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Agus Suyatna, I. Wayan Distrik, Kartini Herlina, Eko Suyanto, and Dita Haryaningtias



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Developing Interactive E-Book of Relativity Theory to Optimize Self-Directed Learning and Critical Thinking Skills

Agus Suyatna^{1,a)}, I Wayan Distrik^{1,b)}, Kartini Herlina^{1,c)}, Eko Suyanto^{1,d)}, and Dita Haryaningtias^{2,e)}

¹⁾Lecturer of Physics Education Department, Lampung University

²⁾Students of Physics Education, Graduate Program, Lampung University
Jl. Prof. Dr. Sumantri Brojonegoro No. 1, Bandar Lampung, Indonesia.

^{a)}Corresponding author: asuyatna@yahoo.com

^{b)} wayandistrik8@gmail.com

^{c)}kkartini.herlina@gmail.com

^{d)}ekosuyanto011@gmail.com

^{e)}ditha_tias@yahoo.com

Abstract. Physics learning in school's aims to foster the ability to think, work and be scientific and communicate as one important aspect of life skills. To achieve that goal, it needs to be supported by the appropriate books. The aim of this research was to develop an interactive e-book of relativity theory to build critical thinking skills and can be used to learn independently for 12th-grade students of Senior High School in even semester. The research method used was research and development. The research stages included literature study, planning, initial product development, expert validation, initial product revision, readability test, and test the ease of operation, revision, and small group test on the actual class using pre-test post-test control group design. Data were collected by using questionnaires and written tests. Data analysis included qualitative and quantitative analysis. Qualitative analysis was used to reference product revision, the practicality of e-book, and to know student response to e-book development result. Quantitative analysis was used to test the effectiveness of e-book. The effectiveness was measured by comparing the N-gain of control class with the experimental class and pre-test and post-test of the experimental class. The results of research showed the e-book of relativity theory that can build the critical thinking skills was prepared according to the stage of scientific approach that is observing, asking, investigating, making conclusions and equipped with adequate experiment simulations. In order for e-books to be used independently, it is necessary to be equipped with a learning instruction manuals, instructions for using the book, materials were prepared from easy to difficult and equipped with exercise questions accompanied by feedback. The results of field test showed that students' critical thinking skills which were using interactive e-books are better than using static books. There was an increase in N-gain of learning outcomes with the moderate category.

INTRODUCTION

There are four issues on learning materials of relativity theory in high school. First, the material is given to class XII in the second semester in which the time is so limited. Second, physics learning is demanded scientific inquiry with a scientific approach, so it becomes a means for students to improve their critical thinking skills. The third is the theory of relativity, including material that is abstract and difficult to be learned by students. Fourth, there is no practical facility of relativity theory in the school laboratory. The fourth issues are very important to be found the solution so that high school students can learn and understand the theory of relativity independently without losing the scientific approach.

The learning process of physics in class XII of high school at the second semester requires at least 52 lesson hours, beyond the time for national exams enrichment and exercises also preparations to get into college. Referring

to the starting time of school examination in 2017, the effective week which is available before the exam is just 10 weeks, meaning that the time which is available to do the process of learning physics is just 40 lessons hours. Based on the results of limited interviews with teachers and students of class XII in Bandar Lampung, is known that conditions make it difficult for teachers and students to complete the basic competence (BC) in the second semester. The facts that occurred in the field with the constraints faced by the teachers and students related to the limited time available to complete the BC, make the teachers teach by means of question exercises that are expected to come out in the school exam and national exam. Such learning is not in accordance with the purposes of physics learning which are building the ability to think, working and behave scientifically, also communicate as one of the important aspects of life skills.

Curriculum 2013 emphasized the application of scientific approach in learning. The scientific approach is believed to be the golden bridge and the development of attitudes, skills, and knowledge of students [1]. Scientific approach refers to the techniques of investigation of phenomena or symptoms, acquiring new knowledge, or correcting and integrating previous knowledge. In order to be scientific, the inquiry method must be based on the evidence of the object which is observable, empirical and measurable with the principles of specific reasoning [2]. The scientific approach is characterized by the projection of the dimensions of observation, reasoning, discovery, validation, and explanation of a truth. Thus, the learning process should be carried out with the guiding values, principles, or scientific criteria [1]. The scientific approach to learning includes observing, asking, trying, reasoning (associating), processing, presenting, and concluding [3]. The learning purpose of scientific approach is based on the advantages of this approach include: (1) to improve the intellectual ability, especially the high order thinking skills of students, (2) to build the students' ability to solve a problem in a systematic way, (3) to exist the learning condition where the students feel that learning is a necessity, (4) to obtain a high learning outcomes [4]. The theory of relativity material can be used as a means for students to improve critical thinking skills when using the scientific approach in learning.

The theory of relativity in high school discussed the relative motion, Galilean transformation, Michelson-Morley experiment, Einstein postulates, Lorentz transformations, Time Dilation, the Twin Paradox, Length Contraction, Relativistic Mass, Relativistic Momentum, and Relativistic Kinetic Energy. Overall, these materials, including materials that are difficult and abstract and rare or even not found in the daily life of students. In order to teach such materials with the scientific approach in scientific inquiry, it required an appropriate teaching materials that can demonstrate various phenomena of relativity theory in the classroom. It needs to be supported with video, animation, experiments simulation based on ICT, packaged in the form of an interactive e-book. The integration of ICT in the teaching-learning process can be used as an alternative that can transform the traditional classroom into a limitless world of imagination environment [5]. Some studies showed that a virtual laboratory could equally well or even better than the traditional laboratory experiments [6]. The results of research on the computer simulation, mainly as a supplement, has shown some evidence that the virtual laboratory can help in strengthening the students' conceptual knowledge [7-8].

The discussion on moving objects such as the Galilean transformation, Time Dilation, and Twins Paradox would be better if visualized using a moving object in an animation [9]. Along with the research above [10], it proposed a new strategy is to integrate the animation to enrich the students' science learning environment. It can be designed using the animation program.

Physics has multiple representations such as models, analogies, equations, graphs, pictures, mathematical operations, and motion. All of it can be used with an integrated animation for different effects of single representation compared to multi-representation [11]. Everything can be packed in a multimedia. A multimedia which integrated the digital combination of words, graphics, animation, and voice in physics learning can attract the visual, stimulate students' motivation and produce an effective physics learning [12]. In addition to the use of multimedia, learning also needs to be supported by the use of modules or teaching materials which are suitable. The use of integrated modules with physics learning animation can enhance the students' understanding of concepts and skills [13]. The results of the research [14] showed that an innovative change to support teachers in using the integrated animation in physics learning makes the development of science education is successful. However, not all integrated animation applications are certainly appropriate or effective strategies to improve students' performances [15]. Looking at the excellence of the computer-based interactive learning media as described above and the intended use of this research, the creation of interactive e-book for theory of relativity learning in class XII of High School in the second semester will be able to answer the problem of the lack of time to learn face to face, the development of thinking skills, and the application of scientific approach.

The interactive e-books can be designed based on learning content development system (LCDS) program. It is more dynamic than e-book in .pdf format that had been used as a textbook by high school students. Responding to

the problem of the limited time available for the learning process of relativity theory, it should be initiated something that makes the students can learn independently. Self-learning does not mean they just learn on their own but it can be done in groups, as in the tutorial groups. Self-learning is one way to improve the willingness and skills of learners in the learning process without the others' assistance and does not depend on teachers, mentors, friends, or others. The teachers' job, in this case, is as a facilitator or the one who provide convenience or assistance to students. Therefore, it needs to develop a physics teaching materials of class XII of high school in the second semester that can be used by students independently and can build up high order thinking skills of students also give an experience of doing scientific inquiry.

The e-book will provide a lot of conveniences and flexibility in the self-learning process of class XII students of high school in the second semester. Features in the LCDS software can lead the independent learning for class XII students of high school. LCDS-based e-book can make the physics material becomes more dense and simple, can be equipped with animation physics phenomena, video, virtual labs, and interactive quizzes, featuring the visualization of abstract material and can be used by the students wherever they are, at home, in the library, and even can be used repeatedly. Learning with e-book can provide flexibility in each of the limitations faced by the students and teachers of class XII students of high school, thus the development of the interactive e-book on relativity theory based on LCDS can be one solution to overcome the time constraints faced by the class XII students of high school in the second semester.

The ICT-Based Interactive Module on Waves Subject Matter with Scientific Approach is proved effective which is indicated by 79% of students completed the minimal mastery criteria [16]. Other research conclusions related to the use of ICT in learning, such as the use of ICT media experiments, tutorials, and simulations in physics learning can improve cognitive learning outcomes, brings out the science process skills, build the character, and improve the students' activity [17-18]. Some of the test results of the implementation of LCDS-based physics e-book on showed that physics learning becomes more effective and attractive. The LCDS-based e-book is rated easy to use by students independently [19-20].

METHOD

The method used was research and development. The development design was implemented by ADDIE development model that included five phases of activity that is Analyze, Design, Development, Implementation, and Evaluation.

Analyze

The analysis activity included need analysis, material analysis, and standards content analysis which were done in high school as the first step of product development. Instruments used in this analysis phase were in the form of a questionnaire of needs analysis given to the physics teacher and class XII students. The analysis was also conducted by the experts of the subject matter to determine the content/component contained in the e-book of relativity theory

Design

At this stage, design (storyboard) was made that includes the learning objectives, the content, and the component of the e-book. The materials presented were adjusted to the basic competence of the theory of relativity to class XII students of high school in the second semester. Selection of materials and instructional media loaded in the e-book is based on expert judgment instrument revealing the e-book component needs of relativity theory.

Development

The activity of this development was done by creating an e-book of relativity theory which is valid in terms of content and design. The first stage was the election to the materials so that it will be suitable for the competence to be achieved. The second stage was making the experiments simulation and animations to be loaded in the e-book. The third stage was to design an instrument that can measure the students' critical thinking skills that will be published in the form of interactive tests in the e-book. After the process of making e-book was completed, expert validation test and readability test were done by the students. The experts' validation was conducted by 5 experts in

the field of science education and 5 physics teachers who were already certified. Legibility test was conducted on 10 students of class XII.

Implementation

The implementation is the step where the products that have been developed and revised were tested to the students. The test is done by class XII students in the second semester of the academic year 2017/2018 from one of high school in Bandar Lampung. The subjects were divided into two classes, one class as the experimental class and the other class as the control class. The total of students in each class were 29 students. In the experimental class, students were asked to use interactive e-book that has been developed. In the control class, students were asked to use e-book that is static and commonly used in the learning activities at the school.

Evaluation

Evaluation is the process to see whether a product which has been developed is successful, in line with initial expectations or not. The test was done to determine the practicality and the effectiveness of the interactive e-book. The research design used in the evaluation step of the product is pretest-posttest control group design. The evaluation was given to class XII students by using questionnaires and tests. Questionnaires were given used to determine the practicality of e-book that has been developed as a basis for evaluation. The test was used to measure students' critical thinking skills.

Collecting and Data Analysis Technique

Validity, readability, and ease to operation data analysis technique

The data of construct validity and content validity test of the e-book, e-book readability, and the ease of operation were collected by using a questionnaire with four possible answers, which is "very appropriate" given a score of 4, "appropriate" given a score of 3, "not appropriate" given a score of 2 and "not appropriate" given a score of 1. The scores which were obtained from each respondents were summed and averaged, then converted to a scale of 100. The validity test results which was stating that the validity of the product and the readability of the e-book also the ease of operation of the development product were then analyzed by using Criteria for Achieving Validity [21]

E-book effectivity data analysis technique

The effectiveness of the interactive e-book was tested by determining the N-Gain, discrimination power test on the average of pretest and posttest, and discrimination power test on the average of control class and experimental class. N-gain was calculated using the formula [22].

$$N_gain = \frac{S_{post} - S_{pre}}{S_M - S_{pre}}$$

Discrimination power test on the average of pretest and posttest was analyzed using paired sample t-test and discrimination power tests on the average of control class and experimental class were analyzed using independent sample t-test.

RESULT AND DISCUSSION

The Structure and Content of Interactive E-Book Theory of Relativity

The interactive e-book of relativity theory was created as an independent learning resources for class XII of High School. It was designed based on scientific approach which can foster the students' critical thinking skills. This physics interactive e-book was accompanied by giving feedback, facilitating the discovery, stimulating an activity in understanding the concepts through images, and animation or lab simulation. The e-book was equipped by sample

questions and exercises to foster critical thinking skills. The e-book structure of the development results are presented in **Figure-1**.

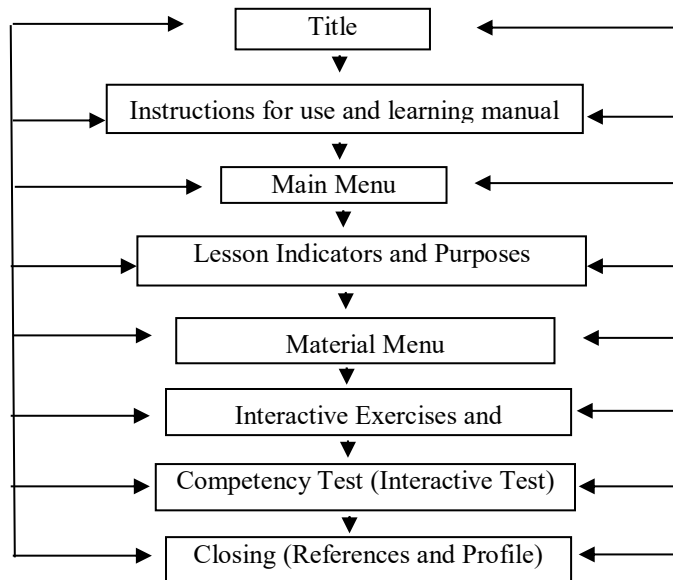


FIGURE 1. The Structure of Interactive E-Book Theory of Relativity

The structure of an interactive e-book theory of relativity has been validated by an expert, the results are presented in **Table-1**. After a cyclical revision, all feature indicators of e-book structure are valid by expert.

TABLE 1. E-book construct validation test results

Feature	Validity	Category
Layout design of interactive e-book	84%	Valid
<i>Typography</i> of interactive e-book	82%	Valid
Illustration on interactive e-book	91%	Very Valid
Appropriate for self-directed learning	85%	Very Valid

The e-book was designed to foster the critical thinking skills by reducing each indicator of critical thinking skills in the cognitive indicator of relativity theory. Later in the e-book, it was provided a phenomenon that can stimulate thinking skills. For example, the ability to analyze the Galileo and Transformation Equation and Lorentz Transformation were stimulated by presenting an image and animation of the relative motion, Galileo transformation, time dilation, length contraction and relativistic mass. Then the students were given the initial questions that need clarification. Furthermore, pictures and simple explanations of the material (text, formulas, and sample questions) were included in the interactive e-book that can provide a guide to understand the material of relativity theory.

As an example, the ability to conclude the results of the Michelson-Morley experiment was raised through the simulation of the Michelson-Morley experiment. It was a scientific experiment to find the presence and properties of a substance called aether, a substance believed to fill empty space. The interferometer simulation is designed to measure the speed and direction of "aether wind" by measuring the difference between the speed of light moving in different directions. The difference in direction by shining a beam of light into a mirror that is only partially silver coated. Part of the rays will be reflected in one direction, and the other part will switch to the other way. The two parts will then be reflected back to their separate places and combined. By looking at the pattern of interference in the light rays of recombination, any change in speed due to ether wind can be seen (**Figure-2**). Recent studies, using computer simulations, especially as a supplement, has shown some evidence that this laboratory can help in

improving the test scores, improve the students' attitudes, improve the readiness for direct practice, and strengthen the conceptual knowledge [23]. For further understanding, it was provided an interactive exercise such as changes in particle size when the particle moves closer to the speed of light.



FIGURE 2. E-Book Page Example of Michelson-Morley Experimental Simulation

The ability to make a conclusion based on facts and concepts of length, time, mass, momentum and relativistic energy was stimulated by observing animations and simulations of the phenomena. Furthermore, it was provided questions that stimulate students, so that students can infer the meaning of animations and simulations that have been observed. To have the better understanding of the material, it was provided by interactive questions in the form of statements. The students were asked to select and consider the question based on facts and concepts.

The ability to analyze Einstein's postulates was done by providing an explanation of the material about Einstein's postulates. The explanations consisted of a brief description of the specific relativity postulate. Furthermore, the students were asked to study the Einstein's postulates so that the students can define the term and consider the definition of such explanations. Then, it was also provided an interactive question that presents some assumptions, the students were asked to choose the appropriate assumptions. The ability to evaluate the theory of relativity and to consider alternative solutions were raised by providing a summary of the theory of relativity material so that students can reflect what they have learned and consider an alternative in solving the problems.

This e-book was designed to be used by students to study independently. In the e-book, learning objectives were provided so that students can determine their own learning goals of the main objectives (indicators) that had been set. Self-learning can be characterized by the ability to use a variety of sources and learning media. In the e-book, it was also provided by links to other learning resources that can help students to understand the material. Self-learning can be done anywhere and anytime, based on students' desired time. This e-book was designed to be operated offline and online which makes it easier for students to bring it anywhere which is possible to do the learning activities that are suited for their comfort. Learning speed and intensity of learning activities can be determined by the student, in accordance with the needs of capabilities, and the available opportunities. This e-book contained interactive exercises and tests as an evaluation that can be done by the user. Students can do their own reflections to the results of an independent study that has been done since the e-book contained feedback on the interactive questions which can be done by the user independently. Content and structure of the e-book are presented in **Figure-3**.

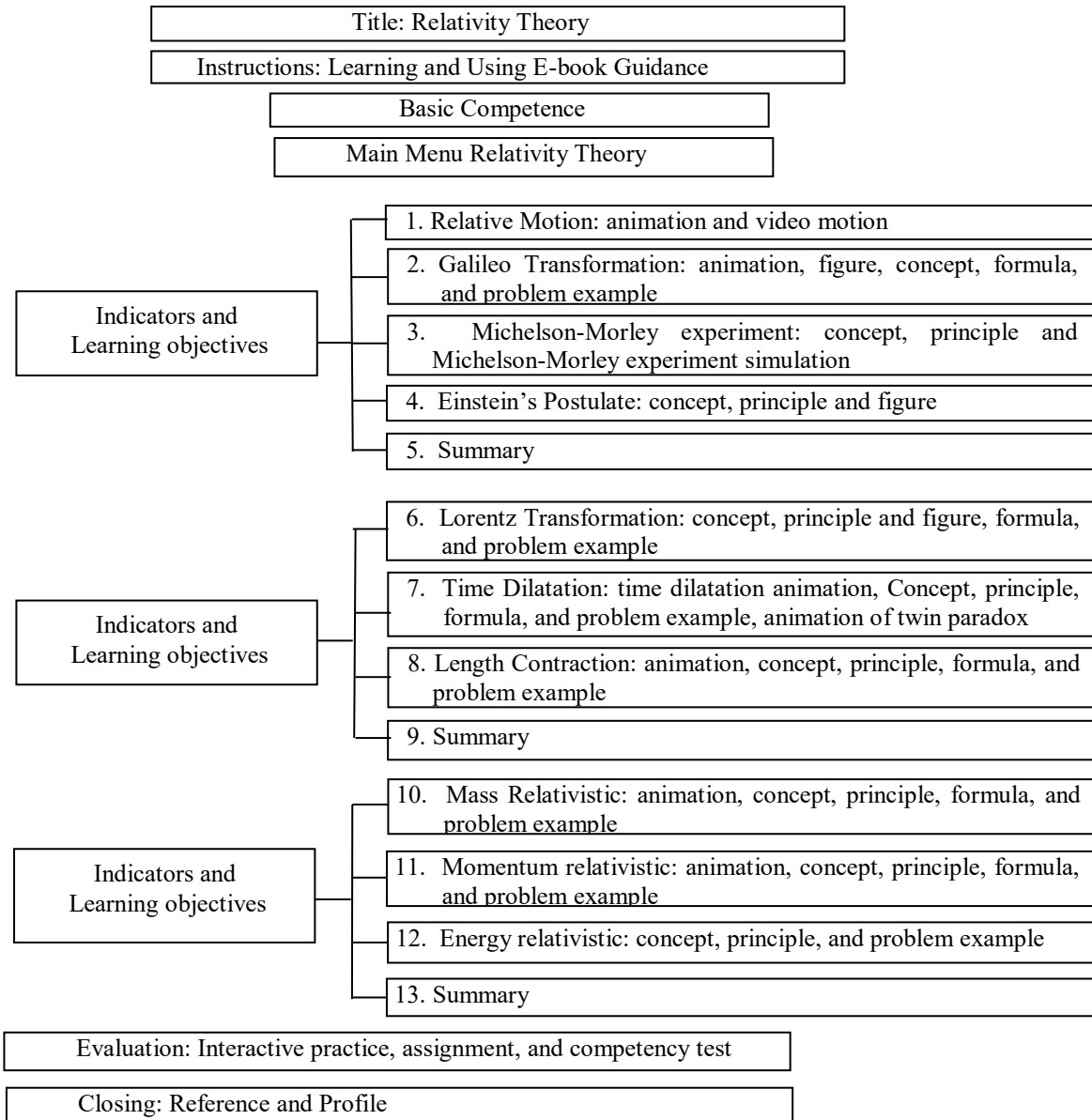


FIGURE 3. The Content of Interactive E-Book Theory of Relativity

The content of an interactive e-book theory of relativity has been validated by an expert, the results are presented in **Table-2**. After a cyclical revision, all aspect indicators of e-book content are valid by expert. Experts repair suggestions, such as links not to blogs/invalid sources and consistency of term use, have been done.

TABLE 2. E-book content validation test results

Aspect	Validity	Category
The width and completeness of the material	86%	Very Valid
Materials and test accuracy	84%	Valid
Latest Material	82%	Valid
Critical thinking is stimulated	83%	Valid
Scientific Approach	87%	Very Valid

Suggestions relating to the content of e-book such as relative motion video, do not increase the student's misconception, the animation on the time dilatation is fixed so that the concept is not misunderstood by the students, the Michelson-Morley experiments are improved so that the laser beam travels only in the form of destructive interference and constructive interference, adjusting the color to a dark light pattern, have been done.

Effectiveness and Practicality of Interactive E-Book

The main objective of the development interactive e-book which is to build the students' critical thinking skills on the material of relativity theory has been achieved. This is shown by the results of the written test of 29 students as the subject test of the e-book in **Table-3**. Based on the analysis, it can be concluded that there are differences in the average of pretest and posttest which is significant at the level of 95%. The average score of posttest is higher than the pretest with N-gain is in the category of moderate [24].

The development results of the interactive e-book is better than static e-book (in pdf format), it is indicated by the difference in the average of N-gain which is significant at the confidence level of 95% between experimental class which is using interactive e-book learning resources with the control class which is using static e-book learning resource. This finding is certainly related to the students' assessment of the interactive e-book development results.

TABLE 3. Critical thinking test results

Class	n	pretest	posttest	N-gain	p
Experiment Class	29	39.8	80.6	0.65	0.000*
Control Class	29	41.4	62.7	0.36	0.000*
p		0.426	0.000*	0.000*	

*) $p < 0.05$, differ significantly on the level of confidence 95%

The data analysis results of questionnaires which were distributed to 29 subjects showed that the e-book of the practical development results can be used in the field and in accordance with the purpose of the development. All students stated that the e-book development result is very effective in building the critical thinking skills. Interactive aspects obtained an average value of 83%. All students stated that the e-book development result is very interactive. Efficient aspects obtained an average value of 81%, meaning that all of the students stated that the e-book is efficient to be used as a source of learning the theory of relativity. The ease of using e-book aspects obtained an average value of 82%. All students stated that the e-book development result is easy to use. E-book development results can be used for independent study. In this aspect, it obtained an average value of 83%. It means that students can determine the purpose of learning by themselves from the main objective, the students can understand the material independently through e-book developed, students have an awareness to learn through interactive e-book outside the school hours, and students can evaluate the progress of their learning through the interactive e-book. Students' opinions about the interactive e-book development outcomes relate to student learning outcomes. Students who learn by using interactive e-books get better learning outcomes than students who learn by using printed book or static e-books. This is in line with the research findings of [25] improved student attitudes toward the course in general and lectures in particular. One group received a multimedia module-assisted learning and two other groups received printed text books-assisted learning. All students were tested on their learning two weeks later. Students' outcomes that received multimedia module-assisted learning are better than students who use textbooks. This finding is supported by [26] who's stating that an interactive module which is simple and flexible can effectively complement the learning tool in the classroom and also improve problem solving skills or clarify the concept. In addition, the use of computers that present interesting teaching materials, can improve student learning motivation and can lead students in achieving learning objectives [27]. A study was performed comparing the efficacy of multimedia learning modules with traditional textbooks for electricity and magnetism course. Students were randomly assigned to three different groups experiencing different presentations of the material; one group received the multimedia learning module presentations and the other two received the presentations via written text. All students were then tested on their learning immediately following the presentations as well as two weeks later. The students receiving the multimedia learning modules performed significantly better than the students experiencing the text-based presentations on both tests [28]. The results of these studies increasingly convince the author that interactive e-book is effective in improving student learning outcomes, and can be used independently.

CONCLUSION

The results of research showed that the e-book of relativity theory that can build the critical thinking skills is prepared according to the stage of a scientific approach that is observing, asking, investigating, making conclusions and equipped with adequate experiment simulations. In order for e-book to be used independently, it is necessary to be equipped with learning instruction manuals, instructions for using the e-book, materials are prepared from easy to difficult and equipped with exercise questions accompanied by feedback. The results of field tests showed, students' critical thinking skills which using interactive e-books are better than using static books. There is an increase in N-gain learning outcomes with moderate category.

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