Analysis of Quantum Physics Lectures from the Perspective of the MBKM and OBE Based Higher Education Curriculum

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Abstract – *Lecture analysis in the core courses of the study program contributes to the evaluation of the curriculum used. This field study was carried out to analyze Quantum Physics lectures from the perspective of a university curriculum based on Independent Learning Campus (MBKM) and Outcome-Based Education (OBE). Data collection techniques were carried out through observing the implementation of learning in the Quantum Physics course, interviews with lecturers teaching quantum physics courses, and reviewing curriculum tools in the form of curriculum books, semester lecture plans (RPS), and assessment documents. The instruments used refer to content standards, process standards and learning assessment standards listed in Permendikbud Number 3 of 2020, Permendikbudristek Number 56 of 2022, and Permendikbudristek Number 53 of 2023. The participants involved in this research were a lecturer and 29 students of the undergraduate physics education study program at one of the universities in Garut Regency. The lecturer in question is a lecturer who teaches quantum physics courses, while the students in question are final year students who are taking quantum physics courses in the odd semester of the 2023/2024 academic year. Data collection was carried out over the period October – November 2024. Data analysis was carried out qualitatively using a data triangulation approach. The results of data analysis show that in the Bachelor of Physics Education curriculum, the Quantum Physics course is in the group of upper-level compulsory courses with physics concept study material. From an MBKM perspective, this course can be converted to Program Pertukaran Mahasiswa (PMM) and Program Magang dan Studi Independen Bersertifikat (MSIB), but cannot be converted to the Teaching Campus Program. Conversion to the PMM program is carried out by taking courses in other study programs that have course learning outcomes that are related to quantum physics. Conversions to the MSIB program are carried out at companies or agencies related to the application of quantum physics concepts. From an OBE perspective, this course contributes to graduate learning outcomes in Specific Skills and supports the graduate's profile as a Physics Teacher. The special skill in question is being able to apply mathematical models in explaining physical phenomena in learning.*

Keywords*: Higher Education Curriculum; MBKM; OBE; Quantum Physics*

INTRODUCTION

The Physics Education Study Program is a type of higher education that aims to produce prospective physics teacher graduates. Universities as organizing institutions must be able to prepare their students to have good and quality competencies and skills (Fatkhurrohman et al., 2023). One way to achieve this quality is through a good curriculum. The curriculum becomes the operational framework for achieving educational goals. The aim of education itself is primarily to prepare students' careers and contribution to their community (Sinaga & Setiawan, 2022).

The Physics Education Study Program must be able to adapt to the latest developments in physics, including the concepts covered in quantum physics. This is in line with the government's efforts through the Ministry of Education, Culture, Research and Technology (hereinafter

Kemendikbudristek) in implementing the Independent Learning Campus (hereinafter MBKM) program. MBKM itself aims to provide flexibility for students so they can determine their own path in the learning process according to their interests and talents (Khaeroni & Sabri, 2021). Apart from that, higher education is also moving towards implementing Outcome Based Education (hereinafter OBE), where the main focus is on achieving the desired results or outcomes from the education and learning process (Hasan & Ampa, 2023).

In the physics education curriculum at undergraduate level there are at least five main study materials, including (1) educational and teacher theory, (2) laboratory concepts and management, (3) mathematics, computing and instrumentation, (4) physics concepts, and (5) physics education research. One form of professionalism that prospective physics teacher students must have is the mastery of physics concepts (Widiarini, 2020). In physics concept study materials, there are three levels of courses, namely basic, intermediate and higher-level courses. Quantum Physics as a higher-level course is often considered difficult by students. Students have difficulty understanding the concepts in this course (Doyan, 2015). In fact, the essence of learning physics is to explain natural phenomena, including quantum phenomena (Irvani & Warliani, 2022; Nurhuda & Irvani, 2021).

There are many difficulties faced by students in mastering Quantum physics content. Several studies related to quantum physics lectures show problems related to understanding concepts, solving mathematical problems, visualization and mathematical modeling (Bitzenbauer, 2021; Wan et al., 2019). Students often have difficulty understanding the time evolution of quantum systems (Passante & Kohnle, 2019). Students also experience difficulty in developing coherent models to determine probabilities about quantum states (Wan et al., 2019). Even when using mathematical tools, students experience difficulties such as partial differential equation techniques in quantum mechanical equations (Tu et al., 2020).

The preparation of a curriculum based on MBKM and OBE in the Physics Education Study Program is becoming increasingly crucial considering the challenges in understanding quantum physics concepts at a high level. In fact, in the MBKM program there are things that hinder the lecture process on high-level physics concept study material. This obstacle occurs because of the policy of taking courses outside the study program (Suwanti et al., 2022). In this case, there is a need to review in depth the way the material is delivered in the Quantum Physics course, as well as evaluate the extent to which the curriculum can provide an adequate approach to help students overcome their difficulties.

What also needs to be considered is how MBKM and OBE can support students in facing learning challenges at the conceptual level of quantum physics. Evaluation in lectures must also be able to consider aspects of mastery of physics concepts as a whole, including students' ability to apply these concepts in real life contexts, which is one of the main focuses of OBE. Mastery of this concept is adapted to the learning outcomes of graduates of physics education study programs, one of which is quantum physics (Amiroh et al., 2021)

Analysis of quantum physics lectures from the perspective of MBKM and OBE-based university curricula is important. This is not just evaluating teaching methods, but also identifying the extent to which the curriculum implemented is able to support students' achievement of competencies and skills and prepare them to face the increasingly complex demands of the world of work.

A careful analysis of the implementation of the MBKM and OBE-based curriculum in the context of Quantum Physics lectures will provide a comprehensive view of the university's efforts to create graduates who not only have strong theoretical knowledge, but are also able to apply this knowledge in practical situations. Thus, this article will discuss the relevance of the MBKM and OBE-based curriculum in helping students overcome difficulties in understanding quantum physics concepts, and how this relates to their preparation as prospective professional physics teachers.

Based on the description above, the author made observations to reveal how Quantum Physics lectures are implemented in the field and analyze their position in the Physics Education Undergraduate Curriculum from the perspective of MBKM and OBE.

RESEARCH METHODS

The method used in this research is qualitative method. This qualitative research is based on field studies conducted at one of the universities in Garut Regency. Participants in this field study were a lecturer and 29 students from the Physics Education study program at the university. Data collection was carried out through learning observations, interviews, and document analysis. The documents analyzed are the curriculum book and Semester Lecture Plan (hereinafter RPS) for the Quantum Physics course. Learning observations were carried out in one full meeting of the Quantum Physics course. Meanwhile, interviews were conducted with the lecturers who taught the course.

The instrument used refers to Regulation of the Minister of Education and Culture (hereinafter Permendikbud) No. 3 of 2020, Part Four regarding Learning Process Standards, Regulation of the Minister of Education, Culture, Research, and Technology (hereinafter Permendikbudristek) Number 56 of 2022 concerning Teacher Education Standards, and Permendikbudristek Number 53 of 2023 concerning Quality Assurance of Higher Education (Kementerian Pendidikan dan Kebudayaan RI, 2020; Kementerian Pendidikan Kebudayaan Riset dan Teknologi RI, 2022, 2023).

Data analysis used in this research includes document and implementation review. Document review includes curriculum documents, RPS, and assessment documents. Implementation studies include classroom learning observations and interviews related to the learning process.

RESULTS AND DISCUSSION

The basis of this preliminary study refers to three ministerial regulations as mentioned in the methodology section. This legal basis becomes a reference in compiling research instruments. The scope of observations based on Permendikbud No. 3 of 2020 can be seen in Table 1 below.

Table 1. Coverage of Observations on the Implementation of the Higher Education Curriculum Based on Permendikbud No. 3 of 2020

Aspect (Data Collection)	Minimum Standards
Characteristics (Classroom Observations)	Interactive, holistic, integrative, scientific, contextual, thematic, effective, collaborative, and student-focused

Aspect (Data Collection)	Minimum Standards
Planning (Document Analysis)	● RPS is developed by lecturers independently/in team ● The RPS must at least contain the name of the Study Program, name and code of the course, semester, credits, name of the lecturer, Graduate Learning Outcomes (hereinafter CPL), Course Learning Outcomes (hereinafter CPMK), study materials, learning methods, time, student learning experience, indicator criteria and assessment weights, list of references used ● The RPS must be reviewed and adjusted periodically
Implementation (Document Analysis and Interviews)	● The learning process uses effective learning methods ● The methods in question include: group discussions, simulations, case studies, collaborative learning, cooperative learning, project-based learning, problem-based learning, or other learning methods, which can effectively facilitate the fulfillment of the CPL. ● Learning form: lecture; responses and tutorials; seminar; practicum, studio practice, workshop practice, field practice, work practice; Research, design, or development; military training; student exchange; apprenticeship; businessman; and/or other forms of Community Service.
Student Learning Load (Document Analysis)	● Study load is stated as credits ● Minimum learning process of 16 weeks (including midterm and final tests) ● The maximum undergraduate study period is 7 years with a minimum load of 144 credits. ● The maximum study load is 40 credits (2 semesters) outside the study program

Standards in Permendikbud No. 3 of 2020 is the main reference in analyzing the lecture process in higher education. Even though there were two subsequent ministerial regulations, Permendikbud No. 3 of 2020 still applies with confirmation of the latest regulations. Confirmation of the scope of observation of the lecture process based on Permendikbudristek Number 56 of 2022 concerning Teacher Education Standards can be seen in Table 2.

Table 2. Coverage of Observations on the Implementation of the Higher Education Curriculum Based on Permendikbudristek Number 56 of 2022

Aspect (Data Collection)	Description
Characteristics of a student-centered learning process (Observation)	Active, Reflective, Holistic, Contextual, Innovative, Scientific, Collaborative, Constructive, Interactive, Integrative, Thematic, Effective
Learner-centered learning process planning (Document Analysis and Interviews)	Apply the concept of academic integrity
Implementation of a student-centered learning process (Document Analysis and Interviews)	● lectures; ● responses and tutorials; ● seminars or other equivalent activities; ● practicum, studio practice, workshop practice, or field practice (microteaching and Introduction to the School Environment/PLP); ● enrichment; and/or ● remediation.
Student learning load	● Microteaching minimum 2 credits ● PLP minimum 4 credits ● Study load refers to National Higher Education Standards/SNPT (Permendikbud No. 3 of 2020)

Permendikbudristek Number 56 of 2022 confirms the minimum standards for teacher education programs. This is relevant to the Physics Education study program which has one of the graduate profiles as a physics teacher. There are important points in this regulation, namely practical learning, microteaching, and introduction to the school environment.

Permendikbudristek Number 53 of 2023 concerning Quality Assurance in Higher Education also emphasizes the standards of the learning process in higher education. The scope of standards for implementing learning in higher education based on Permendikbudristek Number 53 of 2023 can be seen in Table 3.

Table 3. Coverage of Observations on the Implementation of the Higher Education Curriculum Based on Permendikbudristek Number 53 of 2023

Aspect (Data Collection)	Minimum Standards
Learning Process Planning 1. learning outcomes which are learning objectives 2. how to achieve learning goals through strategies and methods 3. how to assess the achievement of learning outcomes	● RPS includes CPL and CPMK ● Includes learning strategies and methods ● Includes ways to assess the attainment of CPMK
Implementation of the Learning Process	● Creating a learning atmosphere that is fun, inclusive, collaborative, creative and effective ● Providing equal learning opportunities without differentiating educational, social, economic, cultural and language backgrounds, as well as student admission routes and special student needs ● Ensure the safety, comfort and welfare of the academic community ● Providing flexibility in the educational process to facilitate continuous education throughout life ● Study load of 1 credit = 45 hours/semester ● Form of learning: guided learning, structured assignments, and/or independent.
Learning Process Assessment carried out in a valid, reliable, transparent, accountable, fair, objective and educational manner	● The forms of assessment are formative and summative ● Formative to monitor student learning progress, provide feedback so that students meet their learning outcomes, and improve the learning process ● Summative to assess student learning outcomes ● Summative assessment is carried out in the form of written exams, oral exams, project assessments, assignment assessments, competency tests, and/or other similar forms of assessment. ● The assessment mechanism is socialized to students.

Result

The results of the analysis of curriculum documents that correspond to the focus of this research are graduate profiles, CPL, study materials, CPMK, MBKM policies, and RPS. The CPMK and RPS analyzed are specifically for the Quantum Physics course.

Graduate profiles and profile descriptions can be seen in Table 4.

Table 4. Profile of Physics Education Undergraduate Study Program Graduates

Graduate Profile	Description
Physics teacher	Physics Education Study Program graduates have the competence, knowledge and attitudes as physics teachers who have the ability to master learning material, design effective curricula, use educational technology, develop analytical skills, create an inclusive learning environment, assess and provide feedback.
Research Assistant for Physics Education	Physics Education Study Program graduates master physics education research methodology, are able to conduct physics education research which can be used to provide guidance for choosing various alternative problem solutions in the field of education, as well as communicating research results in the field of physics education.
Mathematics and Natural Sciences Laboratory Manager	Physics Education Study Program graduates master laboratory management, are able to plan and manage resources in administering laboratories under their responsibility, are able to make strategic decisions based on information and data analysis, are able to monitor and evaluate activities in managing the laboratory comprehensively, and communicate the results of monitoring and evaluating activities in Mathematics and Natural Sciences laboratory.
Edupreneur	Physics Education Study Program graduates are able to combine elements of education and entrepreneurship, creating individuals who are able to build physics-based education businesses such as developing learning media, teaching materials, digital learning systems, education businesses, and other educational products.

CPL from this study program consists of four elements, namely attitude (S), knowledge (P), general skills (KU), and Special Skills (KK). The CPL for attitudes and general skills is exactly the same as the standards in Permendikbud Number 3 of 2020 which consists of 10 CPLs for attitudes and 9 CPLs for general skills. The specific skills and knowledge can be seen in Table 5.

The study materials written in the Physics Education Study Program curriculum document consist of five groups of study materials. The study material groups, and their descriptions can be seen in Table 6.

Table 5. Special Skills and Knowledge CPL for Undergraduate Physics Education Study Program

CPL elements		CPL Description
Special skill	**1**	Plan, implement, and evaluate innovative physics learning by utilizing ICT and the surrounding environment to develop thinking abilities according to the characteristics of physics material, and scientific attitudes according to student characteristics.
	2	Utilize and manage physics laboratories to support physics learning by integrating technology and the environment.
	3	Able to apply mathematical models in explaining physical phenomena in learning.
	4	Carrying out physics education research as a form of problem solving and presenting it in scientific work.
Knowledge	**1**	Understand basic educational concepts and learning theories in designing, implementing and evaluating innovative physics learning by utilizing ICT (Information and Communication Technology) and the surrounding environment.
	2	Understand the concepts and principles of physics laboratory management by integrating technology and the environment.
	3	Mastering mathematics, computing and instrumentation to support understanding of physics concepts.
	4	Mastering physics concepts and physics scientific thinking patterns based on natural phenomena that support physics learning in schools and master's education programs.
	5	Mastering the problem identification process and appropriate physics education research methods as alternative problem solving, as well as techniques for writing scientific papers.

Table 6. Study Materials in the Undergraduate Physics Education Curriculum

Study Materials		Sub Study Materials
Education and Teacher Theory	1	Theory of student development
	2	Learning theories
	3	The nature of physics
	4	Revised Bloom's taxonomy and objectives taxonomy
	5	Literacy, Numeracy, and higher order thinking abilities
	6	Basic teaching and learning management skills
	7	Learning approaches, models and methods
	8	Development of teaching materials and learning media based on the surrounding environment and technology
	9	Physics curriculum in schools
	10	Assessment as, for, and of learning
	11	Assessment aspects, preparation of assessment instruments
	12	Literacy, numeracy and HOTS assessments
	13	Analysis of question items
	14	Planning, implementing and evaluating physics learning
	15	Practicing physics learning using basic teaching skills, innovative learning approaches and models
	16	Developing comprehensive physics learning tools
Laboratory Concepts and Management	17	The class functions as a physics laboratory,
	18	Laboratory management (planning tools and materials, scheduling use, maintenance and calibration)
	19	Health, safety and security at work in the laboratory
	20	Designing and managing physics laboratories at schools
	21	Utilizing the physics laboratory at school for physics learning development activities
Mathematics, Computing, and Instrumentation	22	Functions, limits, derivatives and integrals
	23	Matrix operations
	24	Complex numbers
	25	Row
	26	Algebra and complex functions
	27	Ordinary Differential Equations
	28	Partial Differential Equations
	29	Integral Transformation
	30	Systems of Linear Equations
	31	Calculus of Variations
	32	Definition of probability
	33	Introduction to Numerical Methods
	34	Electronics and its application in everyday life
	35	Using mathematical models, computing, and instrumentation in solving physics problems
Physics Concept	36	Classical Mechanics
	37	Mechanics of Many-Particle Systems
	38	Thermodynamics
	39	Statistical Physics
	40	Vibrations and Waves
	41	Optics
	42	Electromagnetic
	43	Modern Physics and Quantum Physics
	44	Nuclear Physics
	45	Solid State Physics
Physics Education Research	46	The nature of physics education research
	47	Issues and identification of problems in physics education
	48	Variety of research methods
	49	Physics education research design
	50	Preparing a research proposal
	51	Conducting research
	52	Writing research results

The Quantum Physics course includes study material on physics concepts with study sub-material number 43, namely Modern Physics and Quantum Physics. The CPMK for Quantum Physics based on RPS document analysis includes:

- M1: Understand the history of the development of the concept of quantum physics
- M2: Understand the concept of wave-particle dualism
- M3: Formulate quantum physics methodology
- M4: Apply quantum physics concepts to various cases

The MBKM policy in the curriculum includes the Teaching Campus Program (*Program Magang*), Student Exchange Program (*Program Pertukaran Mahasiswa/* PMM), and Certified Independent Study and Internship Program (*Studi Independen Bersertifikat*/ MSIB). The courses that can be converted into the MBKM program can be seen in Table 7.

Table 7. List of Courses that Can Be Converted to the MBKM Program

COURSE NAME	Number of Credits
KULIAH KERJA NYATA (Community Service)	2
MANAJEMEN KEPEMIMPINAN PENDIDIKAN (Educational Leadership Management)	2
PATOLOGI SOSIAL (Social Pathology)	2
BELAJAR PEMBELAJARAN FISIKA (Learning Physics)	2
PERENCANAAN PEMBELAJARAN FISIKA (Physics Learning Planning)	3
PENGEMBANGAN BAHAN AJAR FISIKA (Development of Physics Teaching Materials)	2
PENGEMBANGAN MEDIA PEMBELAJARAN FISIKA (Development of Physics Learning Media)	3
DATA SCIENCE	2
ETNOSAINS (Ethnoscience)	2
FISIKA LINGKUNGAN (Environmental Physics)	2
INOVASI PEMBELAJARAN FISIKA (Physics Learning Innovation)	2
KARYA TULIS ILMIAH (Scientific Papers)	2
KOMPUTASI FISIKA (Computational Physics)	2
PENGEMBANGAN E-LEARNING (E-learning Development)	2
PENGEMBANGAN MULTIMEDIA PEMBELAJARAN (Learning Multimedia Development)	2
SEJARAH FISIKA (History of Physics)	2
STUDI KASUS PENDIDIKAN FISIKA (Physics Education Case Study)	2

Special provisions for the Student Exchange Program can only convert courses that have a corresponding CPMK and number of credits. The Certified Independent Study and Internship Program can only be carried out in companies or institutions or agencies related to the CPL of the study program.

The results of the analysis of the RPS document show that almost all the components required in Permendikbud Number 3 of 2020 are included in it, except for assessment indicators.

Learning observations in the Quantum Course were carried out at the 7th meeting with the topic "Heisenberg's Equation of Motion". The learning approach is carried out with discussions and questions and answers oriented towards discovery-based learning. The results of learning observations can be seen in Table 8.

Table 8. Results of Quantum Physics Lecture Observations

Characteristics	Observation Results	
	Seen	No
Integrative	√	
Holistic		√
Integrative		√
Scientific	√	
Contextual	√	
Thematic		√
Effective	√	
Collaborative	√	
Prioritizing the development of student creativity, capacity, personality and needs		√

The results of interviews with lecturers in quantum physics courses obtained the following notes.

1. Lectures are mostly conducted using expository methods
2. Practical activities are carried out using a virtual lab
3. Difficulties experienced by lecturers include facilities and infrastructure, visualizing abstract material, adapting material to student characteristics, looking for simulations that are relevant to lecture needs.
4. Difficulties faced by students include understanding abstract concepts, mathematical solutions, complex mathematical equations, and imagining physical phenomena.

Discussion

The graduate profile of the Bachelor of Physics Education study program is designed to produce individuals who are competent in various professional roles, including as qualified physics teachers, research assistants in the field of physics education, natural science laboratory managers, as well as innovative edupreneurs in the education sector. Graduates are expected to have abilities that cover various aspects, ranging from professional attitudes, in-depth knowledge of physics and education, general skills needed in the world of work, to specific skills relevant to the fields of physics and education, so that they can contribute effectively in the fields of education, physics research and management of educational laboratories. This is in accordance with the demands for teacher competency in the 21st century (Mardhiyah et al, 2021).

CPL of the Physics Education Bachelor's study program is a series of competencies that must be mastered by graduates, which include attitudes, knowledge, general skills and special skills. The CPL is designed to ensure that graduates not only have strong theoretical understanding of physics and its teaching methodology, but are also able to apply that knowledge in effective and innovative educational practices. It is appropriate that CPL must support the profile of graduates (Mariati, 2021).

Based on Table 6, the position of Quantum Physics is found in theoretical physics study materials. Therefore, quantum physics courses support the CPL knowledge and profile of physics teacher graduates. This shows that the Quantum Physics course is a mandatory subject in the Physics Education Study Program (Doyan et al., 2020).

If seen from CPMK, Quantum Physics has contributed to achieving CPL in the third Special Skills element, namely being able to apply mathematical models in explaining physical phenomena in learning. Apart from that, it also supports the fourth CPL knowledge, namely mastering physics concepts and a physics scientific mindset based on natural phenomena which supports physics learning in schools and master's education programs. These two CPLs are closely related to the professionalism of physics teachers and are the basis for continuing master's studies. CPMK cumulatively supports the fulfillment of the study program's CPL (Wijaya et al., 2023).

In relation to OBE, quantum physics plays a role in terms of content to support the knowledge and skills that prospective physics teachers must have. The knowledge in question is related to mastery of the concepts of modern physics and quantum physics. The skills referred to are related to learning planning which includes teaching materials, learning media, and learning evaluation.

If associated with the MBKM program, the Quantum Physics course is not listed in the list of conversion courses. Therefore, it is possible to convert this course through the PMM and MSIB programs provided it supports the appropriate CPL.

From the results of learning observations, it was found that there were four learning characteristics that were not visible. However, because learning observations were only carried out in one meeting, this cannot be used as a conclusion. Lecture observations must be carried out thoroughly in order to obtain a holistic picture (Setiono & Widiningtyas, 2021).

Based on the results of interviews with lecturers, it was found that many problems were encountered in the Quantum Physics course. The problem that is often encountered is the difficulty of students in mastering the concepts of quantum physics and solving problems mathematically. Physics students often encounter problems in quantum physics (Tu et al., 2020).

CONCLUSION

The Quantum Physics course is in the upper-level group of compulsory courses with physics concept study material. From an MBKM perspective, this course can be converted to the Student Exchange Program and Certified Independent Study and Internship Program, but cannot be converted to the Teaching Campus Program. From an OBE perspective, this course contributes to graduate learning outcomes in Specific Skills and supports the graduate's profile as a Physics Teacher. This course supports CPL KK3 and P4. This CPL is related to the professionalism of physics teachers and preparation for continuing master's studies.

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