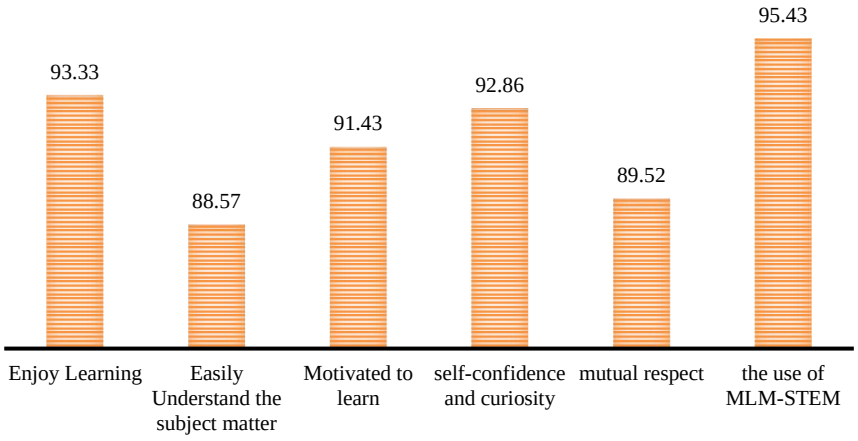

Figure 1. Students' perceptions result

In Figure 1, it can be seen that every aspect of student perception is in the high category according to the interpretation presented by Sugiyono (2016). The results of the students' perceptions of the experimental group towards MLM-STEM, it is known that as many as 93.33% of students stated that they enjoyed the learning process using MLM-STEM. In addition, 88.57% of students stated that MLM-STEM helped in understanding the material being taught, and 91.43% revealed that using MLM-STEM further increased their learning motivation compared to textbooks. Then 92.85% of students felt more confident and curious about the material being studied using MLM-STEM, and 95.43% of students said that using MLM-STEM was easier and had a positive impact on learning. So it can be concluded that students gave a positive response to the use of MLM based on the STEM approach on temperature and heat during learning.

In addition, STEM-based MLM can be well received by students during learning. This is in line with the results of interviews with students after learning, where students feel helped by the existence of STEM-based MLM which was developed because it contains various media such as images, videos and animations so that it is easier to understand the material. Students who use MLM during physics lessons feel that learning is more effective and helps students understand the physics concepts being taught, and MLM is very easy to use (Darma, Setyadi, Wilujeng, Jumadi, & Kuswanto, 2019). Students prefer MLM because they can better visualize the concepts being taught and the ease of accessing MLM independently (Sadagdiani, 2012).

▪ CONCLUSION

Based on the results and discussion regarding the impact of using MLM-STEM on learning temperature and heat material which is accessed via mobile phones and PCs to train students' critical thinking skills in class XI SMA Muhammadiyah 1 Klaten, it can be seen that: (1) improvement of critical thinking skills in the experimental class in the high category, while in the control class it was in the moderate category, (2) the critical thinking skills of the experimental class students who used MLM-STEM were higher than the control class which used electronic textbooks, (3) there was a significant difference between the improvement of the experimental class' critical thinking skills and control class, and (4) students gave a positive response to the use of MLM-STEM in learning. So it can be concluded that MLM-STEM can be a solution for teaching materials that can train students' critical thinking skills.

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