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Development of Interactive Multimedia Learning Materials for Improving Critical Thinking Skills

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ABSTRACT

Learning materials offer students and teachers valuable assistance in physics lessons. This article was aimed at developing and evaluating interactive multimedia learning materials that are equipped with games in Linear Motion and Newton's Laws for improving critical thinking skills. The evaluation consists of an expert review, based on grades from four experts, practicality testing by 30 students, and effectiveness testing concerning students' critical thinking skills after they have used interactive multimedia learning materials. Thus, the research result shows that interactive multimedia learning materials are valid, practical, and effective. Based on this result, it appears that interactive multimedia learning materials can enhance students' critical thinking skills.

KEYWORDS

Critical Thinking Skills, Games, Interactive Multimedia, Learning Materials, Physics Learning

1. INTRODUCTION

Education has not been able to develop at the same pace that current technology develops. Today, rapid technological developments have caused students to become addicted, making them unable to separate from their gadgets for long periods of time. In addition, when students are addicted to technology, they can have a greater preference for their gadgets than their textbooks. Based on students' behavior, it becomes clear who feels more comfortable when their books are left behind. In contrast, students can feel uncomfortable when their gadgets are left behind. For further evidence of students' addiction to technology, one can observe their level of interest in games, which is quite high, as evidenced by the students' frequent game playing outside of class. Based on a survey of 33 students, 43 percent indicated they often play games outside of class, which says that, instead of studying, students are using more of their leisure time to play games. Therefore, physics learning objectives will be difficult to achieve.

Based on Indonesia's 2013 curriculum, one of the physics learning objectives is to develop reasoning in inductive and deductive analysis to solve problems (Sunardi & Zenab, 2014). This objective shows that the 2013 curriculum emphasizes the development of students' critical thinking

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skills. Despite this, in Padang, the result of students' critical thinking skills measurement using the CCTST (California Critical Thinking Skill Test) showed that students' scores in each indicator is only 20-30 percent of an ideal score (Djamas, 2016).

To improve students' critical thinking skills, one effort can be made: using games in learning (Arifin, Akhdinirwanto, & Fatmaryanti, 2013; Frasca, 2001). Furthermore, Amory's (1999) research showed playing and learning are closely related. Students experience a pleasant sensation that is caused by educational games that can enhance learning effectiveness. Games can include three fun elements: fantasy, curiosity, and challenge. Computer games enhanced learning through visualization, experimentation, and creativity when playing; and when problem-solving is included, games can improve critical thinking skills (Amory, Naicker, Vincent, & Adams, 1999).

In addition to using games in learning, use of interactive multimedia can improve critical thinking skills. Interactive multimedia is reader-centered, enabling students to play an active role in deciding the way they learn (Bass, 2014), which can improve students' critical thinking skills (Ramanujam, 2010). Therefore, the aim of this research was to develop and evaluate interactive multimedia learning materials that are equipped with games for improving critical thinking skills.

2. LITERATURE REVIEW

2.1. Interactive Multimedia Learning Materials

Interactive multimedia learning materials combine various media, i.e., text, image, sound, video, animation, and simulation, and students can control the way they use them (Prastowo, 2011). Additionally, they can give students feedback, making students actively involved in learning. Although concepts in physics are abstract, animation and simulation of various phenomena and cases that are near students' daily lives can make them concrete for students to understand. In addition, videos in interactive multimedia learning materials can explain physics concepts that are poorly understood by students, enabling students to learn independently.

The interactive multimedia learning materials that were developed consist of a handout and student worksheet. The structure of the handout consists of Core Competencies (CC), Basic Competencies (BC), a description of lesson materials, questions, and references (Prastowo, 2011). The student worksheet consists of a lesson topic, class, semester, lesson guide, CC, BC, lesson indicators, lesson objectives, information about lesson materials, tools/materials that are needed in the lesson, procedures, and tasks or discussion materials (Prastowo, 2011).

Moreover, the discovery learning model was used as learning steps in interactive multimedia learning materials. In this learning model, students use a given problem and work independently to identify the physics concept and understand the related principle. In addition, since the problem-solving process requires critical thinking, it can improve critical thinking skills. Furthermore, this learning model is student-centered, which can help students be more active, critical, creative, independent, and responsible in their learning.

2.2. Games

A game is a system in which a player is involved in artificial conflict, governed by rules, and provided countable results. In addition, since enjoyment is a factor in playing games, a player is compelled to play and desire to play the games (Salen & Zimmerman, 2004). In learning, if students only receive learning materials that are not used in other activities, then learning will not be meaningful for them. Furthermore, since students cannot measure their comprehension after a lesson, a game is needed to complement the lesson, directly providing students with learning experiences in a fun way. Thus, games developed for education must have conflict, rules and objectives, the ability to provide feedback, and at the end of a game, the player must see a success grade (Prensky, 2001).

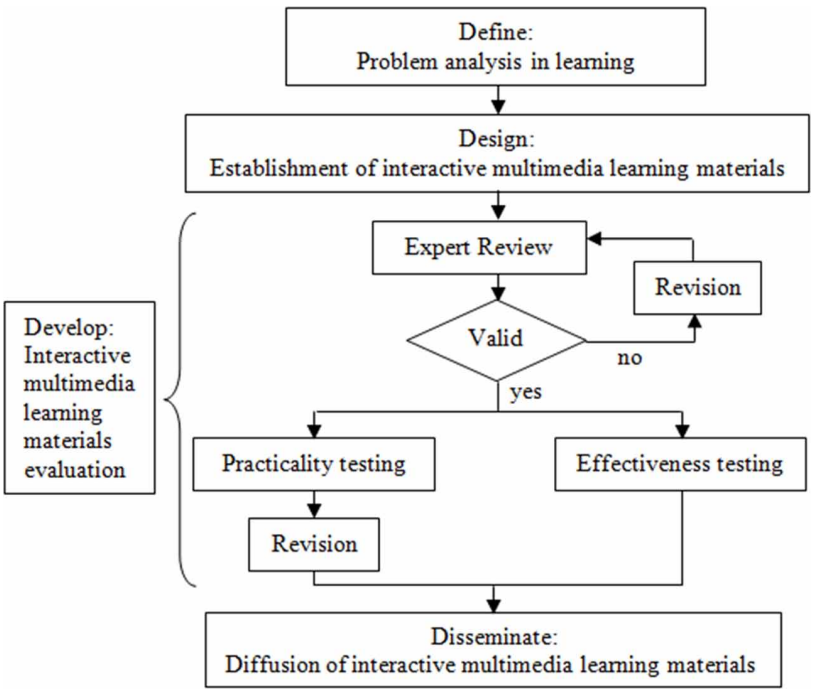
2.3. Critical Thinking Skills

Students must develop and apply critical thinking skills when solving a problem (Oliver & Utermohlen, 1995). Indicators of critical thinking skills include analysis, evaluation, inference, deductive and inductive reasoning (Facione, 2013). The utilization of interactive multimedia learning materials can improve students' critical thinking skills through high level problems that require critical thinking to be solved. As a result, they can directly help students practice their critical thinking skills and become accustomed to thinking critically when solving a problem. In addition, using games in the form of simulation can be beneficial by helping students understand the problem analysis, which requires a higher level of reasoning. Through simulation, students can understand how to solve problems faster, because they can see the direct application of what they are doing.

3. RESEARCH METHOD

The type of research and development that was adopted in this research uses a 4D model consisting of four phases, define, design, develop, and disseminate, as presented in Figure 1 (Thiagarajan, Semmel, & Semmel, 1974). In the defining phase, basic problems in learning were determined, which provides basic knowledge for designing the interactive multimedia learning materials in the designing phase. The criteria for interactive multimedia learning materials could be seen from validity, practicality, and effectiveness (Akker, Bannan, Kelly, Nieveen, & Plomp, 2013) and were tested in the development phase. The validity is rated by an expert review; practicality is based on a practicality questioner; and effectiveness can be seen in the performance of critical thinking skills in the field test. After acquiring interactive multimedia learning materials with valid, practice, and effective criteria, development proceeded to the dissemination phase. In this phase, the learning materials are socialized through distribution to a limited number of teachers and students, with the goal of receiving responses and feedback about the developed learning materials.

Figure 1. 4D Model stages of development



4. INITIAL DESIGN OF INTERACTIVE MULTIMEDIA LEARNING MATERIALS

Interactive multimedia learning materials that are equipped with games were designed to consist of a handout, student worksheets, and games that were incorporated into the student worksheet. The development of interactive multimedia learning materials and games used Macromedia Flash 8 and Adobe Photoshop CS3 software. For ease of use, interactive multimedia learning materials were designed using a user guide and navigation button. Furthermore, interactive multimedia learning materials were created in an executable file format (.exe), so it can run smoothly in a Windows operating system without the need to install any specific software. On the other hand, if Mac users must use the interactive multimedia learning materials, they can run the .exe file on Mac using the WineBottler application.

The structure of the handout consists of lesson guides, identity, CC, BC, lesson indicators, lesson objectives, discovery learning procedures (stimulation and problem statement), description of materials, examples, exercises, and references. The structure of the student worksheet consists of lesson guides, identity, CC, BC, lesson indicators, lesson objectives, lesson materials, discovery learning procedures (data collection, data analysis, verification, and generalization), and references. The interactive multimedia learning materials consist of various media, which were interconnected and can be controlled by each student based on their learning needs (Bass, 2014). Figure 2a shows the cover of the interactive multimedia learning materials, and Figure 2b shows a video as one of the media in the interactive multimedia learning materials. The video only appears when students click a hyperlink. With this condition, if students already understand the physics concept that is demonstrated in the video, they can proceed with their learning without viewing the video. Therefore, the learning process can occur in accordance with each student's learning needs and comprehension.

A frame by frame animation technique and ActionScript 2.0 were used when developing the games. Students could interact directly with the games using feedback that was based on their answers and other choices during game play. In addition, games were equipped with instructions to help students understand the game interface and how to play. At the end of the game, each student's performance during game play was converted to a score and star rating. Game displays can be seen in Figure 3.

5. EVALUATION OF INTERACTIVE MULTIMEDIA LEARNING MATERIALS

5.1. Expert Review

5.1.1. Participant, Instrument, and Analysis

Four experts participated in an expert review of the interactive multimedia learning materials, including one lecturer of education technology, one lecturer of physics, one lecturer of physics education, and

Figure 2. Interactive multimedia learning materials display: (a) Cover and (b) Media

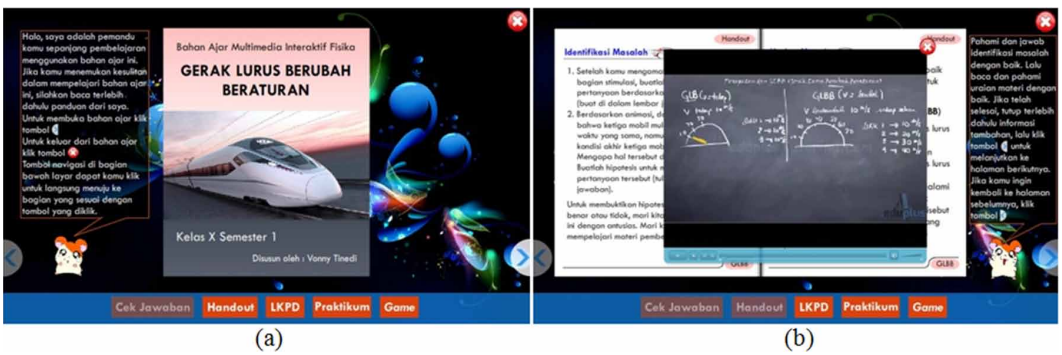
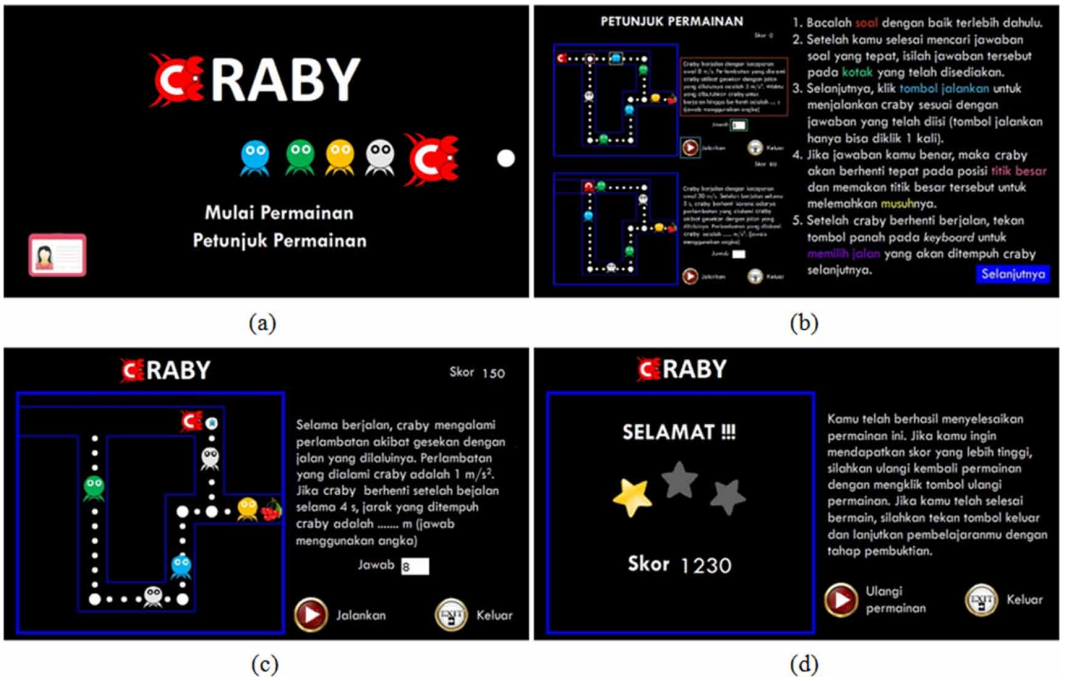


Figure 3. Games in interactive multimedia learning materials: (a) Initial display, (b) Game instruction, (c) Game display, and (d) Score display



one lecturer of language education. The expert review instrument was a validation questionnaire that used a 4-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree). In addition, the conclusion of the questionnaire included an open-ended question that requested each expert provide suggestions for revision.

The handout and student worksheet were validated separately because they have different structures and functions. Three handout validity criteria were assessed: content (10 indicators), construct (12 indicators), and language (7 indicators). First, the appropriateness of the physics concept, media, and questions in the handout were assessed for content validation. Next, presentation methods of the handout, including structure, design, layout, media completeness, and interactivity, were assessed for construct validity. Finally, language consistency and compatibility with grammatical rules were assessed for language validity.

The student worksheets were assessed based on the following validity criteria: content (14 indicators), construct (12 indicators), and language (7 indicators). First, the appropriateness of the physics concept, media, procedures in the student worksheets, and games compatibility based on six game criteria in accordance with Prensky (2001) were assessed for content validation. Second, student worksheet presentation methods, including structure, design, layout, media completeness, and interactivity, were assessed for construct validity. Finally, language consistency and compatibility with grammatical rules were assessed for language validity.

Experts A, B, and C validated all the criteria of the handout and student worksheets. Expert D, a language education lecturer, only validated use of language. After that, responses from each expert were analyzed using Aiken's V equation. As the result, the handout and student worksheets were determined to be valid if validity was greater than 0.60, and not valid if validity was less than 0.60 (Azwar, 2015).

5.1.2. Expert Review Results

The results of the handout and student worksheet validation were not significantly different. The average of handout validity was 0.91 and student worksheet 0.90. Thus, it could be concluded that interactive multimedia learning materials were valid and could be used in a field test. The results of handout validity are presented in Table 1, and student worksheet validity results are presented in Table 2. In addition, there were several suggestions given by experts for interactive multimedia learning materials during validation.

Table 1. Handout validity

Criteria	Indicator	Expert Responses				∑s	Validity
		A	B	C	D		
1. Content validity	Indicator 1.1	4	4	4		9	1.00
	Indicator 1.2	4	4	4		9	1.00
	Indicator 1.3	4	4	4		9	1.00
	Indicator 1.4	4	4	4		9	1.00
	Indicator 1.5	3	4	4		8	0.89
	Indicator 1.6	4	4	4		9	1.00
	Indicator 1.7	4	4	3		8	0.89
	Indicator 1.8	4	4	4		9	1.00
	Indicator 1.9	3	3	4		7	0.78
	Indicator 1.10	4	3	4		8	0.89
2. Construct validity	Indicator 2.1	4	4	4		9	1.00
	Indicator 2.2	4	4	4		9	1.00
	Indicator 2.3	3	4	3		7	0.78
	Indicator 2.4	4	4	4		9	1.00
	Indicator 2.5	4	4	4		9	1.00
	Indicator 2.6	4	4	4		9	1.00
	Indicator 2.7	3	4	4		8	0.89
	Indicator 2.8	4	4	4		9	1.00
	Indicator 2.9	3	4	4		8	0.89
	Indicator 2.10	3	4	3		7	0.78
	Indicator 2.11	4	3	4		8	0.89
	Indicator 2.12	4	3	4		8	0.89
3. Language validity	Indicator 3.1	4	4	4	4	12	1.00
	Indicator 3.2	3	4	4	3	10	0.83
	Indicator 3.3	4	4	4	3	11	0.92
	Indicator 3.4	4	3	4	3	10	0.83
	Indicator 3.5	4	3	4	3	10	0.83
	Indicator 3.6	4	3	4	3	10	0.83
	Indicator 3.7	4	3	4	3	10	0.83
Mean: 0.91							

Table 2. Student worksheet validity

Criteria	Indicator	Expert Responses				∑s	Validity
		A	B	C	D		
1. Content validity	Indicator 1.1	4	4	4		9	1.00
	Indicator 1.2	4	3	4		8	0.89
	Indicator 1.3	4	4	4		9	1.00
	Indicator 1.4	4	4	4		9	1.00
	Indicator 1.5	4	3	4		8	0.89
	Indicator 1.6	4	4	4		9	1.00
	Indicator 1.7	3	4	4		8	0.89
	Indicator 1.8	3	4	4		8	0.89
	Indicator 1.9	4	3	4		8	0.89
	Indicator 1.10	4	3	4		8	0.89
	Indicator 1.11	4	3	4		8	0.89
	Indicator 1.12	4	4	4		9	1.00
	Indicator 1.13	4	3	4		8	0.89
	Indicator 1.14	3	3	4		7	0.78
2. Construct validity	Indicator 2.1	4	4	4		9	1.00
	Indicator 2.2	4	4	4		9	1.00
	Indicator 2.3	3	3	3		6	0.67
	Indicator 2.4	3	4	4		8	0.89
	Indicator 2.5	4	3	4		8	0.89
	Indicator 2.6	4	4	4		9	1.00
	Indicator 2.7	4	4	4		9	1.00
	Indicator 2.8	4	4	4		9	1.00
	Indicator 2.9	3	4	4		8	0.89
	Indicator 2.10	4	4	3		8	0.89
	Indicator 2.11	3	4	4		8	0.89
	Indicator 2.12	4	3	4		8	0.89
3. Language validity	Indicator 3.1	4	4	4	3	11	0.92
	Indicator 3.2	3	3	4	4	10	0.83
	Indicator 3.3	4	3	4	3	10	0.83
	Indicator 3.4	4	3	4	3	10	0.83
	Indicator 3.5	4	3	4	3	10	0.83
	Indicator 3.6	4	3	4	3	10	0.83
	Indicator 3.7	3	3	4	3	9	0.75
Mean: 0.90							

5.1.3. Revision of Interactive Multimedia Learning Materials

Based on the expert reviews, the experts made several suggestions for revisions of the interactive multimedia learning materials. Expert A suggested language consistency for the exercise in the handout. In addition, regarding layout, expert A suggested adding more spacing between paragraphs, thus making writing disposition more organized. As implied by expert A, the background color was also

revised. These revisions can be seen in Figure 4. Further, expert A stated the interactive multimedia learning materials design was not yet attractive, and the blue color that was used for subtitles was not sufficiently contrasted from the background color, which was white. Consequently, the subtitle color was changed to orange, and, to emphasize the sentences, the text color in the handout and student worksheets was converted to four colors. Green was used for additional information about using the interactive multimedia learning materials, pink for questions, and orange and bold text for hyperlink text. Other sentences were written in black, as indicated in Figure 5.

In addition, for the handout, the stimulant in the descriptions of materials was modified to be discovery learning oriented, as suggested by expert A. As a result, a question was added at the end to help students discover a physics concept from the stimulant (Figure 6). Another suggestion given by expert A was to hide the answers and only provide the answer key in examples in the handout. Hence, students would attempt to answer the question independently in accordance with the discovery learning concept. The answers provided in the examples were meant to enable students to check their answers (Figure 7).

The cover design of the handout and student worksheets were modified, as suggested by expert A (Figure 8). In addition, expert A made suggestions for the student worksheet in the conclusion stage, recommending that students obtain the conclusion from the learning process in the student worksheet. Consequently, the conclusion consists of several questions to help students discover the appropriate conclusion based on the physics material they learned (Figure 9).

Figure 4. Revision of space between paragraphs and background color: (a) Before and (b) After

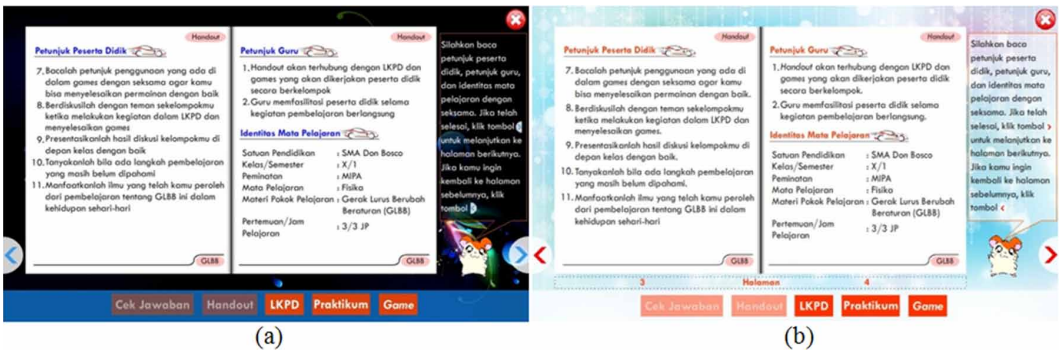


Figure 5. Revision of text color: (a) Before and (b) After

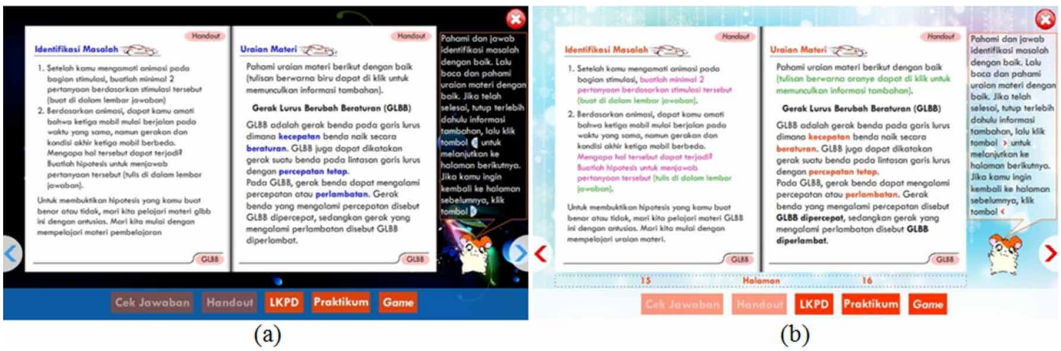


Figure 6. Revision of description of materials in handout: (a) Before and (b) After

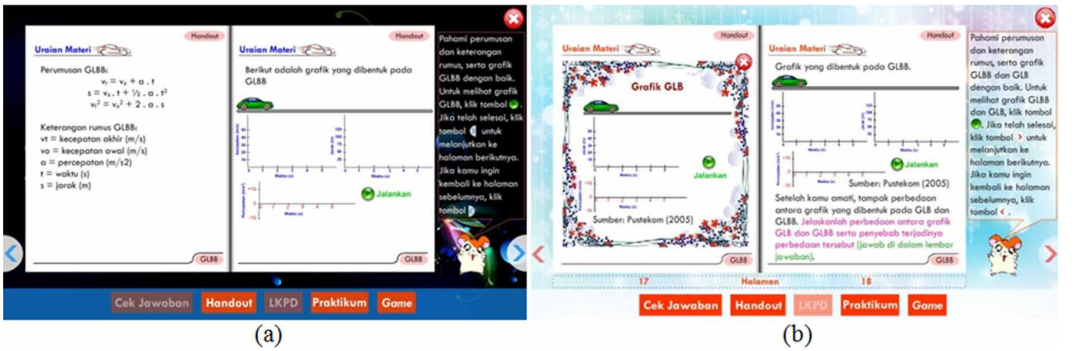


Figure 7. Revision of examples in handout: (a) Before and (b) After

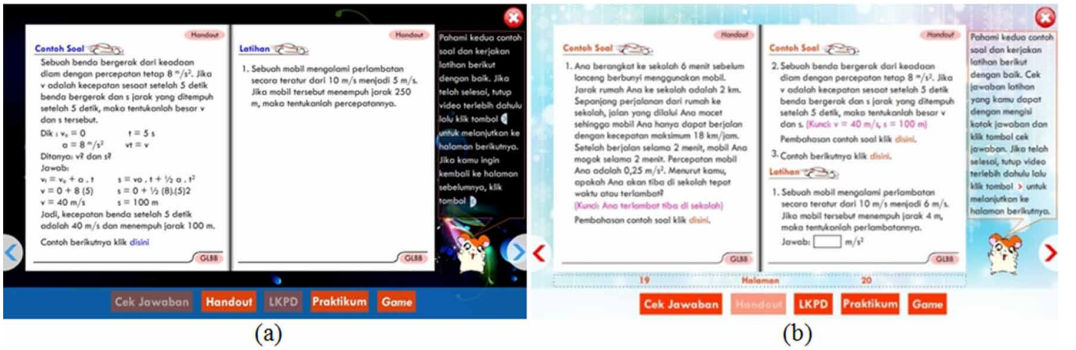
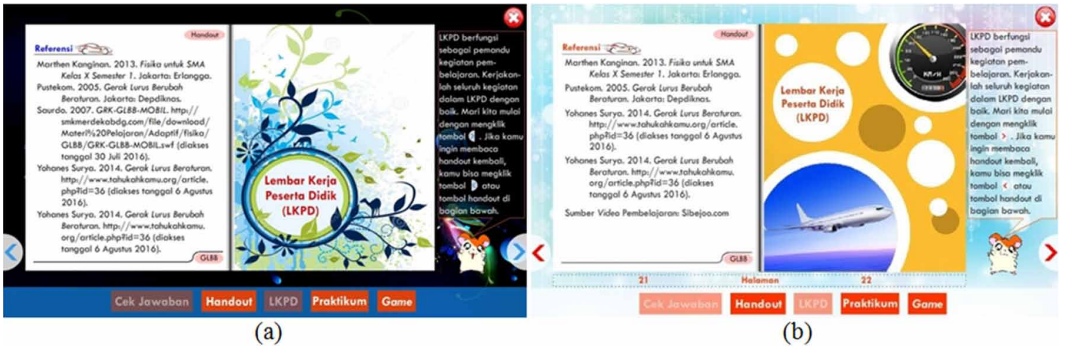


Figure 8. Revision of student worksheet design cover: (a) Before and (b) After



Expert B suggested enhancing the interactivity in the interactive multimedia learning materials. Therefore, an answer box was added to the exercise to help students check their answers, with a dialog box appearing to notify students' whether their answer is correct or incorrect (Figure 10). Finally, expert D suggested paying attention to punctuation marks and foreign language writing formats (Figure 11). The revision list for the handout and student worksheets can be seen in Table 3 and Table 4, respectively.

Figure 9. Revision of student worksheet conclusion: (a) Before and (b) After

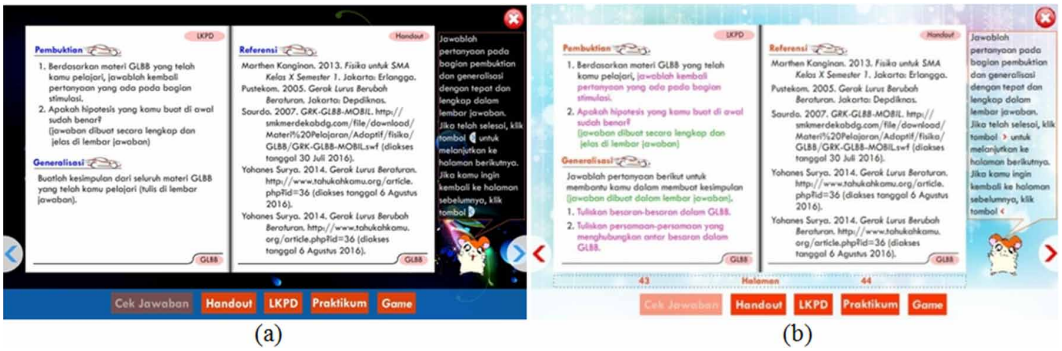


Figure 10. Revision of interactivity: (a) Before and (b) After

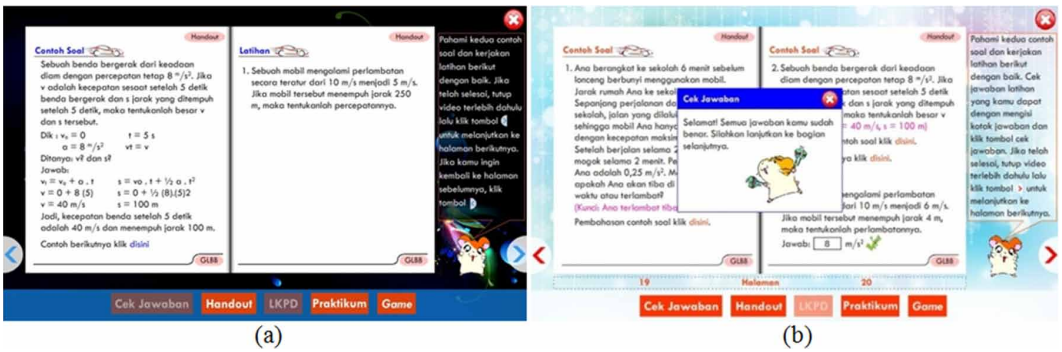
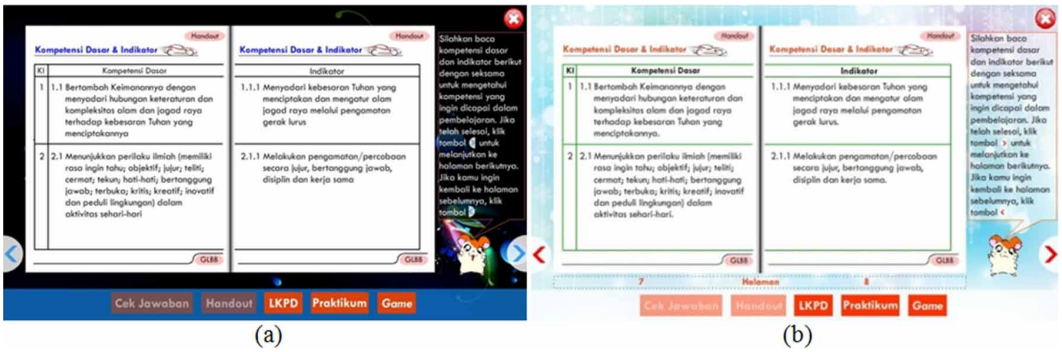


Figure 11. Revision of writing format: (a) Before and (b) After



5.2. Practicality Testing

5.2.1. Participant, Procedures, Materials, and Instrument

The interactive multimedia learning materials practicality testing involved 30 students in first grade at Don Bosco Senior High School. There were five steps in this phase: 1) the objective and user guide were explained to teachers and students; 2) after the interactive multimedia learning materials were introduced, students were requested to collaborate in their discussion groups; 3) in groups,

Table 3. Revision of handout validity

Criteria	Revision
1. Content validity	Indicator 1.7 Adjust stimulant in learning materials with the discovery learning concept.
	Indicator 1.8 Adjust image in the handout cover with learning material.
	Indicator 1.9 Hide the answer in the examples.
2. Construct validity	Indicator 2.3 Change the background color.
	Indicator 2.9 Give variation in space between paragraphs.
	Indicator 2.10 Change subtitle color and add color in text for emphasis the sentences.
	Indicator 2.11 Add check answer box in the exercise.
3. Language validity	Indicator 3.4 Adjust foreign language writing format and complete the punctuation mark.
	Indicator 3.7 Change the inconsistent term in exercise.

Table 4. Revision of student worksheet validity

Criteria	Revision
1. Content validity	Indicator 1.6 Adjust image in the student worksheet cover with learning material.
	Indicator 1.9 Give several questions to help students in making conclusions.
2. Construct validity	Indicator 2.3 Change the background color.
	Indicator 2.9 Give variation in space between paragraphs.
	Indicator 2.10 Change subtitle color and add color in text for emphasis the sentences.
	Indicator 2.11 Add check answer box in the data table.
3. Language validity	Indicator 3.4 Adjust foreign language writing format and complete the punctuation mark.

students learned with the discussion method, using interactive multimedia learning materials that were equipped with games and facilitated by the teacher; 4) the teacher observed the students to see their difficulties; and 5) students were requested to complete the practicality questionnaire. Thus, the interactive multimedia learning materials were revised according to practicality results.

The learning process in practicality testing was student-centered. Hence, students attempted to discover physics concepts using discovery learning procedures with interactive multimedia learning materials as their guidance. In addition, a game was incorporated into the interactive multimedia learning materials as a tool to assist students in utilizing the physics concept that they already learned. When students played the game, they applied both the physics concept and critical thinking skills. Consequently, the game could enhance their understanding of the physics concept and critical thinking skills. During the period, the teacher contributed as a facilitator. Hence, the teacher assisted students only by asking several questions to give ideas about discovering physics concepts throughout the learning process. At the end of the lesson, the teacher would check the progress and outcome of the students' learning process and helped them address deficiencies in their concepts or elaborate their learning.

The practicality testing was completed in the classroom during four physics lessons, using the Windows operating system. During practicality testing, lesson materials were twice related to straight motion with constant acceleration, and twice related to Newton's Law. In addition, the practicality testing of the handout and student worksheets used a different questionnaire sheet. Initially, the indicators for practicality testing were developed based on three aspects: learnability, effectiveness, and satisfaction (Kim & Jin, 2015). These aspects were expanded into several indicators: learnability (7

indicators), effectiveness (5 indicators), and satisfaction (2 indicators). The participants were requested to give responses using a 4-points Likert scale, from strongly disagree to strongly agree. At the end of the practicality questionnaire, an open-ended question was added to request recommendations for revising the interactive multimedia learning materials. The analysis results of practicality are explained in the next section.

5.2.2. The Result of Practicality Testing

Based on the practicality testing, it can be concluded that the practicality of interactive multimedia learning materials was above average for three aspects: learnability, effectiveness, and satisfaction. The average responses of 30 students for the handout and student worksheets are presented in Table 5 and Table 6, respectively. Furthermore, in an interview with the teacher, the teacher recommended using page numbers to make the interactive multimedia learning materials easier to use. In addition, according to the practicality questionnaire, several students stated they were uncomfortable sharing a laptop with their friends during the lesson because they could not use the interactive multimedia learning materials to their liking.

Table 5. Handout practicality results

Aspect	Statement	Average Responses at Field Testing			
		1st	2nd	3rd	4th
Learnability	Interactive multimedia handout is easy to use.	2.40	2.67	2.93	3.07
	Images in the interactive multimedia handout are clear and easy to understand.	2.73	3.30	3.23	3.40
	Graphs in the interactive multimedia handout are clear and easy to understand.	2.70	3.17	3.13	3.23
	Videos in the interactive multimedia handout are clear and easy to understand.	2.67	3.30	3.20	3.47
	Animations in the interactive multimedia handout are clear and easy to understand.	2.60	3.37	3.30	3.60
	Language in the interactive multimedia handout is clear and easy to understand.	2.93	3.17	3.20	3.40
	I can understand the learning steps in interactive multimedia handout easily.	2.70	2.90	3.10	3.27
Effectiveness	I can easily understand the physics material using the interactive multimedia handout.	2.60	3.20	3.07	3.47
	I can quickly understand the physics material using the interactive multimedia handout.	2.63	3.17	3.07	3.47
	Interactive multimedia handout makes me accustom in solving problems.	2.73	3.00	3.20	3.33
	Questions in interactive multimedia handout help me understand the physics material.	2.67	2.83	3.13	3.27
	User guide provided help me in operate interactive multimedia handout.	2.63	3.17	3.27	3.53
Satisfaction	I am satisfied using the interactive multimedia handout.	2.67	3.10	3.23	3.47
	I feel interested in learning using interactive multimedia handout.	3.03	3.43	3.33	3.57

Table 6. Student worksheet practicality results

Aspect	Statement	Average Responses at Field Testing			
		1st	2nd	3rd	4th
Learnability	Interactive multimedia student worksheet is easy to use.	2.57	2.70	2.97	3.13
	Images in the interactive multimedia student worksheet are clear and easy to understand.	2.70	3.33	3.07	3.43
	Animations in the interactive multimedia student worksheet are clear and easy to understand.	2.83	3.30	3.13	3.57
	Simulation in the interactive multimedia student worksheet is clear and easy to understand.	2.77	3.20	3.17	3.60
	Game in the interactive multimedia student worksheet is clear and easy to understand.	2.67	3.07	3.13	3.43
	Language in the interactive multimedia student worksheet is clear and easy to understand.	2.80	2.97	3.20	3.23
	I can understand the learning steps in interactive multimedia student worksheet easily.	2.77	3.00	3.10	3.33
Effectiveness	I can easily understand the physics material using the interactive multimedia student worksheet.	2.63	2.97	3.10	3.33
	I can quickly understand the physics material using the interactive multimedia student worksheet.	2.53	2.80	3.23	3.20
	Interactive multimedia student worksheet makes me accustom in solving problems.	2.70	2.90	3.07	3.37
	Questions in interactive multimedia student worksheet help me understand the physics material.	2.77	2.90	3.20	3.37
	User guide provided help me in operate interactive multimedia student worksheet.	2.83	3.17	3.23	3.33
Satisfaction	I am satisfied using the interactive multimedia student worksheet.	2.67	3.00	3.10	3.27
	I feel interested in learning using interactive multimedia student worksheet.	2.97	3.27	3.23	3.70

5.3. Effectiveness Testing

5.3.1. Participants, Instrument, and Analysis

Thirty students in first grade of Don Bosco Senior High School who were involved in practicality testing for the interactive multimedia learning materials were also involved in effectiveness testing. In addition, effectiveness testing was completed at the same time as practicality testing, using the same materials that were straight motion with constant acceleration and Newton's Law. The instrument that was used during effectiveness testing was an essay test, and it was conducted after students completed their lesson using interactive multimedia learning materials. After that, students' answers were analyzed using a critical thinking skills rubric. This rubric was developed based on five critical thinking skills indicators: 1) analysis (5 indicators), 2) evaluation (3 indicators), 3) inference (3 indicators), 4) deductive (4 indicators), and 5) inductive (3 indicators). Examples of the critical thinking skills rubric are presented in Figure 12. After the students' scores were obtained for each indicator based on the critical thinking skills rubric, the scores were converted into percentages. These percentages represented the students' critical thinking skills achievement for each learning process. The results are explained in the next section.

Figure 12. Critical thinking skills rubric

SCORING RUBRIC

No	Question	Assessment Guidelines	Critical Thinking Skills	The Number of Descriptor
1	Andi berangkat ke sekolah pukul 6.45 menggunakan sepeda motor. Jarak rumah Andi ke sekolah adalah 10 km. Setelah berjalan selama 5 menit, motor Andi mogok selama 5 menit. Percepatan Andi selama mengendarai sepeda	Andi berangkat dari rumah pukul 6.45 dan harus tiba sekolah pukul 7.00 agar tidak terlambat, sehingga waktu total Andi berjalan adalah 15 menit. Diketahui: t_{total} = 15 menit = 900 s, s_{total} = 10 km = 10000 m, t_1 = 5 menit = 300 s, t_2 = 5 menit = 300 s, a = 1 m/s², v_{maks} = 15 m/s	Analysis (a)	2
			Analysis (b)	6
			Analysis (c)	3
			Analysis (d)	0
			Analysis (e)	0
			Evaluation (a)	3

In addition to critical thinking skills, the students' achievement in learning physics concepts was also measured. However, this measurement was based on learning outcomes in physics. Three learning outcomes for both materials were: 1) students can calculate the units that are involved with lesson material; 2) students can apply the physics concept that they learned to find a solution for a problem; and 3) students can apply the physics concept in their daily activities. Critical thinking skills and learning outcomes in physics were assessed simultaneously. Thus, students' answers were analyzed in two different ways, each for critical thinking skills and learning outcomes in physics. However, the assessment and the result for students' achievement in learning physics concepts were not explained in this paper because they were not in line with the purpose of this paper.

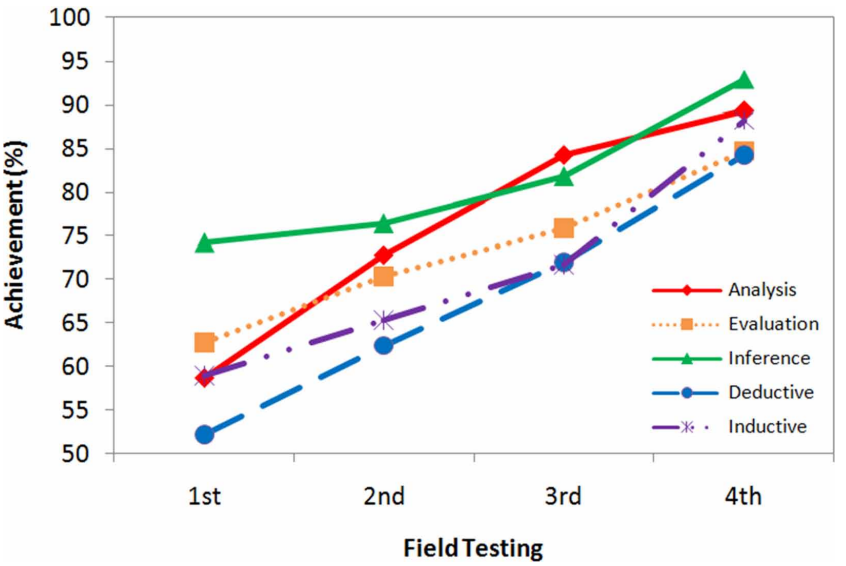
5.3.2. The Result of Effectiveness Testing

Students' critical thinking skills achievement for each learning process is presented in Figure 13. According to Figure 13, the critical thinking skills indicators from the first to last lesson increased gradually. Based on these results, it can be stated that students' critical thinking skills were improving. Therefore, it can be concluded that the utilization of interactive multimedia learning materials equipped with games can enhance students' critical thinking skills, and it was effective in learning physics concepts related to straight motion and Newton's Law materials.

6. DISCUSSION

Based on the handout and student worksheet validation, the value of content and construct validity were almost the same, although the language aspect is slightly low. This happened because of the author's negligence when developing interactive multimedia learning materials. Writing errors happened often, including missing punctuation marks and several incomplete foreign language translations. In these

Figure 13. Indicator achievement of critical thinking skills



cases, when completing the final version of interactive multimedia learning materials, the author performed self-evaluation and peer reading to prevent a reoccurrence of the same writing errors.

In field tests, students were not satisfied when using the interactive multimedia learning materials. This was due to several conditions. First, not all students could bring a laptop to school, so they had to share a laptop with their friends. Consequently, several students felt uncomfortable with this situation, stating they wished to learn with interactive multimedia learning materials using their own laptops and according to their unique learning styles. Students have three learning styles: visual, aural, and kinesthetic (Deporter & Sarah, 2000). When two students with different learning styles learned with the same laptop, they could not learn in accordance with their learning styles, which generated discomfort and reduced their motivation to learn. Second, there was also a time limitation during the research. As the result, not all of the media (especially video) could be learned by students in class, even though there were explanations of material and examples to help students learn from video. This reduced the function of the media, which was meant to clarify information to accelerate the students' achievement of learning objectives (Arsyad, 2007). These two conditions made practicality of interactive multimedia learning materials low.

Several additional conditions were observed in the group activities. At the beginning of each lesson, students always checked the game first. They checked it thoroughly until they knew what the game was about and what responses the game would present for their right and wrong answers. After they were satisfied with their review of the game, they would start their learning process. In the learning process, when students were requested to answer some questions and they obtained the right answer, they would cheer with excitement when they encountered the cheerful animation and congratulatory response from the interactive multimedia learning materials. When they submitted a wrong answer and encountered the dejected animation, they were eager to find the right answer.

During the learning process, several students wished to have their own laptops in order to learn alone. However, when playing the game, students tended to play in a group with their friends, especially in the game with a time limitation. By collaborating with groups, students could solve the game more easily. In addition, when students played the game, they would solve the problem seriously to obtain the right answer. For example, in the snake and ladder game, students obtained 1000 coins in the beginning. After filling in the right answer, they obtained several coins; but when they fill in

the wrong answer, they lost several coins because they were chased by the snake. The following is a conversation between two students while they were answering a question in this game:

A: Are you sure that is the right answer? (with a doubtful face)
B: Yes, I already calculated it.

(After that, they clicked the check answer button. The snake animation appeared and they lost their coins.)

A: Oh no, you see that, the answer is wrong. Now we lost our coins. (feeling disappointed)
B: How can that answer be wrong, the formula and the calculation is right. (with curious face)

Teacher: Now let's analyze the problem again …… (guiding the students to realize the error in their analysis)

According to this conversation, the game generated a condition in which the students were confronted by the gap between their analysis and the right answer. Consequently, this condition enhanced their curiosity, responsibility, and critical thinking skills. When the teacher gave them several questions to guide them in realizing the error in their analysis, they applied their critical thinking skills to process the problem, teacher's question, physics concept, and formula they used until they discovered the right solution for the problem. However, in a game in which the answers were in multiple choice format, students tended to use trial and error to obtain the right answers. Thus, they felt eager to find the right answers by random clicking and would avoid analyzing the problem to obtain the right answer.

For the next project, several changes can be made to prevent the conditions that lowered the practicality of interactive multimedia learning materials. For laptop deficiency, the interactive multimedia learning materials can be utilized in a computer laboratory, enabling students to learn individually on the computer. For time deficiency, the teacher can encourage students to further their learning at home, allowing them to learn the material thoroughly and independently assisted by the media. To prevent the problem of the students' random clicking in the game, the method of answering questions can be changed. In particular, multiple choice questions should be avoided (Ke, 2008). One method that can be utilized to replace multiple choice is fill in the blank. With this method, students must analyze the problem until they obtain the right answer, and they cannot use trial and error or random clicking to obtain the right answer.

In the first field test, the achievement of critical thinking skills was low. This happened due to the students' hesitation and confusion about how to use the interactive multimedia learning materials for the first time. Therefore, habituation is needed when using interactive multimedia (Hayumuti, Susilo, & Manahal, 2016). In addition, students were not familiar with discovery learning procedures; hence, they still needed the teacher's assistance in the learning process. Further, students were not accustomed to analyzing a problem when answering an essay question.

In the second field test, several students were able to learn independently, while others still required the teacher's assistance. The critical thinking skills achievement was enhanced in this field test. In the third and fourth field tests, students were able to learn independently using discovery learning procedures, and they were able to analyze the problems. Thus, in third and fourth field tests, achievement of critical thinking skills was enhanced gradually.

According to the students' critical thinking skills achievement graph, it can be seen that the analysis indicator was enhanced sharply from the first to the third field test; but in the fourth field test, the enhancement was not sharp enough. This happened because of several students' negligence in writing the units when collecting information from the problem, while accuracy is one of the

standards of critical thinking skills (Paul & Elder, 2012). In the fourth field tests, students were able to collect information, understand the questions, and obtain conclusions. Therefore, the inference in this field test was sharply enhanced.

The least deductive improvement was in the third field test. This condition occurred due to the students' deficiency in understanding the difference between the coefficient of static friction and kinetic friction. In addition, students could not entirely apply the concept of Newton's Law in a given problem. In the first problem on the third field test, students were asked to define Newton's Law concept that is involved when a man pushes a cupboard. Only several students were able to associate the three of Newton's Law in this occasion, while others could only associate one or two of Newton's Law. Consequently, the enhancement of inductive achievement was the lowest in the third field test.

7. CONCLUSION

This paper has presented the development of interactive multimedia learning materials equipped with games to improve students' critical thinking skills. In general, the developed interactive multimedia learning materials equipped with games have been valid based on content, construct, and language aspects. Furthermore, the materials have been practical to use, based on learnability, effectiveness, and satisfaction aspects. In addition, they have been effective for improving students' critical thinking skills.

The next step of this project is dissemination in several schools to obtain responses and feedback for the interactive multimedia learning materials. After that, further quasi-experimental research is needed to measure the impact of interactive multimedia learning materials in improving critical thinking skills in one group compared to a control group that does not use interactive multimedia learning materials.

REFERENCES

Amory, A., Naicker, K., Vincent, J., & Adams, C. (1999). The use of computer games as an educational tool: Identification of appropriate game types and game elements. *British Journal of Educational Technology*, *30*(4), 311–321. doi:10.1111/1467-8535.00121

Arifin, E. G., Akhdinirwanto, R. W., & Fatmaryanti, S. D. (2013). Penggunaan Permainan Monopoli Fisika Dalam Pembelajaran Kooperatif Tipe Teams Games Tournament (TGT) Untuk Meningkatkan Kemampuan Berpikir Kritis Siswa. *Radiasi*, *4*(1), 81–85.

Arsyad, A. (2007). *Media Pembelajaran*. Jakarta: Raja Grafindo Persada.

Azwar, S. (2015). *Reliabilitas dan Validitas Edisi 4*. Yogyakarta: Pustaka Pelajar.

Bass, R. (2014). A Brief Guide to Interactive Multimedia and the Study of the United States. Retrieved from http://faculty.georgetown.edu/bassr/multimedia.html

Deporter, B., & Sarah, S. N. (2000). *Quantum Teaching*. Bandung: Kaifa.

Djamas, D. (2016). *Pengembangan Bahan Ajar Fisika Multimedia Interaktif Berbasis Discovery Learning Berbantuan Game untuk Meningkatkan Keterampilan Berpikir Kritis Siswa SMA*. Padang.

Facione, N. (2013). CCTST Test Manual. (M. Kelly, Ed.), Insight Assessment. San Jose: Insight Assessment.

Frasca, G. (2001). *Videogames of the Oppressed: Videogames as a Means for Critical Thinking and Debate*. Georgia Institute of Technology.

Hayumuti, Susilo, H., & Manahal, S. (2016). Penggunaan multimedia cd interaktif dalam peningkatan aktivitas dan hasil belajar ipa tema selalu berhemat energi di kelas iv sdn klanderan kediri. *Jurnal Pendidikan*, *1*, 1437–1441.

Ke, F. (2008). A case study of computer gaming for math: Engaged learning from gameplay? *Computers & Education*, *51*(4), 1609–1620. doi:10.1016/j.compedu.2008.03.003

Kim, T., & Jin, S. (2015). Development of auditory design guidelines for improving learning on mobile phones. *Computers & Education*, *91*, 60–72. doi:10.1016/j.compedu.2015.09.011

Oliver, H., & Utermohlen, R. (1995). *An Innovative Teaching Strategy: Using Critical Thinking to Give Students a Guide to the Future*.

Paul, R., & Elder, L. (2012). The Miniature Guide to Critical Thinking: Concepts and Tools. In *27th International Conference on Critical Thinking*. doi:10.1002/pfi.4170340606

Prastowo, A. (2011). *Panduan kreatif membuat bahan ajar inovatif menciptakan metoda pembelajaran yang menarik dan menyenangkan*. Yogyakarta: Diva Press.

Prensky, M. (2001). *Digital Game-Based Learning*. New York: McGraw-Hill.

Ramanujam, R. (2010). *Active Learning to Promote Critical Thinking Skills*. Glasgow.

Salen, K., & Zimmerman, E. (2004). *Rules of Play-Game Design Fundamentals*. London: Massachusetts Institute of Technology.

Sunardi, & Zenab, S. (2014). *Buku Guru Fisika untuk SMA/MA Kelas XI*. Bandung: Penerbit Yrama Widya.

Thiagarajan, S., Semmel, D. S., & Semmel, M. I. (1974). *Instructional Development for Training Teachers of Exceptional Children: A Sourcebook*.

van den Akker, J., Bannan, B., Kelly, A. E., Nieveen, N., & Plomp, T. (2013). Educational Design Research Educational Design Research. (T. Plomp & N. Nieveen, Eds.). Enschede: Netherlands Institute for Curriculum Development (SLO).

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