Interactive design for self-study and developing students' critical thinking skills in electromagnetic radiation topic

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Abstract. The purpose of this research are to create interactive electronic school books (ESB) for electromagnetic radiation topic that can be used for self-study and increasing students' critical thinking skills. The research method was based on the design of research and development (R&D) model of ADDIE. The research procedure is used limited the design of the product has been validated. Data source at interactive requirement analysis phase of ESB is student and high school teacher of class XII in Lampung province. The validation of interactive ESB designs is performed by experts in science education. The data of ESB interactive needs were collected using questionnaires and analyzed using quantitative descriptive. The results of the questionnaire obtained by 97% of books that are often used in the form of printed books from schools have not been interactive and foster critical thinking of students, and 55% of students stating physics books are used not meet expectations. Expectations of students in physics learning, teachers must use interactive electronic books. The results of the validation experts pointed out, the design of ESB produced is interactive, can be used for self-study, and increasing students' critical thinking skills, which contains instruction manuals, learning objectives, learning materials, sample questions and discussion, video illustrations, animations, summaries, as well as interactive quizzes incorporating *feedback* exam practice and preparation for college entrance.

1. Introduction

Learning science has an important role in preparing students to be able to think critically, creatively, logical and initiatives. This is in line with the goals of the curriculum in 2013, which is to encourage the students to be able to better observation, questioning, reasoning, and communicate what they earn or they know after receiving learning materials.

Physics is one branch of science that is closely related to the phenomena that occur in the natural environment. Not all physics phenomena can be observed directly, one of which is the material of Electromagnetic Radiation. Learning all this time, the teacher in teaching physics is still limited explanation abstract concepts through lectures, because the material is difficult in practice Electromagnetic Radiation directly, because to do the lab work on the matter requires powerful tools that are not available in schools. Physics is a unique and interesting science, because the subject of physics is difficult to teach and difficult to understand [1]. In the learning process, 83% of students sometimes experience difficulties in learning Physics materials, and 29% of students say teaching methods used by teachers are less appropriate.

Another difficulty is to bring scientific learning in teaching Electromagnetic Radiation, due to limitations of equipment and time owned lab. Limitations of time in discussing this matter because these materials are in the second semester of class XII in which schools use the time to prepare for the National Examination (UN). With the limited time of study that is owned by students of class XII in the even semester, not all class XII material in the even semester complete taught. Though thoroughly learned, the teacher only explains the material briefly or the important material that will be about to come out on the exam and the teacher only gives the exercise questions. Problems given by teachers are limited to the choice of plural and essay/descriptions that only require students to use related formulas, without making students think critically.

Physics learning can be used as a vehicle to train students to think critically. Based on preliminary research that is conducted by researchers to physics teachers and students of grade XII high school in Lampung province. The results of the questionnaire obtained by 97% of media often used in learning in the form of printed books from schools have not been interactive and foster critical thinking of students, as much as 70% of students stated the physics questions provided by teachers have not made students think critically. At 64%, students stated that the physics book should be useful in the learning process that is to facilitate the study of physics, and 55% of students stated that the physics book used in the lesson is less hopeful. Student expectations in physics learning, teachers must use electronic interactive school books (ESB) that can be used independently, which can facilitate the study of physics that contains instructions on the use, learning objectives, learning materials, sample questions and discussion, video illustration, animation, as well as interactive quizzes with feedback for exam exercises and preparing for admission to college.

In the learning process, in addition to using printed books from schools, there are students who seek other learning resources, one of them by using ESB. ESB can be used as a learning resource. Electronic books have a coherent presentation format, both the language, the high level of scholarship, and the extent of the discussion [2]. An electronic book is a book in electronic format containing information that can be texts or images; another advantage of ESB is to be able to display multimedia illustrations, such as animation [3].

Some Physics phenomena on certain subject matter cannot be observed directly by the students, because it is an abstract review, one of them is on Electromagnetic Radiation material. Innovative process of physics learning, which can facilitate students in observing the phenomena that are difficult to observe directly, one of which uses ESB featuring multimedia illustrations. Multimedia is an instrument that can create dynamic and interactive presentations by combining text, graphics, animation, audio, and video [4]. This multimedia-based ESB learning aspect supports a learner-centered learning strategy where each learner is responsible in his/her own learning process [5]. The media can be arranged so that learners can independently learn the material, and gain more knowledge, so that students are able to learn independently.

Physics can be regarded as a science that encourages students to think high-level, it makes enormous academic demands on students in learning [1,6]. Knowledge gained through higher-order thinking processes is easier to transfer, so students with deep conceptual understanding. High-level thinking skills include the ability to think critically. Students who are able to think critically can solve problems effectively [7]. By seeing the demands of the current learning curriculum, students' understanding of concepts can be improved through the development of students' critical thinking skill.

The purpose of this research is to make electronic school book (ESB) interactive electromagnetic radiation material that can be used for self-study and improve students' critical thinking ability. Until recently, a book like this for electromagnetic radiation matter yet, because the material electromagnetic radiation is very abstract, so to solve this problem required electronic school books (ESB) interactive.

Methods and Materials

The research method is based on research and development (R&D) design, which uses the ADDIE development model, consisting of analysis, design, development, implementation, and evaluation. The research procedure used is limited to the validated design stage of the expert. The first stage is the analysis. The ESB needs analysis phase uses interactive data sources of 87 high school students and 2 physics teachers drawn at random from 2 different SMAs in Lampung Province. ESB needs data were collected using a questionnaire. Questionnaire needs analysis is done to get information about real conditions in the learning process in school. Data were analyzed quantitatively descriptively. After performing the data analysis, then made an interactive ESB design followed by design validation stages. This design validation test is performed, to know concepts, formulas, images, animations, simulations, and videos, as well as critical thinking types contained in interactive ESB. Interactive ESB design validation is performed by experts in science education by using expert test instrument in the form of ESB interactive design score sheet. Expert validation test assessment guides are presented in Table 1.

Table 1. **Rubric Assessment Test Validation Expert**

Choiches	Score
Very Important	5
Important	4
Quite Important	3
Less Important	2
Umimportant	1

The results of average score are searched by using below formula:

$$\text{Average Score} = \frac{Total\ Score}{Number\ of\ experts}$$

Having obtained the average, then converted to the assessment statement. The conversion of the score into an assessment statement is presented in Table 2.

Table 2. **Score Convertion**

Average Score	Decision
4,20 – 5,00	It is very important to be put in an interactive ESB
3,40 – 4,19	It is important to be put in an interactive ESB
2,60 – 3,39	It is quite important to be put in an interactive ESB
1,80 – 2,59	It is less important to be put in an interactive ESB
1,00 – 1,79	It is not important to be put in an interactive ESB

3. Results and Discussion

Based on the results of questionnaire of requirement analysis, the preparation of ESB interactive design of Electromagnetic Radiation material for self-study and improving students' critical thinking skill (Figure 1). Interactive ESB is designed as a learning resource that can be used independently by students containing instruction manuals, learning materials, sample questions and discussion, video illustrations, animations, summaries and interactive quizzes with feedback.

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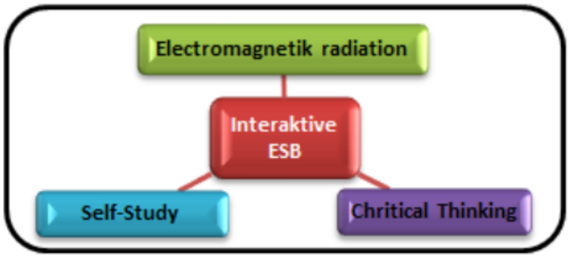

Figure 1. Design chart of interactive ESB

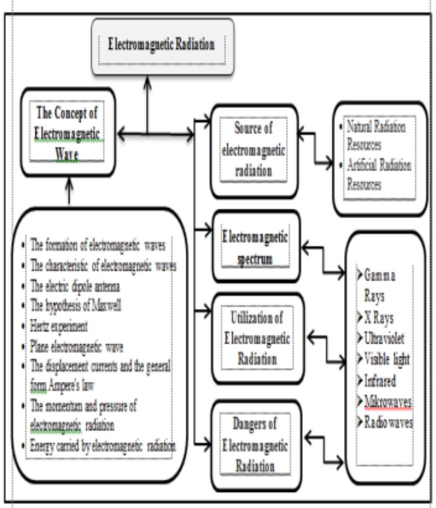

Figure 2. Electromagnetic Radiation Topic

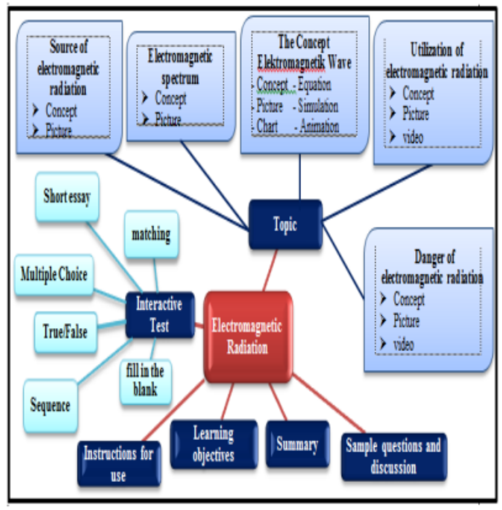

Figure 3. Interactive ESB Design of Electromagnetic Radiation

Based on the results of expert validation tests, the scope of electromagnetic radiation material consists of the concept of electromagnetic waves consisting of the properties of electromagnetic waves, the formation of electromagnetic waves, electric dipole antennae, the Maxwell hypothesis, Hertz experiments, current displacement and general form of Ampere law, electromagnetic waves, momentum and pressure of electromagnetic radiation, as well as the energy that electromagnetic radiation carries. Subsequent material coverage is the spectrum of electromagnetic radiation, electromagnetic radiation sources, and the utilization of electromagnetic radiation and the danger of electromagnetic radiation (Figure 2).

Based on the expert validation results, it is obtained ESB interactive design of electromagnetic radiation material (Figure 3). This interactive ESB design contains usage instructions, learning objectives, learning materials, sample questions and discussion, and interactive quizzes with feedback. Learning materials in this interactive ESB design are equipped with pictures, animations, simulations, and videos. Electromagnetic radiation material is an abstract material, or cannot be observed directly by students. Then it is needed an innovation in learning. There are many innovations in education and knowledge, from face to face with virtual education, different technologies have played a big role at different times [8]. The advancement of computer technology has attracted the attention of many educators. The use of technology in education provides a more suitable learning environment for learning, and helps to increase student motivation. Computer-based teaching has had an impact on the development of educational technology for the most part in the twenty-first century, and has resulted in the production of computer-based instruction software [9].

Table 3. Expert Experiment Test Results of ESB Interactive Electromagnetic Radiation Design

No	Topic	The result of expert validation	Note
A	**The Concept Electromagnetic Wave**		
	1. The formation of electromagnetic waves		
	a. Concept The formation of electromagnetic waves	*4*	*important*
	b. Picture lines of electric field	*3,33*	*important*
	c. Animation lines of electric field	*3,33*	*important*
	2. Characteristic of electromagnetic waves		
	a. Concept characteristic electromagnetic waves	*4*	*important*
	3. The displacement currents and the general form Ampere's law		
	a. Concept The displacement currents and the general Form Ampere's law	*3,83*	*important*
	b. Picture The displacement currents	*3*	*quite important*
	c. Equation Ampere's law	*3,67*	*important*
	d. Simulation the displacement currents	*3*	*quite important*
	4. The electric dipole antenna		
	a. Concept the electric dipole antenna	*3,33*	*quite important*
	b. Picture current the electric dipole antenna	*3,33*	*quite important*
	5. The hypothesis of Maxwell		
	a. Concept electromagnetic Maxwell	*3,67*	*important*
	b. Equation speed of visible electromagnetic waves	*3,67*	*important*
	6. Hertz experiment		
	a. Concept Hertz experiment	*3,33*	*quite important*
	b. Picture Hertz experiment	*3,33*	*quite important*
	c. Simulation Hertz experiment	*3,67*	*important*
	7. Plane electromagnetic wave		
	a. Concept Plane electromagnetic wave	*3,33*	*quite important*
	b. Equation Faraday's law and electric flux	*3,33*	*quite important*
	c. Picture Plane electromagnetic wave	*3,67*	*important*
	d. Chart Plane electromagnetic wave	*3,56*	*important*
	8. The momentum and pressure of electromagnetic radiation		
	a. Concept the momentum and pressure of Electromagnetic radiation	*3*	*quite important*
	b. Equation the momentum and pressure of Electromagnetic radiation	*2,33*	*less important*
	c. Picture the momentum and pressure of Electromagnetic radiation	*2,67*	*quite important*
	9. Energy carried by electromagnetic radiation		
	a. Concept energy carried by electromagnetic radiation	*3,67*	*important*
	b. Equation total instantaneous energy density	*3,67*	*important*
B	**Electromagnetic Spectrum**		
	a. Concept electromagnetic spectrum	*4,33*	*very important*
	b. Picture electromagnetic spectrum	*4,33*	*very important*
C	**Source of electromagnetic radiation**		
	a. Concept Source of electromagnetic radiation	*3*	*quite important*

	b. Picture Source of electromagnetic radiation	*3*	*quite important*
	c. Simulation Source of electromagnetic radiation	*2*	*less important*
	d. Video Source of electromagnetic radiation	*2,44*	*quite important*
D	**Utilization of electromagnetic radiation**		
	a. Concept Utilization of electromagnetic radiation	*4,33*	*very important*
	b. Picture Utilization of electromagnetic radiation	*4,33*	*very important*
	c. Video Utilization of electromagnetic radiation	*5*	*very important*
E	**Danger of electromagnetic radiation**		
	a. Concept Danger of electromagnetic radiation	*5*	*very important*
	b. Picture Danger of electromagnetic radiation	*4,33*	*very important*
	c. Video Danger of electromagnetic radiation	*4,67*	*very important*

Based on expert validation, component concepts, graphics, formulas, images, animations, video illustrations are required in ESB interactive electromagnetic radiation materials (Table 3). Along with the development of information and communication technology (ICT), e-learning has emerged as an innovative approach to promote learning to students for continuing to higher education. E-learning provides an alternative to traditional classroom education and allows students to access information only without time constraints [10]. One of the E-learning that can be used is Electronic School Book (ESB). Electronic books are defined as the electronic form of a book with features similar to traditional print books including pages that can "change," and digital features can help readers like word pronunciation, text highlighting, and hypermedia (e.g. video, animation, and sound) [11]. One of the innovations of physics learning that can associate technology into learning is by using ESB featuring interactive multimedia illustrations. The term 'interactive multimedia' is catching all phrases to describe a new wave of computer software that is primarily concerned with the provision of information. The 'multimedia' component is characterized by the presence of text, images, sound, animation and video [8]. In line with technological advances: technological devices, in particular computers began to be used in educational environments to develop audio-visual materials such as animation and simulation, resulting in the development of computer-based instructional techniques [9].

Based on the data of expert validation results, the images to be contained in the interactive ESB are for the concept of electromagnetic wave formation consisting of electric field lines drawings, GEM sketch drawing, and current drawings in electric dipole antennas, and radiation intensity images produced by oscillating electric dipoles. In the spectrum of electromagnetic materials, the images of the spectrum of electromagnetic waves are gamma rays, x-rays, ultraviolet light, visible light, infrared rays, microwaves and radio waves, and contain images of electromagnetic radiation, electromagnetic radiation drawings and electromagnetic radiation hazards. The animations that will be contained in the interactive ESB are the electric field lines out of the positive charge toward the negative charge. The simulations contained in interactive ESBs include Hertz experimental simulations, and simulations of *Phet Simulation* about electromagnetic radiation depicting electrical charge lines, radio waves depicting electron position graphs.

Videos contained in ESB are interactive utilization of electromagnetic radiation, and the danger of electromagnetic radiation. E-learning has recently become a promising alternative to classroom learning. Video is a rich and powerful media used in e-learning. It can present information in an interesting way. Interactive video improves learning interactivity, thus potentially improving students' effectiveness and student motivation consistently [8]. One of the features that make learning interesting for learners is a real-life concept that makes learning more meaningful when the latest technology is used unlike traditional methods. In addition, most of the knowledge related to natural phenomena is now available in the computer environment. That is why, when teachers use computers and other technologies as teaching tools by means of students can visualize in the form of three dimensions, this will help students to find ways to relate learning to their environment [13]. Interactive test types that are considered to be very suitable in interactive ESB are the multiple choices, true/false, fill in the blank, matching, short essay, and sequence types. The type of interactive test used should adjust the material characteristics. Computer Based Instruction (CBI) allows students to learn by themselves by evaluating and reflecting on their learning. CBI motivates children to learn better by providing direct feedback and reinforcement by creating a fun and exciting atmosphere [9].

The use of computers in education has a positive effect to increase students 'attention and curiosity, and help provide in conceptual learning, so as to enhance students' critical thinking skills. Critical thinking is a learned skill that must be developed, practiced, and continuously integrated into the curriculum to engage students in active learning. Instructions that support critical thinking use interrogation techniques that require students to analyze, synthesize, and evaluate information to solve problems and make decisions (think) not just to repeat information (memorization) [7]. Critical thinking is a group of skills that help to achieve information and outperform difficulty dealing with ease. Critical thinking is not a congenital characteristic, it can be taught, explained and easily applied in the learning process [14]. The most important role of teachers in developing students 'critical thinking skills is to create instructional applications and environments that support critical thinking students, allowing students to comment on lessons, incidents, conceptions and events from a variety of perspectives vital to improving students' critical thinking [15]. Critical thinking skills are an educational goal because through this learner's skill move away from learning to think about what they are learning and not what others are learning [16]. The development of critical thinking as a result of desirable education requires teaching methods that help learners improve their ability to think critically [17]. On the one hand, e-learning is not limited to geographic barriers. Students can engage in self-learning, and learning resources can be used repeatedly [18].

4. Conclusion

Expert validation results show that the resulting ESB design can improve students' critical thinking skills, which include instruction manuals, learning objectives, learning materials, sample questions and discussion, video illustrations, animations, summaries and interactive quizzes with feedback, and can be used independent and interactive.

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