The effectiveness of interactive e-book quantum phenomena compiled with scientific approach in improving higher order thinking skills

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A Suyatna*, C Ertikanto, K Herlina and F A Pradana
Program Studi Magister Pendidikan Fisika, Universitas Lampung, Jl. Sumantri Brojonegoro No. 1, Bandar Lampung 35145, Indonesia

*asuyatna@yahoo.com

Abstract. This study was aims to examine the effectiveness of interactive e-book quantum phenomena compiled with scientific approach in improving higher order thinking skills that have been developed by the authors. The method used was research and development. The development design was ADDIE development model that included five phases of activity that is analyse, design, development, implementation, and evaluation. Implementation phase to test the effectiveness of e-book, using pre-test post-test. Data were collected by using questionnaires and written tests. The effectiveness was measured by comparing pre-test and post-test using using Two Related Samples Test, Wilcoxon and by calculating the normalized gain. The results of evaluation phase showed, interactive electronic book quantum phenomena compiled with scientific approach, effective in improving higher order thinking skills. The learning outcomes of quantum phenomena of students learning through interactive e-books compiled with scientific approach has increased in 67% indicator HOTS at level of trust 95%. The average N-Gain learning result of quantum phenomena is 0.31, entered in moderate category.

1. Introduction

Results of questionnaire analysis obtained from 697 high school students of class XII IPA from 48 classes, 17 schools in 5 regencies / cities Lampung Province and 22 physics teachers class XII high school, showed the learning process has not lead to higher order thinking skills (HOTS). According to the students, the convenient way to learn physics is by doing experiments directly followed by seeing what the teacher explained and listening to teacher explanations. The same thing is also mentioned by the teacher that is teaching which gives comfort to the students by doing the experiment directly, see the demonstration experiment or example of physics application in everyday life, followed by listening to teacher explanation. However, experimenting directly in class XII of even semester classes, such as quantum phenomena, is difficult to implement because there is no suitable experimental tool in the school physics laboratory. Laboratory equipment required is a heavy equipment that is expensive and difficult to use by high school students. This problem can be solved by simulating experiments using virtual laboratory that can be packaged in the form of an interactive e-book. An interactive e-book can be defined as a form of presenting self-directed learning materials systematically arranged into the smallest learning unit to achieve learning objective, presented in an electronic format, in which each learning activity in it is linked by a navigation that makes learners become more interactive with the

program, complemented by interactive video, matter presentations, animations and experimental simulations that enrich the learning experience [1].

Quantum Phenomena in High School discussesBlack Body Radiation, Stefan-Boltzmann Law, Wien Shift Law, Rayleigh-Jeans Law, Planck Theory, Photoelectric Effect, Compton Effect, and X-Rays.Quantum Phenomenon is a material that is abstract, so there are often obstacles in explaining the material to students, especially teachers are required to implement learning using a scientific approach. Quantum physics studies things that are not directly observed by the senses, not interesting and not interested students, even though modern science and technology is currently developing as a result of the development and research of the topic. Quantum physics is the beginning of the development of microscopic physics studies, as the main basis for understanding the universe, therefore it is very important to learn [2,3]. Problems with this can be solved by utilizing an interactive e-book based on learning content development system (LCDS). LCDS is a software learning management system (LMS) to create e-learning content such as presentation of subject matter, quiz, games, test, animation, video, and other multimedia, can be interactive, accessible both online and offline [4].

Higher order thinking skills are needed to solve problems, make decisions, and explain the phenomena encountered in everyday life [5]. HOTS are needed to compete in this era of globalization. Therefore 21st century education goals need to be directed to encourage each individual to improve HOTS. The learning process should shift from teacher-centered to student-centered, from isolation to the network environment, from passive to active investigating, from abstracts to real-world contexts, from a single tool to a multimedia tool [6].

Learning through a scientific approach is a learning process designed in such a way that learners actively construct concepts, laws or principles through observing stages, formulating problems, collecting, analyzing data, drawing conclusions and communicating. Scientific approach has advantages: (1) improve intellectual ability, especially HOTS, (2) stimulate students' ability to solve a problem systematically, (3) create learning conditions where students feel that learning is a necessity, (4) achieve high learning result, (5) train students in communicating ideas [7,8]. This study is aims to develop and examine the effectiveness of interactive e-book quantum phenomena compiled with scientific approach in improving higher order thinking skills.

2. Research methods

The method used was research and development. The development design was ADDIE development model that included five phases of activity that is analyse, design, development, implementation, and evaluation. In the analysis phase, collected data about learning problems in class XII even semester of high school and the needs of students and teachers to learning resources that can be a solution to the problem. Data collected form 697 high school students of class XII IPA from 48 classes, 17 schools in 5 regencies/cities Lampung Province and 22 physics teacher class XII high school using questionnaires and analyzed using percentage techniques.

In the design phase, the researcher collected data about the material, material form, form questions, forms of learning media quantum phenomenon with reference to basic competence. Data were validated by the physics education experts and analyzed it using scoring techniques. The results of this stage analysis have been reported in the article [1]. The next stage is to create a story board and create an interactive e-book quantum phenomenon-based LCDS (Learning Content Development System) Program. The e-book validated by five experts and physics-learning practitioners. Validation includes material content and e-book design. Validation data is collected using instrument in the form of product assessment sheet. Each indicator of the assessment aspect was scored 1-4. A score of 1 indicates the product does not meet a valid prescription, while a score of 4 indicates the product meets a very valid prescription. Next the score of each indicator is summed and averaged, then converted to a scale of 100.

Implementation phase is done by testing the e-book product in the actual class. Implementation phase to test the effectiveness of e-book, using pre-test and post-test. Data were collected by using HOTS written tests. Data analyzed using Two Related Samples Test, Wilcoxon and by calculating the normalized gain [9].

3. Results and discussion

The interactive e-book of quantum phenomena for class XII students of high school in the second semester consists of the basic material: Black Body Radiation, Stefan-Boltzmann Law, Wien Shift Law, Rayleigh-Jeans Law, Planck Theory, Photoelectric Effect, Compton Effect, and X-Rays. Each subject matter is presented using a scientific approach, ie observing a physical phenomenon, questioning the phenomenon, investigating phenomena, making conclusions about a phenomenon, and communicating the conclusions obtained. Physical phenomena are shown in video form, narrative descriptions, graphs, simulations, or animations. Further challenged questions to be solved through experimental simulations. For example, in a photoelectric experimental simulation, a photoelectric effect phenomenon is presented, then asked the following questions: Mention metals that can be used in a photoelectric effect practicum? How are metallic characteristics that can be used? How is the relation between the wavelength of the light and the electron's movement velocity coming out of the metal? How is the relationship between the intensity of light and the number of electrons coming out of the metal? How is the relation between the wavelength of light and the stop potential of a metal? These questions can be answered after students doing experiment using photoelectric experimental simulation. In order to answer this question through experiments it is necessary to draw conclusions, the ability to elaborate, explain, and other abilities that are indicators of HOTS. This interactive e-book can therefore stimulate HOTS. The electronic book chart is presented in figure 1.

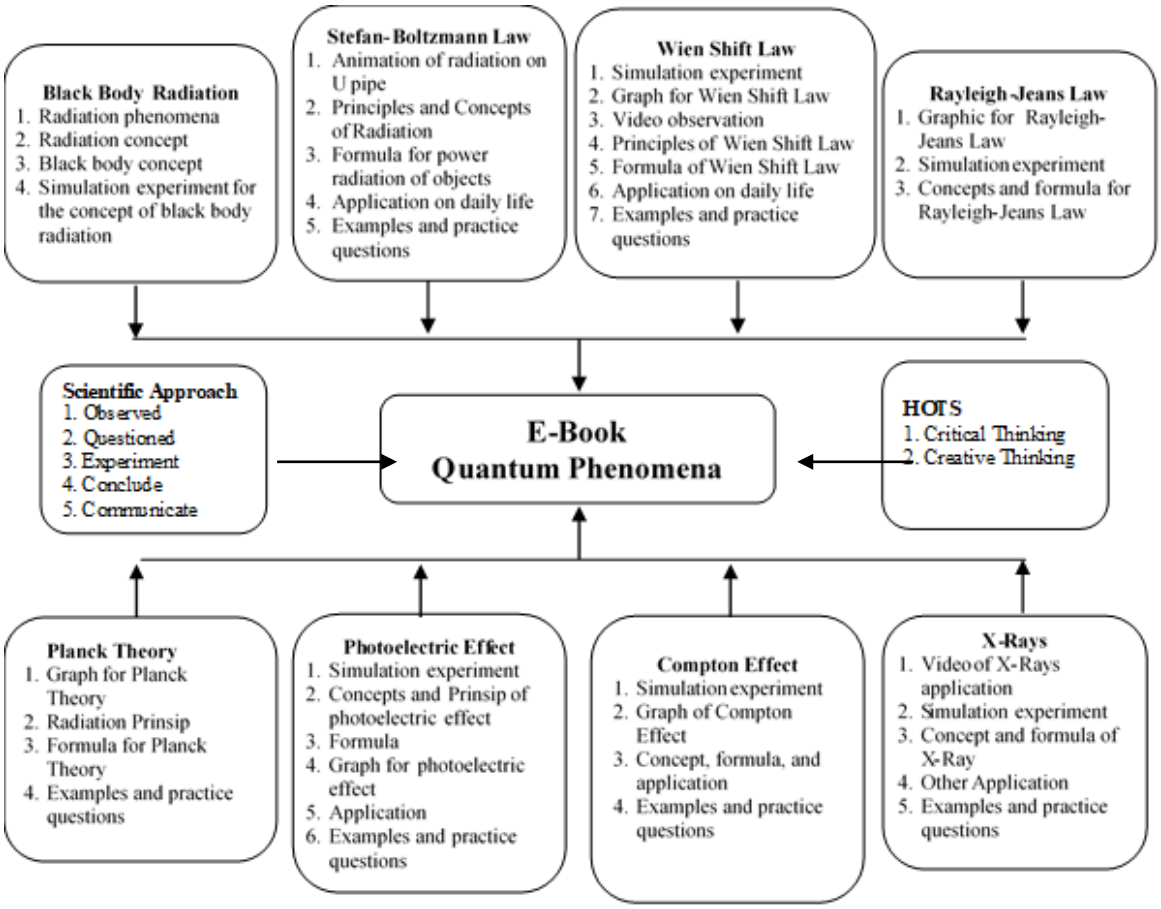

Figure 1. Interactive e-book structure of quantum phenomena.

This interactive e-book of quantum phenomena has been tested both in terms of content, design, ease of operation, and effectiveness in growing HOTS capabilities. The results of content validation test are presented in table 1 and the results of the design test are presented in table 2. Based on the two tables, it can be concluded that all aspects of content validation and validation aspects of the e-book is valid. It

should be emphasized that the validation test also measures the appropriateness of the e-book structure with the scientific approach and the suitability of the interactive e-book to self-direct learning.

Table 1. Content validation test results.

Aspect	Score	Category
Material completeness	93	Very valid
Material accuracy	88	Very valid
Accuracy of the test	90	Very valid
Material content updates	89	Very valid
Compliance with a scientific approach	93	Very valid

Table 2. Design validation test results.

Aspect	Score	Category
Layout design	86	Very valid
Typography	93	Very valid
Illustration	90	Very valid
Appropriate for self-directed learning	90	Very valid

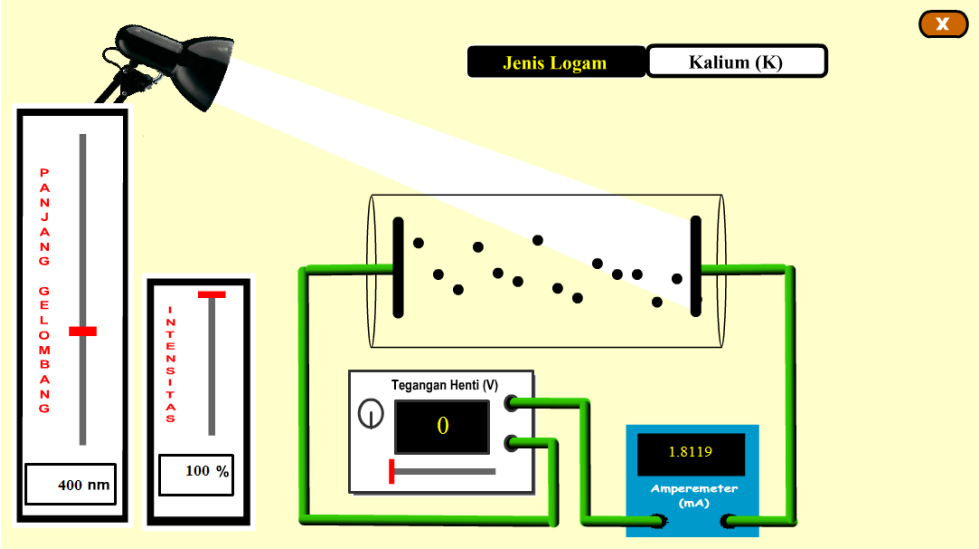

Figure 2. E-book page example of photoelectric effect experimental eimulation.

Experimental simulations provided on interactive e-books are: simulation of black body radiation experiments, Rayleigh-Jeans experiment simulations, photoelectric experiment simulation, Compton effect experiment simulations, and X-ray experiment simulations. Experimental simulations packed in an interactive e-book are the excellence of e-books compared to static e-books and textbooks. For example, photoelectric effect experimental simulation are designed so that students can determine the relationship between variables that affect the photoelectric effect (figure 2). Through experimental, students can determine which metal can be used in a photoelectric effect experiment, determining the metal characteristic that can be used for a photoelectric effect, determining the relationship between the wavelength of light and the velocity of the electron out of the metal, determining the relationship between the light intensity and the number of electrons out of the metal, determining the relationship between the wavelength of light and the stopping potential of a metal, determining the factors affecting the kinetic energy of the electron. This can stimulate the ability of HOTS.

The interactive e-book quantum phenomena was tested in one class XII students in the second semester of the academic year 2017/2018 from one of high school in Bandar Lampung. The number of

learning, including the implementation of the test was twice, conducted in April 2017. The first learning, students are taught how to use interactive e-book based LCDS and given the task to learn quantum phenomena using e-book independently. The second learning, the students asked to asking question about the matter that have not been understood, including the exercise in the interactive e-book. The learning is ended with a post-test. The test questions were designed to measure the HOTS indicator. Test to measure HOTS using essay problem, each question measures one HOTS indicator. Test results and data analysis are presented in table 3.

Table 3. The results of HOTS test data analysis.

Indicators	Pre-test	Post-test	N-gain	p
Critical thinking				
Give an explanation	3.64	6.86	0.33	0.000*
Build basic skills	3.17	6.66	0.50	0.000*
Make a conclusion	3.85	4.19	0.04	0.666
Provide further explanation	0.53	3.32	0.30	0.000*
Consider and integrate	0.87	2.73	0.15	0.000*
Average of Critical thinking	2.41	4.75	0.26	0.000*
Creative Thinking				
Thinking Well	0.00	0.18	0.02	0.180
Think flexible	5.27	6.00	0.06	0.119
Thinking original	0.91	7.12	0.65	0.000*
Think elaborative	3.61	7.68	0.65	0.000*
Average of Creative Thinking	2.45	5.25	0.35	0.000*
Average HOTS	2.43	5.00	0.31	0.000*

*) $p < 0.05$, different at 95% confidence level

The results of data analysis showed an increase in 67% indicator HOTS significantly at the level of confidence 95%. The average score of posttest is higher than the pretest with N-gain is in the category of moderate. This is shows the advantages of interactive e-books in developing HOTS. This advantage is related to the structure of the e-book. The interactive design makes it easy for students to choose and repeat the topics that have not been mastered. Interactive HOTS exercises allow students to get feedback from e-books on their learning progress. Learning outcomes using interactive media are better than others [10,11]. The experimental simulation helps students to understand the material. The results of this study are in accordance with the findings [12] that virtual laboratory applications made positive effects on students' achievements and attitudes when compared to traditional teaching methods. The simulations improved the students' ability to make acceptable predictions and explanations of the phenomena in the experiments. The use of simulations also fostered a significant conceptual change in the physics content areas that were studied [13]. The developed virtual chemistry laboratory software is at least as effective as the real laboratory, both in terms of student achievement in the unit and students' ability to recognize laboratory equipment [14]. The scientific approach to e-books trains students to think critically, systematically, and logically. Application examples through interactive video presentation provide further explanation on quantum phenomena. This is supported by the results of the study [15], students in the e-learning environment that provided interactive video achieved significantly better learning performance and a higher level of learner satisfaction than with non-interactive video, and without video. Video can be an effective medium to present authentic situations in order to enhance student satisfaction, empathy, and learning achievement in problem-based instruction [16].

A small number of HOTS indicators did not improve: make a conclusion, thinking well, think flexible. This can be due to the number of topics to be studied on quantum phenomena very much while the time of interaction between teachers and students is insufficient. Students whose initial abilities are lacking, need to get immediate help from teachers.

4. Conclusion

The interactive electronic book quantum phenomena compiled with scientific approachwith the structure as in figure 1, effective in improving higher order thinking skills. The learning outcomes of quantum phenomena of students learning through interactive e-books increase in the moderate category significantly at 95% confidence level. Experimental simulations, video interactive, animations of quantum phenomena, make interactive e-books compiled with scientific approach, effective as independent learning resources and build student HOTS.

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