STEM-Based Interactive Learning Media to Improve Student's Critical Thinking Skills on Number System Materials

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***Abstract*— The goal of the study is to produce STEM-based interactive learning media that can enhance student's critical thinking skills on number system materials. The research method used is the method of development or Research and Development (R&D) with addie design (Analysis, Design, Development, Implementation, Evaluation). The instruments used in the study consisted of expert media validation sheets, materials, critical thinking tests, and student questionnaire sheets to determine student's responses to interactive learning media. To find out the practicality and effectiveness of interactive learning media in improving the ability of critical thinking, a double choice test is grounded. The results show that 1) the results of media and material validation by 2 experts were 86% (very high) and the results of validation of tests of learning results by experts and teachers were 90.67% (very high), 2) interactive learning media can improve student's critical thinking skills which is shown with average pretest results by 54.7%, average post-test by 91.9% and average %N-Gain by 68.48% (height), 3) Student's responses to the use of interactive learning media earned 84% (excellent) grades.**

Keywords*— *Critical Thinking, Interactive Learning Media, STEM

I. INTRODUCTION

In the 21st century, everyone is required to master a variety of skills; as a result, education is expected to prepare students to master these various skills in order to become successful in life. Some of the skills needed in the 21st century are still related to the four pillars of life that include learning to know, learning to do, learning to be, and learning to live together. The four principles of each contains specific skills that need to be empowered in the learning process, such as critical thinking skills, problem solving, metacognition, communication skills, collaboration, innovation and creation, information literacy, and various other skills.

Critical thinking is a thought process that boils down to drawing conclusions about what we should believe and what actions we will take. It is not only to look for the answers, but also to question the answers as the main thing, facts, or information that exist [1] . Critical thinking skills have become a very noticeable thing in student's thinking development. Some developed countries have developed educational systems that are able to hone and train student's critical thinking skills in order to develop properly [2] .

In this era of globalization, all information gains easily to each student. The easy entry of all information makes students have to think critically to filter the information. The reason is because not everything in the global information is good, but there is also a bad nature. They must be able to distinguish between good and bad reason, and distinguish truth from lies [3].

However, in reality, the critical thinking ability of Indonesian students is still relatively low. This is known based on the results of trends in International Mathematics and Science Study (TIMSS), the science scores of Indonesian students in 1999, 2013, 2007, 2011, and 2015 were always below the international average. TIMSS problems using cognitive domains include knowledge, reasoning, and applying and using critical thinking indicators including providing basic explanations, applications, providing further explanations, concluding and regulating strategies and tactics [4]. To improve student's critical thinking skills, learning supports are needed, one of them is learning media.

Media is a messenger that comes from the source of the message (which can be a person or object) to the recipient of the message. Media serves to convey learning messages so that it can stimulate the minds, feelings, attention, and interests of students that leads to the learning process which is called the learning media. Learning media is a tool in the learning process both inside and outside the classroom, further explained that the learning media is a component of learning resources or physical vehicles that contain instructional materials in the student environment that can stimulate students to learn [5].

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The use of learning media will greatly help the effectiveness of the learning process as well as the delivery of messages and lesson content so that it can help students improve their understanding and thinking skills because it presents information in an interesting and reliable manner. One of the learning media is computer media. The use of computer is to present and combine text, sound, images, animation and video with tools and connections so that users can interact, work, and communicate; this is known as interactive learning media. From this usage it can be seen the importance of media transformation from non-interactive to interactive tool so that learners are more excited and interested despite of learning from home.

The use of interactive learning media in learning will increase efficiency, motivation, as well as facilitate active learning, experimental learning, it is consistent with student-centred learning, and it also guides learners to learn better [6]. The memory of people who read alone is ± 1%. This memory can be increased to 25%-30% through television, while the use of hypermedia can improve memory by as much as 60% [7]–[9] .

Another advantage of interactive media is that users can be given the ability to control existing elements. The varied display and controller elements that present in interactive multimedia software allow users to be more easily choose the desired scene. The use of interactive media in IPA learning is able to improve student's critical thinking skills, increase student's learning motivation and challenged students to have self-study [10]. Learning media can increase the effectiveness of learning science, and able to improve academic achievement and scientific attitudes of students [11]. Furthermore, the use of interactive multimedia in learning affects the mastery of student's critical thinking concepts and skills [12].

Currently, teachers have used information and communication technology by utilizing software in learning; software used are including Microsoft Office (Microsoft word, Microsoft excel and Microsoft PowerPoint), Macromedia flash application software, and learning software mass produced by companies. However, the use of computer software in mathematics learning is only used as a medium of learning presentations conducted by teachers, only a few teachers who utilize the interactive media to students in mathematic learning [13]. In addition to the utilization of interactive media, mathematics learning today needs to involve the use of technology and precision in designing mathematics learning which is known as Science, Technology, Engineering, and Mathematics (STEM) based learning.

STEM is an approach in the development of the world of education. STEM education is formed based on the fusion of several disciplines into a whole new form of approach. Disciplines that are components of stem approaches are science, technology, engines, and mathematics. The integration of several disciplines in one unit is expected to produce competent and qualified graduates not only in terms of mastery of concepts but also in applying them to life.

The STEM approach is a blend of science, technology, engine, and mathematics into one curriculum as a whole [14]. The STEM curriculum involves "4C" of 21st century skills, which includes creativity, critical thinking, collaboration, and communication [15].

In general, the application of STEM in learning can encourage learners to design, develop and utilize technology, hone cognitive, manipulate and affect, and apply knowledge [16]. STEM-based learning can train students in applying their knowledge on problem solving related to number systems by utilizing technology. Similarly, learning about number systems in class X of vocational school can be done through STEM approaches, because the approach needed in learning on number systems is a learning approach that can encourage learners to be able to solve problems about converting number systems by applying knowledge and utilizing technology.

Based on the description above, the authors are interested in conducting research with the title "STEM-Based Interactive Learning Media to Improve Student's Critical Thinking Skills on Number System Materials"

II. METHOD

This research uses Research and Development methods with ADDIE (Analysis, Design, Development, Implementation, Evaluation) design [17]. Research methods with ADDIE design have been widely carried out, especially in research development of learning media. In this research, the product developed is STEM-based interactive learning media.

The description of ADDIE 's STEM design-based interactive learning media research and development methods is as follows:

A. Analysis

- Potential and Problems

Research is conducted based on potential and problems, then potential and problems can be known by collecting data through preliminary studies with both literature studies and field studies through observation to several schools. This preliminary study aims to obtain the data and information required in the research. The stages of preliminary study are carried out as follows:

1) Analyse the content standards that include Core Competencies and Basic Competition of computer system subjects of class X of SMK to get an overview of basic competencies as well as indicators of competency achievement in computer system learning.

2) Analyse the subject matter of SMK computer system about number system material in the student book of class X on odd semester and analyse the number system material from other sources.

3) Conduct literature studies on interactive learning media and its development in computer system learning, with the aim of obtaining data and information about interactive learning media and the development of interactive learning media, and also the implementation of interactive media in computer system learning.

4) Conducting literature studies on STEM learning, which aims to get an explanation, overview, and development of STEM learning; the sources of this literature study are stem learning articles and journals.

5) Conduct a literature study on critical thinking skills, which aims to get an explanation and overview of student's

critical thinking skills; the sources of study are articles and educational journals.

6) Conduct direct observations and interviews with vocational computer teachers in Banjarmasin, to find out the learning process related to the standard content of the curriculum and the use of learning media.

- Data Collection

Data collection is a follow-up to the excavation of potential and problems that have been done before, based on potential problems that have been found, then efforts are made to overcome the potential and problems through a product. Research data collection is related to the development of STEM-based interactive learning media as an effort to improve the critical thinking skills of vocational students. The process of collecting data is carried out through literature studies in the form of books, articles, journals, and other relevant sources.

B. Design

Product design is the first step to produce a product, in this research the product is developed in the form of interactive multimedia based on STEM. In the process of designing STEM-based interactive learning media, several activities are carried out, they are:

- Formulation of indicators and objectives of learning cognitive aspects through a study of science, technology, design, and mathematics content on computer system of subject matter. These learning indicators and objectives are further used as a reference to develop computer materials in STEM-based interactive learning media.
- Analysing discourse on number system materials. Discourse analysis has been developed as part of the stages in the development of teaching materials and media. Discourse analysis is carried out at this media development step is aimed at obtaining clarity of structure and content from the text. Based on several studies that have been done, it is mentioned that the clarity, structure, and content of the text affect how readers read, understand, remember, and learn from the text.
- Creating a STEM-based interactive learning media flow chart. Material resulting from discourse analysis is poured into the storyboard. Nevertheless, to find out the relationship between the material and the components in the learning media, a flow chart is created that will describe the flow in interactive media about the interrelationship of one component to another component.
- Making material transformation in the form of presentation. The material resulting from discourse analysis is further transformed to the form of presentation material as the basic material in the creation of storyboards. The creation of material transformation in the form of presentation is done to make it easier to see the structure and presentation of the material that will be displayed in interactive media.
- Create a storyboard. Storyboarding is an important step in the development of interactive media. On the storyboard will be seen an overview of interactive media developed. This storyboard includes the design of learning media both in terms of subject matter content, interactive media principles, and multimedia components (animation, video, audio, text and images). Storyboards that have been created are validated by two experts to assess the clarity and depth of the material that will be presented in interactive learning media.

C. Development

At this stage of development, the steps include the creation of STEM-based interactive media, validation of STEM-based learning media design, and revision of STEM-based learning media design. Description of the three activities at the development stage as follows:

- Creating STEM-based interactive media

  The finished storyboard is created at a later design stage translated into the form of STEM-based interactive media. The components contained in interactive media are made to adapt to the images contained in the storyboard. The creation of STEM-based interactive learning media using the web that has been created will be validated by lecturers.

- Validation of STEM-Based Interactive Media Design

  The validation stage is an activity to assess the feasibility of STEM-based interactive media from the point of view of material experts, media experts, and teachers as implementers of learning. In validation, this design is still an assessment based on rational thinking, it is not field facts. STEM-based interactive media validation includes an assessment of media development principles, media components, STEM content in media, as well as media conformity with student's curriculum and cognitive aspects. Validation from an expert point of view is carried out by learning materials experts and expert lecturers in the field of computers related to STEM learning. In the implementation of validation, each expert lecturer becomes a validator to assess interactive learning media and the material from various aspects that are already available on the validation sheet. Validation from the point of view of the teacher as the implementer of learning is carried out by one vocational computer teacher. The teacher gives an assessment of the material from various aspects listed on the material validation sheet.

- Revision of STEM-based Interactive Media Design

  After the media is validated by experts and teachers from various aspects of assessment, information is obtained about the weaknesses and advantages of interactive media that have been developed. Suggestions and input provided by validators are further discussed with the guidance lecturer and improvements are made so that the interactive media developed has good quality so that it can help students in improving student's critical thinking skills.

D. Implementation

The implementation phase is implemented to test the effectiveness of learning using STEM-based interactive media on number system materials. At this stage, research is

designed with pre-experimental methods with pre-test and post-test design [15]. This design is used to see the differences in learning outcomes before and after the treatment is given. The design of the study only used one class as a class that was given the learning treatment using STEM-based interactive media. Pre-experimental methods with pre-test and post-test design are illustrated in Fig. 1.

Fig. 1. One Group Pretest-Posttest Design Experiment Method

Information:

O_1 = Pre-test

O_2 = Post-test

X = Treatment

Through the above experimental method, it will be found an overview of the effectiveness of learning using STEM-based interactive media to improve the ability of student's critical thinking in number system materials. Improved critical thinking skills can be seen from the pre-test and post-test grades obtained by the students. As for the effectiveness of learning using STEM-based interactive learning media to improve student's critical thinking skills can be seen from normalized gain values (N-gain).

E. Evaluation

The evaluation stage is the final stage of research and development implementation with ADDIE design. At this stage, a questionnaire is given to students to find out the student's responses regarding to the use of STEM-based interactive media on number system materials. The results of the student's responses are used as additional data to answer the formulation of problems and research questions asked. In addition, the results of the questionnaire are also used as the input on the improvement of interactive learning media that have been developed, and as the addition to the effectiveness score obtained from the implementation stage.

III. Results and Discussion

A. STEM-Based Interactive Learning Media Design

Product validation results by material experts is 86%. The score shows that interactive media in terms of material belongs to a very high category. Product validation results by media experts is 86%, the score shows that interactive learning media in terms of media belongs to a very high category. Furthermore, multimedia will be initiated based on advice and input from field practitioner validators.

Based on the results of validation of material experts, media experts and teachers as field practitioners, STEM-based interactive learning media developed falls into a very high category, and deserves to be used in learning. The application of STEM in learning can encourage learners to design, develop and utilize technology, hone cognitive, manipulate and affect, and apply knowledge [16]. STEM-based learning can train students in applying their knowledge on problem solving related to number systems by utilizing technology.

B. Effectiveness of STEM-Based Interactive Learning Media to Improve Critical Thinking

The implementation phase of interactive learning media is conducted to test the effectiveness of learning by using STEM-based interactive media to improve student's critical thinking skills on number system materials. At this stage, the design is pre-experimental method research with pre-test and post-test design. The results of pre-test and post-test of critical thinking ability in the matter of the number system can be seen in Fig. 2.

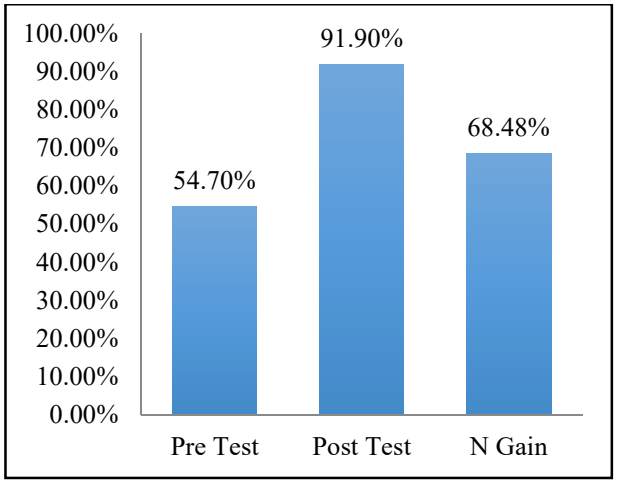

Fig. 2. Improved Student's Overall Critical Thinking Skills

Based on Fig. 2, the average pre-test obtained by all students is 54.70%, the average post-test obtained is 91.90%, and the average N-Gain obtained is 68.48%. The N-Gain score demonstrates that STEM-based interactive media can improve student's critical thinking skill, which is 68.48% (medium category). The results of this study are in line with research by [18] who states that the use of interactive multimedia is more effective in improving critical thinking skills than learning without interactive multimedia. Moreover, states that the use of interactive multimedia is proven to improve student's ability to draw conclusions and solve the problems [12]. The results of this study are also in line with the opinion of [19] who claimed that multimedia learning can create meaningful learning. Furthermore, explained that meaningful learning is learning that leads to deep understanding and is able to apply concepts to the real world [19]. When a student has a good understanding of concepts, this will make students have good critical thinking skills as well).

The effectiveness of STEM content in interactive media to improve critical thinking skills is analysed through pre-test and post-test results. The results of pre-test and post-test of critical thinking skills based on STEM content can be seen in Fig.. 3.

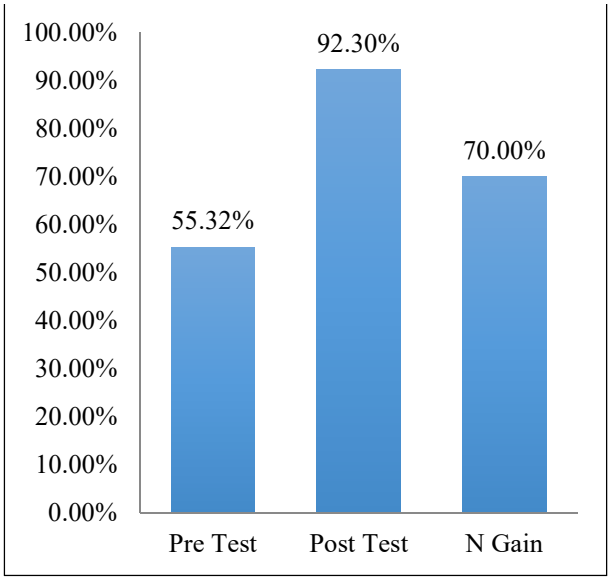

Fig. 3. Effectiveness of STEM Content on Interactive Multimedia Against Improving Student's Critical Thinking Skills

Based on Fig. 3, it is showed the average of pre-test obtained by all students is 54.70%, the average of post-test obtained is 92.30%, and the average of N-Gain obtained is 70%. The N-Gain score demonstrates that STEM content in interactive media can improve student's critical thinking skills, which is 70% (medium category).

This is in line with the results of the study by [20] who state that STEM learning supported through inquiry-based and technology-based. Collaborative learning strategies has a significant influence on high school student's critical thinking skills. The results of this study are also in line with [15] opinion who claims that STEM curricula involve 21st century skills, namely creative thinking, critical thinking, collaboration and communication. Furthermore, the score of %N-Gain of critical thinking ability per Indicator can be seen in Fig. 4.

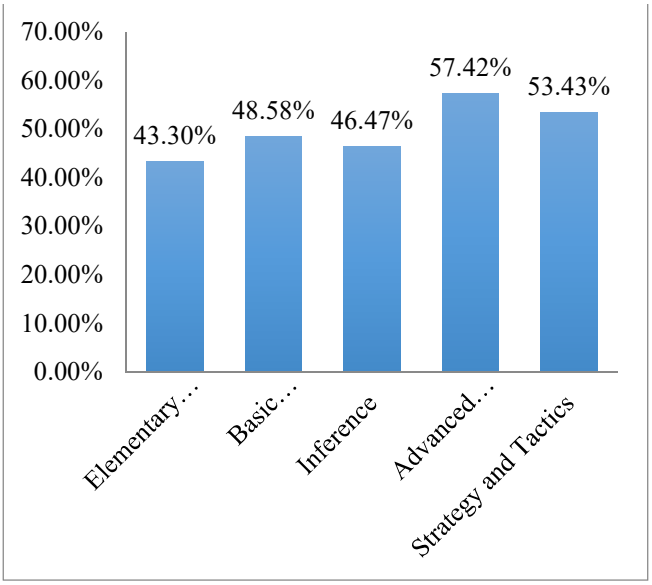

Fig. 4. Value %N-Gain critical thinking ability per Indicator

Based on Fig 4, it is showed that the student's critical thinking ability on the indicator that provides further explanation has the highest %N-gain score, that is 57.42% while the indicator that gives a simple explanation has the lowest %N-gain score, that is 43.30%.

Learning a number system with a critical thinking indicator about providing further explanation on the matter of converting numbers. Matter converts numbers to be replicated in media in the form of text, images, tables, and videos. Therefore, the learning material in this material has been well visualized. This is in line with the results of research by [21] who claims that the use of charts and videos in IPA learning can improve student's understanding about the concepts. Furthermore, the results of the study by [22] shows that video and animation have a more significant effect in improving student's learning achievement in the context of chemical laboratories. Both results of this study are in line with Dale's Cone of Experience theory [23] that the use of visual messages in learning can contribute to the learning success.

The learning material of the indicator number system provides a simple explanation of the material of understanding the types of decimals, binary, octal, and hexadecimal. Four materials have been visualized with text, images, tables, and videos, but the video cannot be diced/ stopped by the students to make the students understand and the video also does not have a voice. This is what is supposed to lead to an improvement in the critical thinking ability of indicators that provides further clarity into the highest and indicators that provides simple explanations of the lowest.

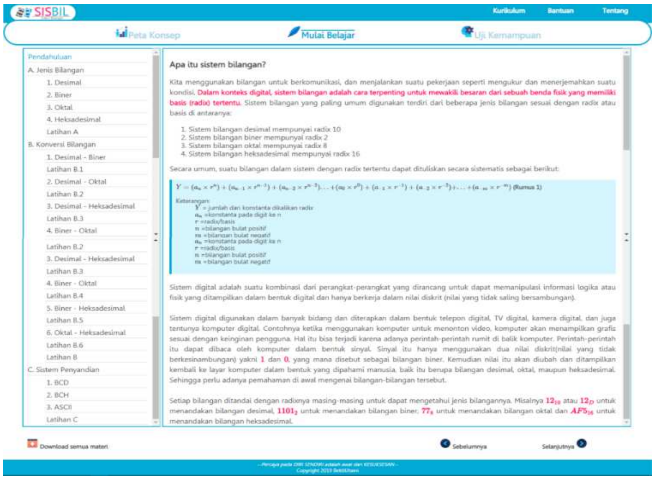

Fig. 5. Implementation of Interactive Media (Start Learning)

Based on Figure 5, it can be seen examples of interactive media used by students during the learning process. In the learning start menu, users will be faced with the navigation of the material on the left side and the material on the right side. Users can also press the previous and next buttons located at the bottom right corner to view the previous and previous content. In the lower-left corner, there is a download button for all materials so that users can download the entire material in PDF form. The end of each sub-section of the material will be linked on the let's try page and also formative exercises at the end of each sub-chapter.

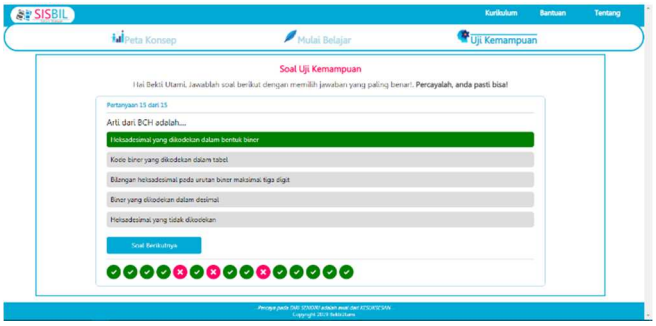

Fig. 6. Implementation of Interactive Media (Ability Test)

Based on Fig. 6 above, on the ability test question page, users will be faced with multiple-choice questions. This question is about all the material that has been studied. If the user's answer is wrong, it will be recorded in the score tracker in the form of a pink cross. If the user answers correctly then the tracker will appear with a green checkmark. The user cannot go back to the previous question or make direct corrections to the wrong answer, because the correction is made immediately after the user presses the answer. Notification of ability test results will appear immediately after the user has completed all the questions. Ability test results will also be automatically downloaded at that time.

C. *Student Responses to the Use of STEM-based Interakti Learning Media in Learning*

At this stage, students are given a questionnaire to find out the student's response on the use of STEM-based interactive learning media. Questionnaires are given to students after learning using interactive media, student's responses to the use of interactive media include STEM content, the potential of interactive media in increasing learning motivation, and the ease of using interactive learning media.

In general, students give excellent responses by 84% to the role of interactive learning media that helped in understanding learning materials about the understanding of number types, number conversion, and encoding systems.In addition to student responses about STEM content in interactive media, students also trawled data related to the potential of interactive learning media in increasing student learning motivation. Based on the results of questionnaire, it is showed that students give an excellent response to the potential of interactive learning media in increasing learning motivation. Students feel comfortable in learning by STEM-based number system materials, feel happy in learning number systems, feel interested in learning number systems using interactive media and are more challenging than ordinary learning. Furthermore, students state that they want to reuse the interactive media in learning other materials.

Overall, the data show that interactive learning media can increase learning motivation in learning number systems. All students respond that interactive learning media can help in understanding learning materials and able to increase learning motivation. This is in accordance with the research by [24], who state that various types of multimedia learning materials in various variations have a significant influence on social perception, interests, learning experiences, learning motivation, and student learning outcomes. Furthermore, research by [25] shows that multimedia learning is able to help in understanding learning outcomes and improve learning motivation. This is in line with cognitive theory of multimedia learning who claim that the use of multimedia in learning can create an active process that requires five cognitive processes namely word selection, image selection, word organizing, image organizing, and the process of connecting it with existing knowledge. Responding to the ease of operation of STEM-based interactive media, students respond very well to the components of interactive learning media such as text, images, and video. As well as students can complete very well all learning activities in interactive learning media [19].

After the implementation stage, the use of STEM-based interactive learning media in learning obtained various information related to learning media developed. The information relates to the advantages and disadvantages of interactive learning media which is based on the effectiveness of interactive media learning in improving student's critical thinking skills. The effectiveness of learning using interactive media to improve student's critical thinking skills is in the category of both overall and on each indicator. The effectiveness of interactive media with both categories because the display, components, and interactive media content developed have not been maximized. To increase the effectiveness of the high category, it is required the improvement of display, components, and interactive media content that refer to the indicators of critical thinking.

IV. Conclusions

Based on the results of research and discussion that has been outlined, it is concluded that STEM-based interactive learning media on the number system material developed fit to the design that can be used in STEM learning. The STEM content is displayed in the form of text, images, tables, and videos.

Learning by using STEM-based interactive learning media on SMK's class X on number system material is effective in improving the process of student's thinking skills with moderate categories. The ability to think critically on indicators provides simple explanations, builds basic skills, concludes, provides further explanation, and develops strategies and tactics with moderate categories. Improved critical thinking skills with moderate categories due to STEM-based interactive learning media developed still have shortcomings, especially in the display, components, and content of interactive media. In addition to improving student's critical thinking skills with some categories, it can be done through the use of interactive media supported by other learning activities. Students respond very well to the use of STEM-based interactive media in learning on number system materials, in general students respond that STEM-based interactive media helps in understanding learning materials and is able to improve learning motivation.

Based on research conducted, it is suggested that the presentation of STEM content design in interactive media should be more varied and detailed in each display. Further research is needed to determine the significance of the role of STEM-based interactive learning media to improve student's critical thinking skills with experimental quasi design using experimental classes and control classes.

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