

DEVELOPMENT OF SCIENCE EXPERIMENTAL VIDEO WITH STEM-CRITICAL THINKING ASPECT: MAKING THERMOMETER FOR MEASURING THE MODEL OF THE GREENHOUSE EFFECT ON GLOBAL WARMING TOPIC

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Abstract

This research was motivated by the results of observations through interviews with science subject teachers at SMP Negeri 7 Padang. From the observation, experimental activities in the classroom were rarely carried out due to time constraints, so the research aims to develop the science experimental video with STEM-critical thinking aspect: a thermometer for measuring the model of greenhouse effect on global warming topic. The type of research used is development research using the Plomp model which consists of 3 stages, namely preliminary research (initial investigation), prototyping stage (prototyping), and assessment phase (assessment stage). In this study, it was limited to the prototyping stage. The research instrument used was a questionnaire in the form of a validity and practicality sheet. The validity test was conducted on 3 expert validators and the practicality test was carried out to the seventh grade students of SMP Negeri 7 Padang. The results of the validity test in the form of a validity sheet were obtained at 0,91 with a very high validity category, while the practicality test carried out on students was found to be 93% with a very practical practicality category. Based on the data obtained, the science experimental video with STEM-critical thinking aspect: making thermometer for measuring the model of greenhouse effect on global warming topic is very valid and very practical.

Keywords: *Experimental Video, STEM Oriented, Critical Thinking, Global Warming*

Accepted: August 2022, Revised: October 2022, Published: February 2023

INTRODUCTION

Education has entered the 21st century where science and technology are developing rapidly. 21st century competencies are needed in education to improve literacy skills, knowledge, skills, attitudes and mastery of technology (Anggraeni & Sole, 2018). Natural science is the scientific basis of technology, while technology is the application in everyday life of natural science. Science is a branch of science that deals with natural events and phenomena (Rahayu et al., 2012). The problem that often occurs in education is the weakness of the learning process. Lack of students' skills in being positive about science learning material because it is considered difficult. Science achievement based on the Trends in Mathematics and Science Study (TIMSS) survey by The International Association for the Evaluation of Educational Achievement (IEA) in 2015, Indonesia was ranked 44th out of 47 participating countries with below average scores in ability science (Nugraha et al., 2017). The results of this survey show that science has become a difficult lesson for students in Indonesia. The main purpose of science education is to help students develop higher-order thinking skills as a provision to face challenges in everyday life, one of the higher-order thinking skills is critical thinking (Saido et al., 2015).

The 2013 curriculum is one of the government programs in the field of education with the aim of being able to face the challenges that will be faced by the Indonesian nation in the future. The 2013 curriculum emphasizes the educational process that includes the cognitive, affective, and psychomotor domains (Setiadi, 2016). This is what makes students must be able to change the concept of thinking, through thinking more deeply, namely by thinking critically, they can build and gain better knowledge. Critical thinking is thinking by deciding a reasonable decision so as to achieve a learning goal (Saputri et al., 2020). In the period before and the occurrence of Covid-19, the 2013 curriculum was used in the learning process. During the Covid-19 pandemic Kepmendikbudristek No. 56 of 2022 Guidelines for Implementing Curriculum in the context of Learning Recovery, namely the independent curriculum, which aims to complete the previous curriculum. The independent learning curriculum makes students free to gain knowledge without any pressure (Saleh, 2020). Through the STEM approach students can express opinions and innovate so that students can find solutions and solve problems in the real world (Rahmatina et al., 2020).

The use of the right teaching material media can be the key to success in learning, one of the popular communication and information media and is able to reach the wider community, namely video media. Video as an electronic medium is able to combine audio and visual technology simultaneously which produces a dynamic and interesting show, so that students can remember the learning message (Yuanta, 2020). In science learning, there are many experimental activities, with experimental videos being able to overcome the limitations of laboratory equipment. STEM-oriented experimental video (Science, Technology, Engineering, and Mathematics) is one of the learning media that makes critical thinking skills can be achieved (Agustina et al., 2020). The soul of critical thinking can grow through an integrated learning approach known as STEM (Fathoni et al., 2020). The STEM learning approach provides opportunities for teachers to show students that in everyday life there are concepts, principles, science, technology, engineering, and mathematics that are used in an integrated or integrated manner.

Based on the results of interviews and observations conducted by researchers with science subject teachers through questionnaires and research observations, it can be seen that the school implements the 2013 curriculum, the science learning method carried out by science teachers in the classroom in the form of lectures and class discussions, this has not fully made the participants' critical thinking skills learn is achieved. During the COVID-19 period, the teaching and learning process was carried out in hybrid learning. In offline learning, the time provided by the school is very limited, so the teacher is not optimal in explaining the material. The use of this learning method does not maximize critical thinking skills that can connect real-world knowledge with classroom learning through an integrated STEM approach. During the learning process, especially on Global Warming material, the STEM-Critical Thinking-oriented experimental video has never been applied to learning. Learning using videos can help improve students' understanding in science learning, whether studied at home or at school. For this reason, researchers conducted research on the development of the science experimental video with STEM-critical thinking aspect: making thermometer for measuring the model of the greenhouse effect on global warming topic.

RESEARCH METHODS

Methods and Research Design

This research was conducted in the Department of Science Education Universitas Negeri Padang and SMP Negeri 7 Padang. The study used the Plomp model, which was developed by Tjeerd Plomp which consists of 3 stages, namely preliminary research, prototype formation (prototyping stage) and assessment phase (Plomp, 2013). Initial design (preliminary research), at this stage consists of several stages, namely: needs analysis which aims to analyze what is needed in developing videos, curriculum analysis, concept analysis and student analysis. The next stage is the formation of a prototype, for this research it begins with making prototype I of a science experiment video with aspects of STEM critical thinking: making a thermometer to measure the model of the greenhouse effect on the topic of global warming. Furthermore, at the stage of prototype II (revised result of the prototype I), a self-evaluation was carried out on prototype I. At the stage of prototype III (revised result of the prototype II), the expert reviews were carried out, which were carried out by 3 expert validators. Prototype IV (revised result of the prototype III) is carried out in a one-to-one evaluation stage. At this stage, practicality test was carried out to 3 students. Next, the formation of the prototype IV by conducting a small group evaluation consisted of 6 students, which included the practicality test of the final revision of the science experimental video. This research was limited to the prototyping stage. The assessment phase of the research will be done as the next project to investigate the effect of the video into the students' learning outcomes in global warming topic.

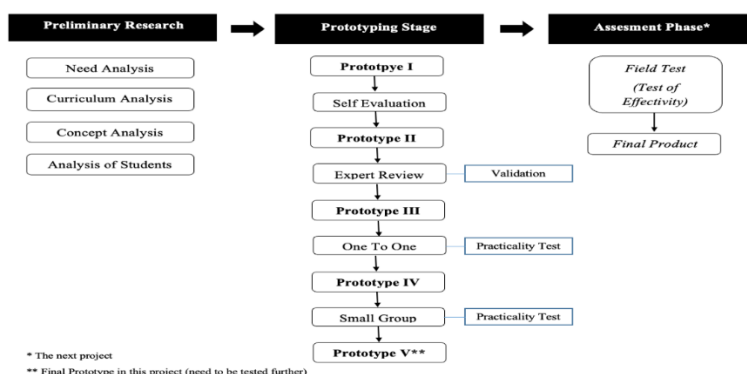


Figure 1. The Process of the Development of the Video Prototypes (adapted from Plomp, 2013)

Instruments and Data Collection

The instrument used in this research were validity and practicality questionnaire sheets. The validity sheet used to evaluate the science experimental video with STEM-critical thinking aspect: making thermometer for measuring the model of the greenhouse effect on global warming topic, while the practical sheet is to assess the use of the video. The validity instrument has several assessment aspects, namely: (1) Instructions are easy to understand, (2) Easy to understand language, (3) Statement of the Clarity of Message component (clarity of the message) according to the indicator, (4) Statement of the Stand Alone component according to the indicator, (5) Statement of the User Friendly component (friendly/familiar to the wearer) according to the indicator, (6) Statement of the content representation component according to indicators, (7) indicator statements of visualization components according to indicators, (8) statements of components can be used classically/individually according to indicators, (9) statements of critical thinking components according to indicators, (10) statements of STEM components according to indicators. Practicality instruments have several assessment aspects, namely: (1) Ease of use, (2) Attractive, (3) Benefit of use. This assessment questionnaire sheet consists of 4 points with different levels of assessment, 1 for the very low category, 2 for the low category, 3 for the high category and 4 for the very high category.

Data Analysis Technique

To determine the level of validity of the video, validation was carried out and then the data was obtained using the Kappa Cohen formula (Boslaugh & Watters, 2008). To determine the validity of the resulting product, the formula used is as follows.

$$\text{Moment kappa } (k) = \frac{Po - Pe}{1 - Pe}$$

Description:

Po = realized proportion

Pe = unrealized proportion

Table 1. The Category of the Validity Based on Moment Kappa Value

| Interval | Category |
|-----------|-----------|
| 0,81-1,00 | Very High |
| 0,61-0,80 | High |
| 0,41-0,60 | Currently |
| 0,21-0,40 | Low |
| 0,01-0,20 | Very Low |
| 0,00 | Invalid |

Meanwhile, to determine the level of practicality of the resulting product, the formula used is as follows (Purwanto, 2012).

$$\text{Practicality Level} = \frac{\text{Score Obtained}}{\text{Highest Score}} \times 100 \%$$

Table 2. The Category of The Practicality Level

| Interval | Category |
|----------|------------------|
| 86%-100% | Very Practical |
| 76%-85% | Practical |
| 60%-75% | Quite Practical |
| ≤ 54% | Very Impractical |

RESEARCH RESULTS AND DISCUSSION

Results

1. Preliminary research

The initial investigation was carried out in 4 stages: (1) Needs analysis was the process of determining problems in the field, at this stage observations and interviews were carried out, interviews were conducted

with science subject teachers. The purpose of the interview was to find out what kind of problems occurred during the learning process, it was found that the implementation of practical activities in the form of experiments is rarely carried out in schools because of time constraints, (2) Curriculum analysis was to determine basic competencies and core competencies in accordance with the curriculum being studied, (3) Concept analysis, is to determine the concepts needed during learning, (4) Analysis of students was to identify the character of students during the learning process, conducted interviews and distributing questionnaires. In addition, learning videos are one of the important aspects in learning because based on literature review, learning videos can increase student motivation (Agustini & Ngarti, 2020) and improve learning outcomes (Busyaeri, et al., 2016).

2. Prototyping Stage

There are 5 stages of prototype formation: prototype I, prototype II, prototype III, prototype IV and prototype V. At the prototype stage I, the initial design was carried out on a STEM-oriented experimental video and critical thinking: making thermometer for measuring the model of the greenhouse effect on global warming topic. This initial design contains the title of the experiment to be carried out, there is an opening, introduction, preparation of tools and materials, activities to conduct experiments, and closing. At the prototype stage II, a self-evaluation was carried out, this stage aimed to assess the completeness and self-error in the developed video before proceeding to the validation stage. The next stage is the formation of prototype III by conducting an expert assessment (expert review), expert assessment is carried out by 3 expert validators.

Table 3. The Product Suggestion by Expert Validator

| Comment | Revision |
|---|---|
| Add the STEM approach chart | Added STEM approximation chart |
| Write subtitles when explaining the material | Improvements have been made by adding additional subtitles when explaining the material |
| The changing color in subtitle when answering the critical thinking questions | The answer to the thinking question has been fixed with a color change |

The next stage is the formation of prototype IV, at this stage a one-to-one evaluation is carried out by providing practicality assessment questionnaires to students with different abilities (high, medium, low). The last stage in the formation of the prototype is a small group evaluation, this stage produces a prototype V of the final product of making a thermometer to measure the model of the greenhouse effect on global warming material, this stage is tested for the level of practicality to 6 students who are taken randomly.

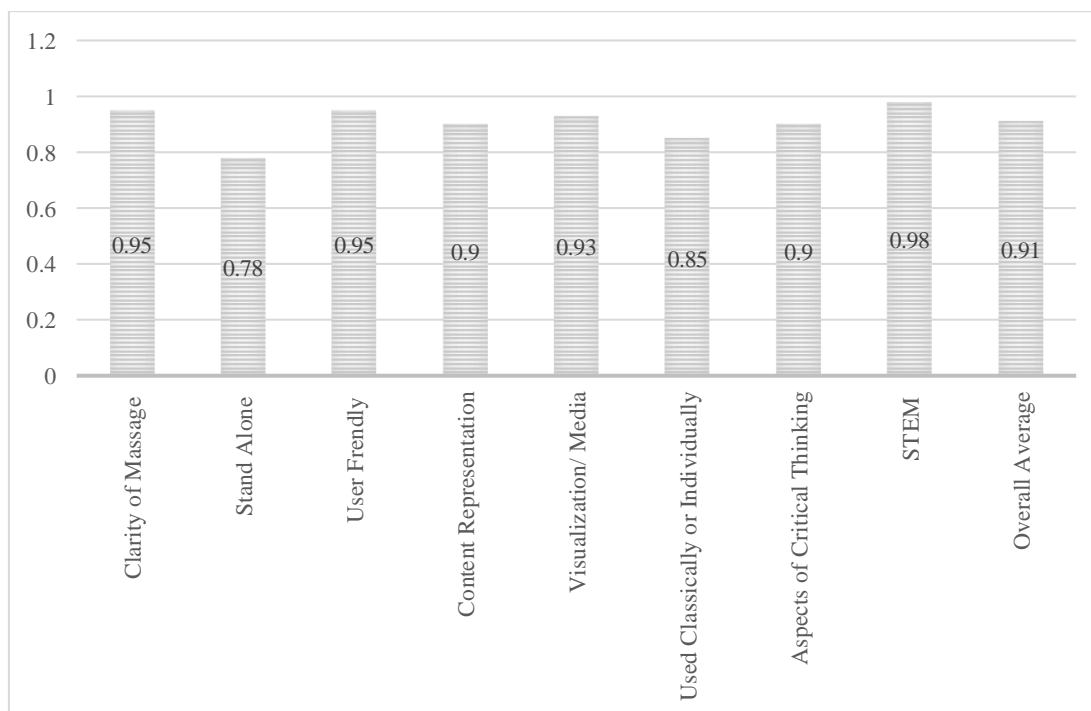


Figure 2. The Validation Result of the Science Experimental Video

The results of the practicality test of the experimental video from one-to-one evaluation can be seen in Figure 3.

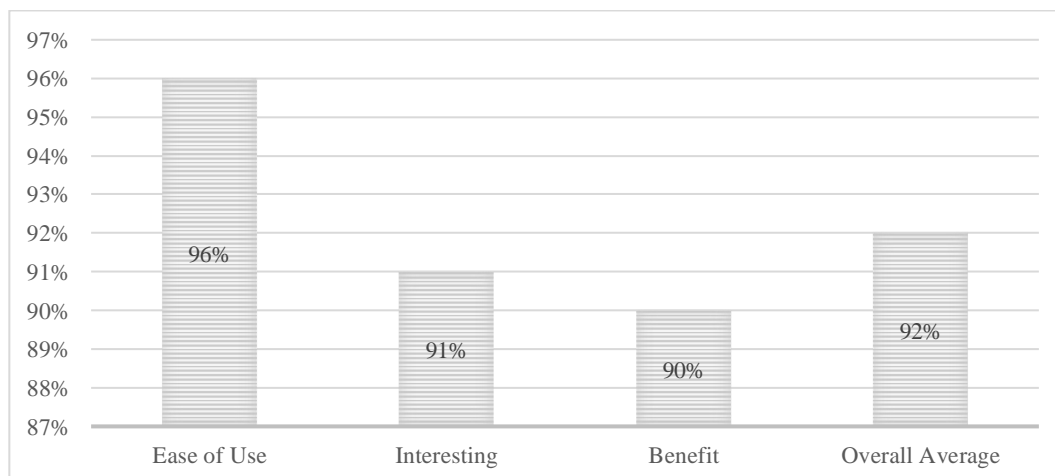


Figure 3. Practicality Data on One-to-One Evaluation Stage of the Science Experimental Video

The results of the practicality test of the experimental video from the small group evaluation can be seen in Figure 4.

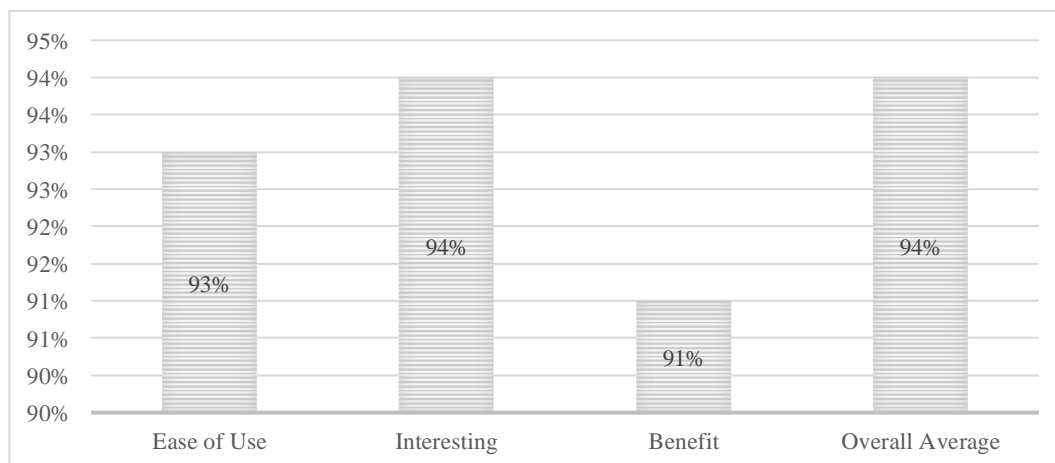


Figure 4. Practicality Data Analysis of Small Group Evaluation of the Science Experimental Video

Through the assessment of the validity and practicality data analysis, it was found that the results of validity and practicality were very valid and very practical to use. The results can be seen in Table 4.

Table 4. Average Result of Overall Assessment Data

| Data analysis | Overall Average | Category |
|-------------------------------|-----------------|----------------|
| Validity | 0.91 | Very Valid |
| <i>One To One Evaluation</i> | 92% | Very Practical |
| <i>Small Group Evaluation</i> | 94% | Very Practical |

Experimental video of making thermometers to measure the model of the greenhouse effect on global warming materials developed using a STEM approach and critical thinking oriented. In the video that was developed there are critical thinking questions that aim to train students' critical thinking skills, critical thinking questions are made based on ennis 1996 indicators, namely: giving simple explanations, building basic skills, concluding, giving further explanations, strategies and tactics. Critical thinking is thinking that focuses on decision making that will be carried out logically and reflectively, critical thinking skills consist of two abilities, namely critical thinking abilities and critical thinking dispositions (Ennis, 2011). From this definition, it can be found that critical thinking ability is "decision making that will be trusted", while critical thinking

disposition is "decision making that will be carried out". Based on this explanation, it can be concluded that critical thinking ability is the ability to make decisions that are believed to be directed, precise and valid. STEM is an approach that integrates disciplines of science, technology, contextual problem-based techniques, STEM education leads to reasoning skills, critical thinking, logical and systematic to be able to face global competition where there are many roles of science, technology, engineering and mathematics (Anita et al., 2021). The STEM approach involves students actively in exploring and understanding the meaning of the lessons they face. The development of a science experimental video on making a thermometer to measure the model of the model of the greenhouse effect of this experiment has the main components, namely:

1. The opening of a science experiment video on making thermometers to measure the model of the greenhouse effect



(a) Opening



(b) Title

2. Contents of the science experiment video on making thermometers to measure the model of the greenhouse effect



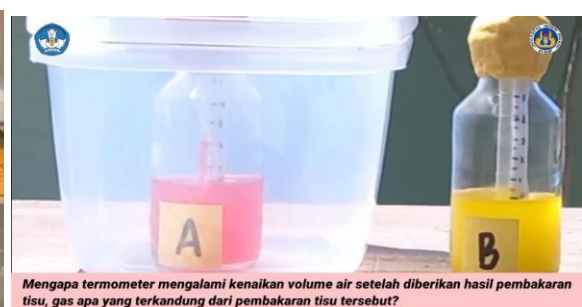
(a) STEM Approach



(b) Theory

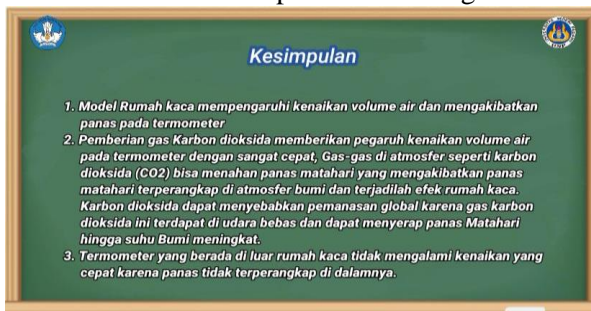


(c) Tools and Materials

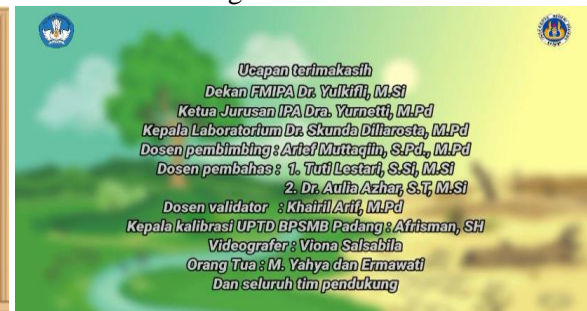


(d) Experimental Activities

3. Video cover of science experiment making thermometer to measure the greenhouse effect



(a) Conclusion



(b) Thank you note

Discussion

1. Validity test of the science experimental video with STEM-critical thinking aspect: making thermometer for measuring the greenhouse effect on global warming topic

There are several aspects of validity test that have been evaluated by the expert validators. For the clarity of message aspect, the average of Kappa Moment is 0.95 with a very high category. This shows that the developed video has very high clarity, both in terms of the narrator's voice, the narrator's articulation, the text provided and the instructions for carrying out the experiment. Learning media must have clear messages that can convey strategies to students, be it people, tools or materials (Weda, 2013). The clarity of this message is to make it easier for students to understand the material and improve thinking skills in the learning process (Fahrurrozi et al., 2017). In line with this theory, video media that have clear messages are expected to increase students' understanding of critical thinking skills. The clarity of the message to the video through the STEM approach can make students have a broad view and can develop critical power and form logical thinking in its application to various sciences (Afriana et al., 2016). It can be concluded that the video media on the aspect of message clarity through the STEM approach is able to train students' critical thinking skills.

For standalone aspect, the average Kappa Moment of this aspect is 0.78 in the high category. It illustrates that the experimental video developed contains an introduction to material that is in accordance with the experimental objectives and this experimental video can be used without assistance from other sources because the video includes the experimental objectives to be achieved. Video in learning has the advantage of helping students understand the subject matter without being bound by other teaching materials, the use of video learning media is easier to remember and understand, because it relies on the senses of sight and hearing (Purwati, 2015).

For user friendly aspect, the average of Kappa Moment is 0.95 with a very high category. This shows that the experimental video developed is very easy to use because it uses words that are in accordance with the understanding of students and uses communicative language. Video that is familiar to the user is a video that is easy to use, video media is more effectively applied during the learning process, learning using media in the form of video leads to the concept of thinking, therefore the thinking process will be further improved through video media (Merkt et al., 2011).

For content representation aspect, the average of Kappa Moment is 0.90 with a very high category. It shows that the video developed is in accordance with the experimental objectives formulated, the order of delivery of the material in the video is logical and coherent, the material presented is appropriate, both in terms of adequacy and depth and the description of the material presented is relevant to the learning needs of students. The video in its manufacture must include the content of the material, so that in one video there are already details of the material that can be studied by students, the material in the video must be representative or relevant to the needs of students (Sofiyullah, 2018).

For visualization/ media aspect, the average of Kappa Moment is 0.93 with a very high category. It illustrates that this experimental video is interesting, entertaining, educating and stimulating students to think critically, the animation shown adds interest and clarity to the video, and the video quality is good with high resolution. Visualization with media must be presented appropriately and relevantly to provide a complete understanding to students (Prabawa & Restami, 2020).

For the user aspect, the average of Kappa Moment is 0.85 with a very high category. It shows that this experimental video can be used by students individually or in groups. Video is an appropriate medium for sharing knowledge, the use of media in the form of videos can be used in classes, small groups, even individuals, videos with a duration of only a few minutes are able to provide more access for teachers and can direct learning directly to the needs of students, besides that video is able to train students' thinking skills through the shows displayed (Busyaeri et al., 2016).

For the critical thinking aspect, the average of Kappa Moment is 0.90 with a very high category. It can be known that in the video there are already critical thinking aspects with components, providing simple explanations, building basic skills, concluding, providing further explanations, setting strategies and tactics. One of the learning media that can involve students in critical thinking and building understanding is science learning videos. Learning videos are student-oriented learning media, where students are invited to think about problems given by the teacher so that students are able to examine these problems and produce scientific concepts, learning should be able to develop critical thinking in students,

For STEM aspect, the average of Kappa Moment is 0.98 with a very high category. It illustrates that there is already a STEM approach to video consisting of components, Science, Technology, Engineering and Mathematics. The learning process using the STEM approach makes students able to collect, analyze, solve problems, and understand the relationship between one problem and another so that they get an experience in

learning (Nessa et al., 2017). Learning videos using a STEM-based approach can be applied to the 2013 curriculum and meet the skills demands of the 21st century (Nurjaman, 2018).

2. *Practicality test of the science experimental video with STEM-critical thinking aspect: making thermometer for measuring the greenhouse effect on global warming topic*

One-to-one evaluation was carried out to three students with different level of ability (high, medium, low). The results of the experimental video assessment based on the student response questionnaire in the one-to-one evaluation can be seen in Figure 3, the practicality result is 92% with a very practical category (overall). The development of science experiment videos at this stage showed very practical, so that there was no revision required to re-take or edit the videos. The results of the validity of expert judgment and the practicality of one-on-one evaluation generating prototype IV.

Small group evaluation carried out also to six students with different level of ability (high, medium, low). The results of the practicality test of the experimental video assessment data analysis based on the student response questionnaire in the small group evaluation is 94% with a very practical category (Figure 4). The development of science experiment videos at this stage obtained very practical results so that there were no improvements that required. The results of the formation on the validity of expert judgments and the practicality of small group evaluations generating prototype V.

Based on the practical results of one-to-one evaluation and the results of the small group evaluation, the data show that the video is very practical to use both in terms of ease of use, interesting, and the benefits of use. From the aspects of ease of use, science experiment videos have a very practical category, this shows that the science experiment videos that have been developed already have an easy-to-understand language, simple videos in operation, easy-to-access videos so that they can be used repeatedly, and videos can be used anywhere. Learning media using video can be played by students anywhere and anytime, not limited by time, so it can be used easily by students, through learning video media can improve students' thinking skills (Nugraha, 2021).

From an interesting aspect, the science experiment videos have a very practical category which shows that the science experiment videos that have been developed have been presented with an attractive appearance, there are animations in the experimental videos that are relevant to the material, and the animations displayed add to the characteristics and clarity of the experimental videos. Thinking skills of students can be trained through learning videos because videos are good for conveying information, learning using videos will attract more students' interest in learning (Clossen, 2014). Video media is interesting to apply in the learning process because there is a STEM (Science, Technology, Engineering, and Mathematics) approach. The STEM approach can increase learning activities and train students in mastering concepts (Astuti et al., 2019)

Based on the aspects of the benefits of using science experiment videos have a very practical category which shows that the science experimental videos that have been developed can help students understand science materials and concepts, especially Global Warming material, can make students understand that the greenhouse effect is the cause of Global Warming, experimental videos can eliminate boredom during the science learning process on Global Warming material, experimental videos can increase students' curiosity, experimental videos can increase students' learning enthusiasm, and experimental videos make the learning process more fun. Learning that contains experiments by utilizing a video as a learning medium before the practicum is carried out, makes students' practicum activities more focused (Dimiyati, 2006).

From the data obtained, it can be found that the science experiment videos, the prototype V, is very practical to be used by students both in terms of ease of use, attractiveness, and benefits. This experimental video is very practical to be used and can train critical thinking skills because there are critical thinking questions in it. The use of learning media in the form of videos makes it easier for students to understand the material so that learning videos can improve critical thinking skills (Septianty et al., 2018). In addition, this experimental video contains a STEM (Science, Technology, Engineering and Mathematics) approach, the use of the STEM approach in learning provides opportunities for students those concepts and principles from science, technology, engineering, and mathematics are used in an integrated manner.

CONCLUSIONS

The science experimental video with STEM-critical thinking aspect: making thermometer for measuring the model of the greenhouse effect on global warming topic was developed using the Plomp model, the stages carried out in this study started from the preliminary research and prototyping stage. Based on the data obtained, it can be concluded that the video has a very high validity value and very practical. It shows that the video has fulfilled several aspects to be used by the teacher and learner. However, in order to be used in

the larger scale, the efectifity test must be implemented to investigate the effectivity of the video toward the students' learning outcomes in the global warming effect.

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