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Quantum physics lecture profile in supporting student computation thinking (CT) integration program

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ABSTRAK

The purpose of this study is to describe how the profile of lecture needs related to content in quantum physics at the UNTIRTA Physics Education Study Program. The methods used in this field study are: 1) paper, in the form of curriculum documents, national curriculum and RPS; 2) person, lecturer in quantum physics; 3) the place is located in the Department of Physics FMIPA UNTIRTA. Data collection techniques in field study activities are carried out using non-test instruments carried out through document analysis, questionnaires, interviews and tests. The results of the analysis show that the curriculum of the Quantum Physics Study Program (compulsory) in semester V has not been well developed and is not specifically designed to consider students' deep conceptual understanding, the assessment system has not been able to appropriately follow the 21st century learning system, and learning has not been student-centered. Therefore, an analysis is needed based on the needs of a more in-depth study program to determine the topic of study materials in the Quantum Physics course if it is to be applied in the curriculum.

Keywords: *Computation Thinking, Field Study and Quantum Physics*

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INTRODUCTION

Current research on quantum teaching and learning focuses on developing students' conceptual understanding (Dini &; Hammer, 2017). This line of research explores the conceptual difficulties of students to identify common patterns in their reasoning (Modir, et al., 2019), namely research related to the main causes of conceptual difficulties in quantum physics and the reasons why these difficulties persist for a long time. It is often concluded that the abstractness of quantum physics is the main cause of student misunderstanding. The formation of the meaning of the student understanding process is also a cause of students' conceptual difficulties because students are faced with new situations they face when reasoning (Modir et al., 2019; Wan et al., 2019). Student conceptual difficulties often persist over long periods of time because students do not realize that the assumptions underlying their understanding come from invalid classical conceptual frameworks. Students must enter a new conceptual framework that requires extensive restructuring of the 'old' understanding (Ayene, et al., 2019; Malgieri, et al., 2017).

Exploring the reasons for the abstract nature of quantum physics makes it possible to provide a better understanding of the origins of students' conceptual difficulties, students' struggles overcoming these conceptual difficulties and the problems teachers face in teaching quantum physics. There are four reasons that underlie students' conceptual difficulties and prevent students from overcoming these difficulties, including: (1) linking mathematical formulas to experiences in the physical world; (2) to interpret counter-intuitive aspects of quantum physical phenomena; (3) to shift from a deterministic to a probabilistic worldview; (4) understand the limitations of language, concepts, and objects to explain and express quantum physics phenomena (T. Bouchee, et al., 2021).

The Physics Education Study Program of FMIPA Sultan Ageng Tirtayasa University (UNTIRTA) as one of the LPTK for teacher printers, has the responsibility to prepare prospective teachers who can compete globally. The birth of the Indonesian National Qualifications Framework (KKNI) through Presidential Regulation Number 8 of 2012, and Law 2 Number 12 of 2012 concerning Higher Education (PT), encourages universities including Study Programs to be able to adapt to these regulations. For this reason, the Physics Education Study Program must develop a curriculum that can guarantee the quality of graduatesequivalent to learning outcomes according to the level of education that has been formulated inKKNI. In this connection, D3 and S1 graduates must be at the KKNI 5 and 6 levels. Meanwhile,S2 and S3 graduates must be at KKNI levels 8 and 9.

The use of digital materials became one of the teaching strategies shown to reduce four reasons for conceptual difficulties in quantum physics (Krijtenburg-Lewerissa, et al., 2017). On the other hand, the use and instruction of using digital materials in problem solving is one of the characteristics of the use of computing or computational thinking (CT) in learning. Computing has turned into a tool that aids scientific research and becomes a fundamental structure in the study of science. In the last 30 years, computing has grown in status and sophistication until now it is considered by many to be the third pillar of physics, parallel to theory and experiment (B. Skuse, 2019). Computation is becoming a central aspect of 21st-century physics practice used to model complex systems, simulate impossible experiments, and analyze data sets.

Very rapid developments in the field of technology such as games, applications, and simulations that utilize computing can help students in studying physics, such as PhET simulations, Physlets (Christian, et al., 2015), Tychos simulations, and exercises posted to the PICUP Online Repository (Caballero, 2019). Computing knowledge and skills provide the foundation for modern competencies in STEM, driving research on how to best prepare students for the 21st century as a workforce and lifelong learners. Harnessing the synergy between science and computing could result in something fundamentally changing how science learning is formed. Educators, researchers, and industry stakeholders now recognize that college students need to learn computational thinking (CT) to become creators, and not just consumers (Hutchins, et al., 2019).

Video, computer simulation, or animation are often used in quantum physics education digital materials in supporting students' conceptual understanding. The use of digital materials and accompanying learning activities can be beneficial to students' conceptual understanding because they a) relate mathematical formulas to physical reality, b) introduce students to counterintuitive quantum physics principles and outcomes, c) explicitly distinguish quantum and classical behavior, and d) encourage students to express their understanding through the use of language. Digital materials can support students' meaning-making by connecting mathematical formulas to physical reality by visualizing abstract and unobservable quantum physics phenomena. Digital materials allow students to connect between different representations of quantum physics phenomena such as: physical, mathematical, and graphical representations thus connecting mathematical formulas to the physical world. Another benefit of computer simulations is that the complex mathematical calculations involved in quantum physics are incorporated in these simulations allowing students to focus on the underlying principles governing simulation behavior.

Despite these advances, their implementation has not been so thoroughly integrated into the teaching of physics. Despite the influence of curriculum such as material & interaction and the use of certain mathematical tools, most university-level physics courses are still relatively small in involving computation into physics learning (Irving, et al., 2017). There are many systemic factors associated with this lack of adoption (Irving, et al., 2017), but we argue that these factors should not deter the physics education research community from exploring which computational ways can positively influence physics teaching, and vice versa. So, we saw a need for the development of teaching and learning theories that could address the unique challenges and capabilities brought by computing and could help guide the implementation of computing across programs and curricula. There are many topics in physics that can be integrated with computational thinking e.g., modeling the theory of supernova core collapse, investigating pathways to chaos in electrical systems, and analyzing experimental velocimetry data all requiring computational tools, methods, and practices. Computing is part and parcel of many modern research efforts in physics. In fact, the development of new computational approaches and algorithms has helped support a number of important recent discoveries in physics. A national survey of physics faculty was conducted to investigate the prevalence and nature of computational instruction in physics courses across the United States (Caballero &; Laura, 2018).

Based on the description above, we consider it important to conduct a Field Study aimed at describing how the profile of lecture needs related to content in quantum physics in the Physics Education Study Program of UNTIRTA. The results of this field study are expected to be used as an initial study in the development of an integrated quantum physics Computational Thinking (CT) lecture program to improve students' deep conceptual understanding (Deep Learning Conceptual).

RESEARCH METHODS

The methods used in this field study are: 1) paper, in the form of curriculum documents for the 2020 Physics Education Study Program, national curriculum in physics and physics education based on KKNI MIPANET Indonesian Physics Association (HFI), and RPS for Quantum Physics courses from several campuses in Indonesia; 2) person, in the form of a quantum physics lecturer; 3) the place where this field study is carried out is in the Department of Physics FMIPA UNTIRTA.

The subjects involved in the research consisted of 1 lecturer from the Department of Physics FMIPA UNTIRTA related to the Quantum Physics course, namely Prof. Dr. Yayat Ruhiat, M.Si as a lecturer in the quantum physics course. We consider these lecturers to be able to provide information about content related to Quantum Physics. A total of 32 students were involved in filling out the questionnaire.

Data collection techniques in field study activities are carried out using non-test instruments carried out through document analysis, questionnaires, interviews and tests.

a. Documents

The documents collected in this field study are: 1) National curriculum documents in the field of physics and physics education based on KKNI MIPANET Indonesian Physics Association (HFI), HFI Curriculum Documents, KKNI Curriculum Documents for Physics Education Study Program and their attachments in the form of RPS documents for Quantum Physics Courses: 2) RPS documents for Quantum Physics courses from several campuses in Indonesia.

b. Test

The test results collected in this field study are Computational Thinking (CT) ability tests adapted from Bebras Challange CT questions. This test aims to find out how the CT ability of 32 students who have contracted the UNTIRTA Physics Education quantum physics course for the 2021/2022 academic year.

c. Questionnaire

The questionnaire used in this field study is a questionnaire to obtain student responses related to learning quantum physics in the Physics Education Study Program of UNTIRTA for the 2021/2022 academic year as many as 32 students. The questionnaire is given online through google formular.

d. Interview

The interview was conducted with 1 quantum physics lecturer in the Physics Education Study Program FMIPA UNTIRTA. The interview aims to obtain information aboutlecturer responses related to quantum physics learning that can support students' conceptual understanding of quantum physics concepts.

The steps taken in the implementation of this field study are carried out in three stages, namely the pre-implementation stage of the field study, the stage of implementing the field study, and the post-implementation stage of the field study.

RESULTS AND DISCUSSION

Based on the document, it was found that the study material was related to quantum physics content which would later be translated and support the formulation of CPL courses both from the Physics Education Study Program Curriculum FMIPA UNTIRTA and the MIPANET HFI Curriculum in common, namely discussing the equations and solutions to the Schrodinger equation. For the minimum content standards of the curriculum related to the specific content in the MIPANET HFI Curriculum, there is a description of a specific course called Quantum Physics with more complex study materials, this is not found in the curriculum of the Physics Education Study Program FMIPA UNTIRTA. In addition, the results of the analysis of the RPS Quantum Physics course confirm that the quantum physics content provided is only limited to theoretical content through lectures and assignments. This is a gap that needs to be "closed" in supporting the achievement of competencies and profiles of study program graduates. If it is related to the profile of graduates of the physics education study program, namely, 1) Educators in the field of Physics, 2) Researchers in the field of Physics Education, 3) Developers of Physics Learning Technology, and 3) Entrepreneurs in the field of Physics Education, it is clear that the Quantum Physics content that is being run now in the study program can only support the first profile of graduates. Even though the content of Quantum Physics has a very big opportunity to be developed so that it can support three other graduate profiles, especially in the profile of physics learning technology developers, namely the integration of computing in learning. This is in accordance with the results of previous studies such as PhET simulations, Physlets (Christian, et al., 2015), Tychos Simulations, and exercises posted to the PICUP Online Repository (Caballero, 2019) and explains that very rapid developments in technology fields such as games, applications, and simulations that utilize computing can help students in studying physics. Weintrop, et al (2016) stated that the use of digital materials is one of the teaching strategies shown to reduce four reasons for conceptual difficulties in quantum physics.

When lectures on Quantum Physics content can be presented by integratingcomputational thinking in learning can provide deep conceptual understanding of abstract quantum physics concepts. The integration of CT in learning quantum physics will train students to make simple simulations of certain quantum concepts that are considered very abstract and difficult for students to imagine. Students will practice solving problems (critical thinking), creating and innovating in designing simple simulation projects that train creative thinking, testing simulations (bug and debugging) generated using computational concepts, then reporting simulation results will train students to communicate and be responsible.

a. 25 respondents (85.65%) stated that the content in the Quantum Physics course was too much and 16 respondents (19.35%) stated not much. They said that the content of quantum physics feels a lot because the terms contained in quantum physics are new to them, especially those related to probabilistic and deterministic. This shows that students have conceptual difficulties when studying quantum physics.
b. 31 respondents (100%) stated that quantum physics matter needs to be studied despite its abstract nature and no repondents (0%) stated otherwise. They cite that one of the reasons is mainly how to connect the mathematical formulas of quantum physics with the

visualization demanded of the concept. In addition, they also explain that new terms contained in quantum physics that they rarely use in everyday life.

c. 28 respondents (90.32%) stated that it was difficult to visualize quantum physics concepts and experienced some obstacles when learning them and 3 respondents (9.68%) stated the opposite. They mentioned that they had difficulty visualizing because of abstract concepts and terms they rarely used in everyday life. This can show that students have difficulty visualizing the quantum physics concepts they are learning.
d. 31 respondents (100%) stated that in studying quantum physics material, learning resources are needed that can visualize abstract concepts of matter and there is no repondent (0%) who states otherwise. They mention the learning resources in question such as simulations so that they can easily remember the image/visual of the concept. All students (100%) also said that lectures with program visualization can improve their ability to understand quantum physics course material
e. 30 respondents (96.77%) stated that computer-assisted learning can be very helpful in understanding quantum physics topics but some students showed that they were still unfamiliar with the term computing.
f. A total of 25 respondents (80.65%) indicated that quantum physics lectures as had been done were very pleasant, but after being confirmed by interviews they several times did not understand the concepts explained. As many as 28 respondents (90.32%) indicated that the quantum physics learning they often experienced was through lectures and assignments so that as many as 25 respondents (80.65%) felt difficulty in understanding quantum physics concepts.

Based on the results of graduate responses to this course, we believe that graduates who have programmed the Quantum Physics course mostly consider this course difficult and give a high cognitive load because it is abstract and many new terms they encounter so they need digital learning resources with computational thinking concepts to make it easier for them to gain a deep conceptual understanding of physics concepts quantum.

The data from the student's CT ability score is shown in the following diagram. The results of the analysis in the curriculum of the UNTIRTA Physics Education Study Program in2019 related to the contents of Quantum Physics to support the Computational Thinking (CT) integration learning program show that the current curriculum related to the content of Quantum Physics, namely the Quantum Physics course (compulsory) in semester V has not been developed properly and is not specifically designed to consider students' deep conceptual understanding, The assessment system has not been able to precisely keep up with the 21st century learning system, and learning has not been student-centered. Therefore, an analysis is needed based on the needs of a more in-depth study program to determine the topic of study materials in the Quantum Physics course if it is to be applied in the curriculum.

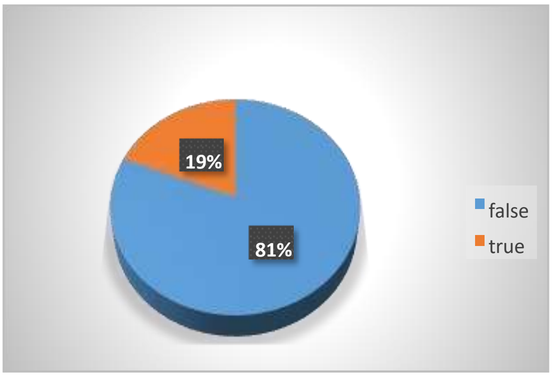

Figure 1. Student CT score results

From the picture, it can be seen that students answered the correct question only 19% while those who answered the wrong question were actually 81%. This shows that students' CT skills need to be developed by interpreting and training them in learning.

a. Results of interviews with Quantum Physics lecturers

The interview was conducted simultaneously with one lecturer who taught the Quantum Physics course (2 credits), namely, Prof. Dr. Yayat Ruhiat, M.Si. He is one of the lecturers at the Department of Physics FMIPA UNTIRTA. This subject is a compulsory course offered in odd semester (V). Related to the content of Quantum Physics lecture material, information was obtained that the content of Quantum Physics Material is a compulsory subject with modern physics and core physics as prerequisite courses. In this course, students are expected to be able to explain under what conditions a physics problem is sufficiently discussed classically and in what conditions a physical problem must be discussed in quantum mechanics, able to explain that classical physics is deterministic while quantum mechanics is statistical and able to explain dynamic equations in quantum mechanics, applying them well in any problem.

From the results of the interview, information was obtained that the existing CPMK has not been developed seriously / well, in its formulation has not fully considered the achievement of indicators as a whole. He said that there is no learning model that is considered effective that is able to illustrate the concept of quantum physics well so that students have a good conceptual understanding. In addition, the results of the RPS analysis confirm the curriculum documents of the physics education study program that have been previously stated such as still using inappropriate learning media, an assessment system that is not in accordance with 21st century learning, and learning with a lecture system (not student-centered). In addition, the formulation of learning outcomes, the lectures that have CPMK 14 and CPMK 15, only at the LOTS level (C2 or C3), the thinking level has not reached the HOTS level. For this reason, it is certainly necessary to develop CT integrated learning programs to increase students' deep conceptual understanding which will have a positive impact on the profile of study program graduates.

b. Challenges, demands and opportunities for lecture development related to Quantum Physics content

The results of interviews conducted with lecturers who teach courses related to the content of Quantum Physics obtained information that the development of science, technology, and art in the era of the Industrial Revolution 4.0 which was marked by the Internet of Things (IOT), Critical Thinking, Communication, Collaboration, and Creativity (4C), Problem solving, Big data analysis, Digitalization and Online Learning, this is a challenge for every study program lecturer to develop a curriculum of courses that are adaptive to every very rapid change.

The curriculum in question is a curriculum that can equip students with the skills needed to compete in the world of work. If the curriculum can be developed properly, then it is necessary to think about how the curriculum can be taught appropriately to students. What kind of learning is suitable, this is a challenge for every lecturer, especially at teacher-producing universities, because, study program graduates are not enough just to master the concept and apply the concept, but need to master how to learn the concept in class. It is necessary to choose the right approach to teach prospective teacher students. In relation to abstract quantum physics MK, lecturers are required to be able to utilize sophisticated technology in learning so that students can switch from deterministic concepts in classical physics to probabilistic concepts in quantum physics. In addition, skills related to information, media, and technology also need to be trained and improved in every learning carried out.

c. Resource support related to Quantum Physics course content

The results of the interview related to the resources needed to support the content of Quantum Physics, we got information that, digital devices needed in lectures can be easily accessed / obtained such as computers and knowledge / information related to programming which is increasingly easy to understand / obtain allows students to make a simple simulation related to quantum physics concepts that they understand. Because the main tools needed are available and can be accessed online and affordable.

CONCLUSION

The results of the analysis in the curriculum of the UNTIRTA Physics Education Study Program in 2019 related to the contents of Quantum Physics to support the Computational Thinking (CT) integration learning program show that the current curriculum of the Study Program related to the content of Quantum Physics (compulsory) in semester V has not been developed properly and is not specifically designed to consider students' deep conceptual understanding, the assessment system has not been able to precisely follow the system Learning is 21st century, and learning is not yet student-centered. Therefore, an analysis is needed based on the needs of a more in-depth study program to determine the topic of study materials in the Quantum Physics course if it is to be applied in the curriculum. The results of graduate responses to this course that graduates who have programmed the Quantum Physics course mostly consider this course difficult and give a high cognitive load because the terms contained in quantum physics are new to them and they rarely use them in everyday life, especially those related to probabilistic and deterministic. In addition, the formulation of learning outcomes, the lectures that have CPMK 14 and CPMK 15, only at the LOTS level (C2 or C3), the thinking level has not reached the HOTS level. For this reason, it is certainly necessary to develop CT integrated learning programs to increase students' deep conceptual understanding which will have a positive impact on the profile of study program graduates.

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