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## The Development of an Electronic Book on Quantum Phenomena to Enhance Higher-Order Thinking Skills of the Students

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# The Development of an Electronic Book on Quantum Phenomena to Enhance Higher-Order Thinking Skills of the Students

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**Abstract.** This research aims to produce electronic books on quantum phenomena which can be used to enhance the higher-order thinking skills of the students. This research is a development research which used ADDIE method consisting of 5 stages, namely: (1) analysis, (2) design, (3) development, (4) implementation, and (5) evaluation. Pre-research data analysis has been collected from 130 students and 4 physics teachers of 3 Senior High Schools in Bandar Lampung by using questionnaire and has been analyzed descriptively-quantitatively. At the design stage, storyboard making was conducted based on the needs of teachers and students in the school as well as the opinion of four experts in physics education. Electronic books on quantum phenomena are developed with a scientific approach based on indicators of higher-order thinking skills. At the development stage, the realization of electronic book design was carried out and it was then followed by the making of the higher-order thinking skills instrument. The implementation of the electronic was conducted on the students in a class of a Senior High School in Bandar Lampung. The result of the development of the electronic book on quantum phenomena is assessed based on 3 aspects: (1) validity, (2) practicality, and (3) effectiveness. Validity and the practicality of data were obtained by using the validity sheet and questionnaire, effectiveness data were obtained by using higher-order thinking test instrument. Based on the result of data analysis, the product of electronic book on quantum phenomena which is valid, practical, and effective to be used to enhance the higher-order thinking skills of the students.

## 1. Introduction

The basic purpose of education is to allow someone to use knowledge in solving problems in daily life. Problem-solving in daily life allows someone to keep learning by developing thinking skill [1, 2]. Generally, learning activity at school: (1) is based only on books (books which are used as guidance or physics learning source), (2) is teacher-centered with lecture method, (3) ends the activity by giving an assignment that will be submitted on the next meeting, and (4) the assessment is based on the student's final answer. The assignment is given by teachers only the completion of calculation questions contained in the student worksheet or guidebook so that the thinking skill of the students is not improved.

In general, students' difficulties in learning physics are found in conducting experiments, using formulas and calculations, reading graphs, and providing conceptual explanations at the same time [3], [4]. Quantum phenomena are one of the abstract physics materials [4, 5] which is highly microscopic and can not be observed directly [7] and it requires higher-order thinking skills to comprehend it comprehensively. Quantum phenomena study dark matter radiation, Stefan-Boltzmann's law, Wien's



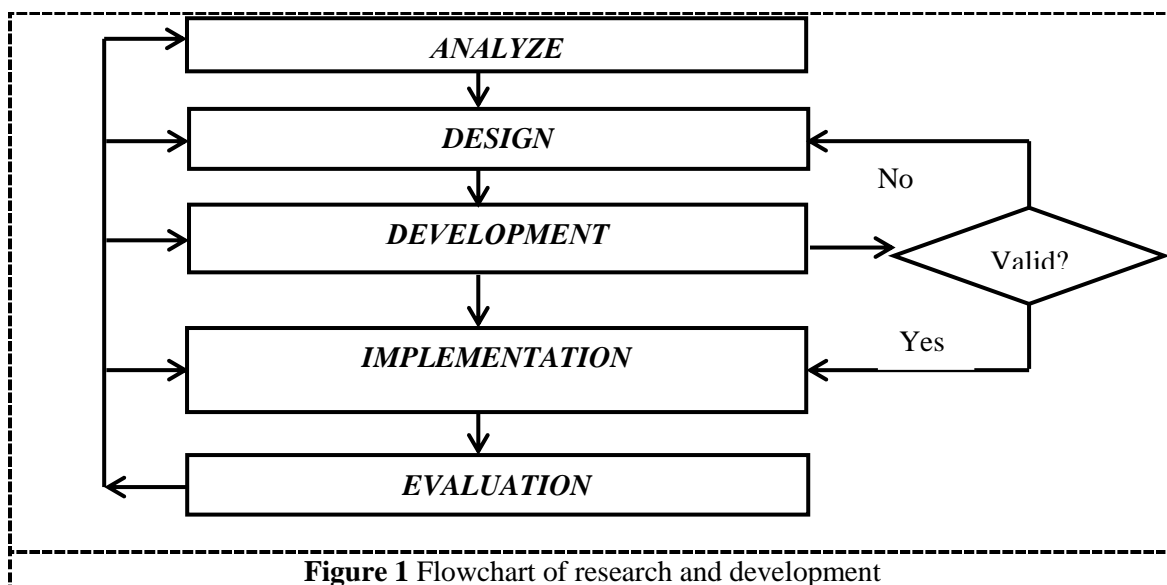
shifting law, Rayleigh-Jeans law, Planck's quantum theory, Photoelectric Effects, Compton effects and X-rays which are essential to study because all of them becomes the basis for the development of modern science and technology[6].

Based on the data of requirement analysis, because the time for XII grade students to study in the even semester is very limited, so, the teachers only explain the materials in a summary which are considered to be used in the exam. The limited time of face-to-face learning made 72% of students have problems in understanding the materials. These limitations made teachers innovative to use various media and learning resources. Learning which uses an electronic book on quantum phenomena based on *Learning Content Development System* (LCDS) program is expected to facilitate teachers to deliver the contents of learning visually and interactively so that learning will be more interesting and effective. Innovations that can be done in learning the material of quantum phenomena are providing a practical simulation, visualizing quantum phenomena, and conducting interactive tests so that it can be easily understood by the students [7, 8].

The effective and innovative learning based on the requirements of teachers and students can be done by providing an alternative to developing an interactive electronic book that can be used independently by the students. The electronic book on quantum phenomena consists of a description of learning materials, animations, simulations, videos, sample questions, and practice questions that can enhance higher-order thinking skills. Higher-order thinking skills are needed to solve problems, to make decisions, and to explain the phenomena encountered in daily life[10]. This research aims to produce an electronic book on quantum phenomena that can be used to enhance the higher-order thinking skills of students.

## 2. Research Method

The method used in this research is developing research based on ADDIE model consisting of: (1) analyze, (2) design, (3) development, (4) implementation and (5) evaluation. Analysis activities include analysis of requirement and analysis of learning materials in school. The instrument used in this analysis stage is questionnaire given to 130 high school students and 4 physics teachers who were randomly drawn from 3 different Senior High Schools in Bandar Lampung to find out the criteria for the required electronic book. At the design stage, an electronic book design on Quantum Phenomena encompasses the breadth and depth of the material were made so that it could foster higher-order thinking skills of the students.

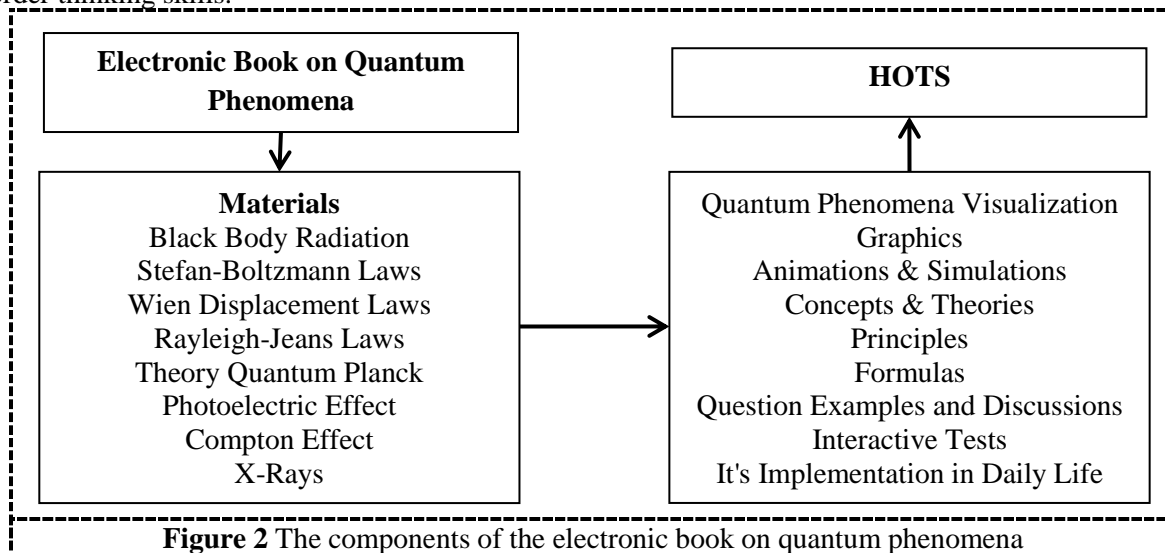


At the development stage, the realization of electronic book design which was then followed by the making of the higher-order thinking skills test instrument. The electronic book on Quantum Phenomena produced was validated by 5 experts in physics education using a validation sheet. The data collected

were then analyzed descriptive-quantitatively. The feasibility of product resulted from the development was assessed on three aspects, namely validity, practicality, and effectiveness and the data were collected by using questionnaire and higher-order thinking test. The validity of the electronic book was judged based on the material and design aspects. The practicality of electronic book was seen in the implementation of learning activities using an electronic book on quantum phenomena. The effectiveness of product resulted from the development was assessed based on responses and improvements in student learning outcomes. The implementation of an electronic book was carried out on high school students in Bandar Lampung to measure the effectiveness of the product using the pre-test and post-test value of students expressed through n-gain value [11].

### 3. Results and Discussion

Based on the results of the analysis of teachers' and students' requirements, it is known that changes are needed in the learning activity, where many activities can be conducted to make students active in learning activities, such as providing other learning resources, conducting experiments, and using various learning media[5]. Technological advances have the potential for innovation in learning so that they can engage students in innovative exploratory learning activities [12]. An electronic book as a portable reading device, provide easiness in accessing and using it [12, 13]. The right design will allow the students to save and to share information in a short time [14, 15] up to integrating it towards other sources and learning media. The interactive electronic book chart is presented in Figure 2. Electronic book on quantum phenomena consist of materials black body radiation, Stefan-Boltzmann laws, Wien displacement laws, Rayleigh-Jeans laws, theory quantum Planck, photoelectric effect, Compton effect, and X-rays. Each material contains quantum phenomena visualization, graphics, animations, simulations, concepts, theories, principles, formulas, question examples, discussions, interactive tests, and implementation in daily life which can be used to enhance higher-order thinking skills.

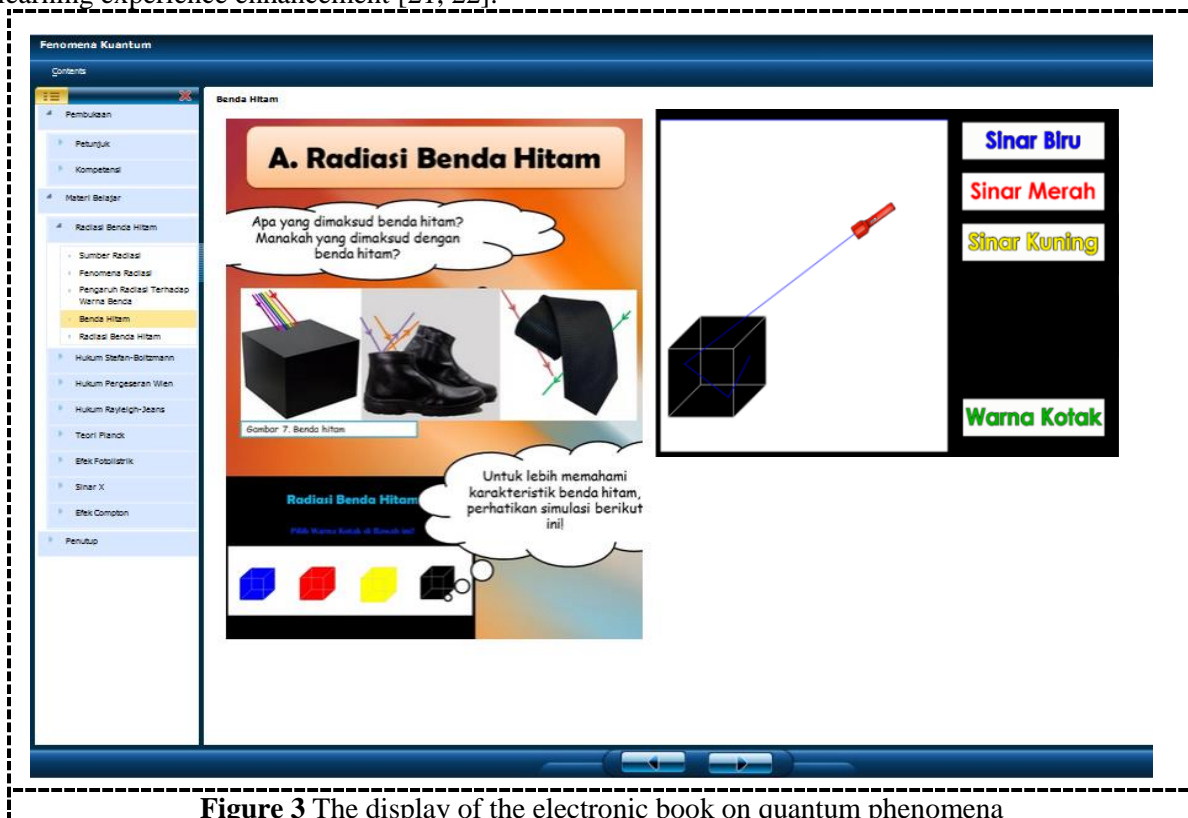


The validity, practicality, and effectiveness of the interactive electronic book have been tested in enhancing HOTS (Higher-Order Thinking Skills). The results of electronic book validation are shown in Table 1. Based on the data in Table 1, it is concluded that the electronic book on quantum phenomena is feasible to use in teaching the material of quantum phenomena, because it has met the aspects of validity (material and design), practicality (implementation of learning activities, implementation of social system, and implementation of reaction principles), and effectiveness (learning outcomes and student responses in learning activities). The effectiveness of the electronic book on quantum phenomena in terms of student learning outcomes obtained an n-gain score of 0,63 (quite effective), meaning that the electronic book on quantum phenomena is effective to enhance higher-order thinking skills of students.

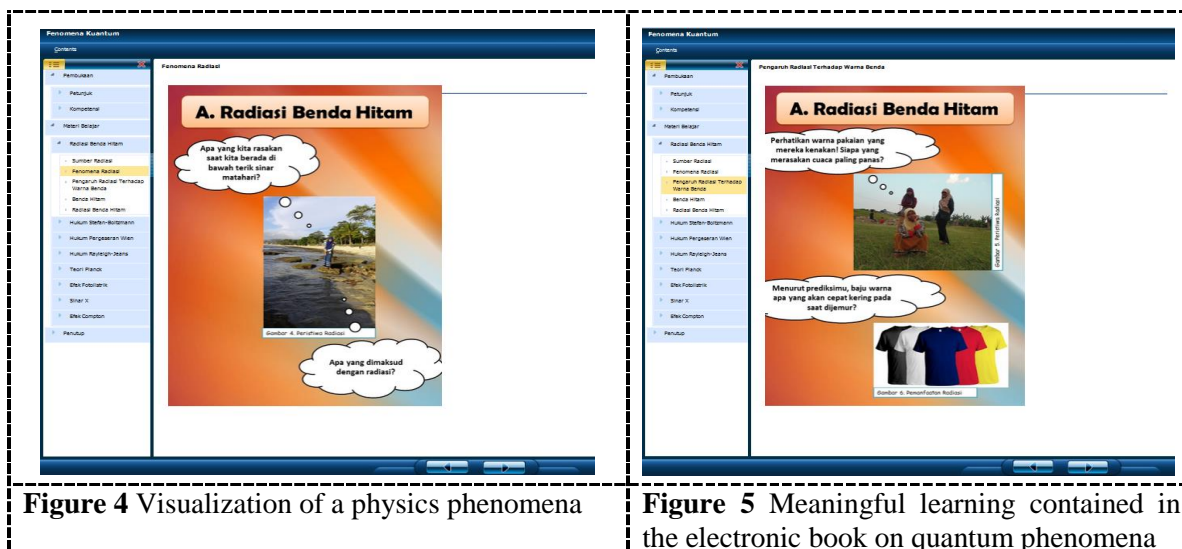
**Table 1** The Validation Test Results of The Electronic Book on Quantum Phenomena

Aspects	Value	Category
<b>Validity</b>		
Material	3,62	Very Valid
Design	3,58	Very Valid
<b>Practicality</b>		
Implementation of Learning	3,63	Very Practical
Social System	4,00	Very Practical
Reaction Principles	4,00	Very Practical
<b>Students Responses</b>		
Effectiveness	3,27	Very Effective
Interaction	3,12	Interactive
Efficiency	3,07	Efficient
Easiness	3,12	Easy

The strengths of the electronic book compared to a textbook in schools are the presence of practical simulations, visualization of physical phenomena, and interactive tests with feedback [16–19]. Based on the practicum simulation for dark matter radiation material (Figure 3), students can find examples of dark matter, identify the characteristics of dark matter, and find out the utilization of radiation in daily life. Higher-order thinking skills that can be grown through the simulation include: (1) building basic skills through observation, (2) making conclusions, (3) considering and integrating, (4) thinking smoothly, and (5) thinking flexibly. Simulation and animation, the examples of the implementation of virtual technology which have only been regarded as learning media, can be used to improve students' understanding of a material and help students develop the explanation of complex material [21]. Virtual technology which used virtual laboratory can incorporate all components of laboratory activities through observed phenomena to improve students' physics learning outcomes and to provide learning experience enhancement [21, 22].



**Figure 3** The display of the electronic book on quantum phenomena



To ease the students in understanding the requirement of a learning is to make learning meaningful [24-26] by preparing materials and concepts that can be linked in daily life. In studying the concept of radiation as the basis of dark matter radiation material, based on the presented phenomena, a number of questions are asked including: "What do you feel when you are under the heat of the sun? (Figure 4). Notice the colors of the clothes they are wearing! Who feels the hottest heat? According to your prediction, what color shirt is dried fastest when it is dried under the sun heat? "(Figure 5). Thus, teachers are required to deliver material by building concepts as the basis for enhancing higher-order thinking skills [27]. In learning activities, Figure 4 and Figure 5 are used to build basic concepts related to radiation phenomena in daily life. After students can build basic concepts, the teacher will guide students to analyze based on available questions. So students can enhance higher-order thinking skills in the learning activity.

#### 4. Conclusion

According to the research results of the electronic book on quantum phenomena containing learning materials equipped by physics phenomena which are displayed either apparently or even using animations, practical simulations, visualizations of physics phenomena, and interactive tests are said to be feasible and can foster higher-order thinking skills of students. The validation test results show a value of 3,60 (very valid), meaning that the electronic book on quantum phenomena has met the validity aspects of material and design. On the practicality test, it obtained a value of 3,88 (very practical), meaning that the electronic book on quantum phenomena is very practical to use in learning activities. The effectiveness of the electronic book on quantum phenomena is based on students' responses and learning outcomes. Based on students' responses, it obtained a value of 3,15 (positive response) meaning that the students feel that the electronic book on quantum phenomena is very effective, interactive, efficient, and easy to use in learning activities. Based on the results of the test using higher-order thinking test instrument, it is known that then-gain score is 0,63 (quite effective), meaning that the electronic book on quantum phenomena can enhance higher-order thinking skills of the students.

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