JPPIPA 11(12) (2025)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

The Needs Analysis in the Development of a Vibration and Wave Course for Improving the Scientific Reasoning Skills of Prospective Physics Teachers

Dwi Fajar Saputri[1], Nurhayati[1*], Syarif Lukman Hakim Alsagaf[1], Wahyudi[1], Adi Pramuda[2]

[1] Physics Education Study Program, Universitas PGRI Pontianak, Pontianak, Indonesia.
[2] Master of Physics Education Study Program, Makassar State University, Makassar, Indonesia.

Received: October 03, 2025
Revised: November 11, 2025
Accepted: December 25, 2025
Published: December 31, 2025

Corresponding Author:
Nurhayati
nurhayatideli@gmail.com

DOI: 10.29303/jppipa.v11i12.13338

Abstract: This study aims to analyze the development needs of the Vibrations and Waves course to facilitate the development of scientific reasoning skills in prospective physics teachers. A mixed-methods approach with a convergent design was used. A parallel approach was used to obtain a comprehensive overview of lecture implementation, students' and lecturers' perceptions, and student scientific reasoning profiles. Participants consisted of 37 students and three lecturers. Data were collected through document analysis, interviews, and a scientific reasoning test adapted from the Lawson Classroom Test of Scientific Reasoning (LCTSR), and a questionnaire. The results of the study indicate that learning outcomes have included elements of concept mastery, problem-solving, and scientific reasoning, but the implementation of learning is still expository, practicums tend to be verification-based, and assessments focus on mathematical calculations. The LCTSR score indicates that students' scientific reasoning abilities are in the very low to low category in almost all aspects, especially proportional reasoning, variable control, probabilistic reasoning, and hypothetico-deductive reasoning. Students and lecturers assessed the need for the implementation of inquiry-based learning strategies, problem-based learning, and project-based learning to optimize the development of scientific reasoning. This study recommends that there is a need to develop Vibrations and Waves lecture tools that explicitly target strengthening scientific reasoning through systematic and planned teaching strategies that encourage students to reason and think deeply, such as inquiry-based learning models, problem-based learning, and project-based learning.

Keywords: Argumentation; Scientific reasoning; Vibrations and waves

Introduction

Teacher Education Institutions play a strategic role in preparing prospective secondary school teachers, including prospective physics teachers. Prospective physics teachers need to acquire a strong mastery of conceptual knowledge as well as relevant pedagogical and professional skills, given that teachers play a central role in educating and shaping students' scientific abilities (Demiral & Çepni, 2018). Science teachers are not only responsible for helping students build conceptual understanding but also for contributing to the development of students' scientific literacy (Kilinc et al., 2017). This is reinforced by Sadler et al. (2009), who emphasize the importance of creating a learning environment that allows students to engage with complex and contextual scientific issues. Moore (2008) adds that hands-on experience in scientific activities in

How to Cite:
Saputri, D. F., Nurhayati, Alsaggaf, L. H., Wahyudi, & Pramuda, A. (2026). The Needs Analysis in the Development of a Vibration and Wave Course for Improving the Scientific Reasoning Skills of Prospective Physics Teachers. *Jurnal Penelitian Pendidikan IPA*, *11*(12). https://doi.org/10.29303/jppipa.v11i12.13338

the classroom can enhance student understanding and contribute to the development of scientific literacy. Therefore, scientific reasoning skills are an essential competency for prospective science teachers (Ding et al., 2016; Lee & She, 2010; Tsabari & Lewenstein, 2013).

Scientific reasoning skills encompass the ability to think logically and systematically through the scientific process to solve complex problems. This process involves analyzing phenomena, integrating information, designing experiments, drawing conclusions, generalizing, verifying, and evaluating scientific evidence (Kambeyo & Csapo, 2018; Koenig et al., 2012; Pascaeka et al., 2023). These skills are considered fundamental because they are part of the professional competencies of prospective science teachers (Khan & Krell, 2019), and serve as a foundation for the development of higher-order thinking skills such as critical thinking and problem-solving (Fischer et al., 2014; Heron et al., 2025; Purwana et al., 2016). Furthermore, scientific reasoning skills have been shown to contribute to improved academic achievement and support conceptual change (Lee & She, 2010; NGSS Lead States, 2013). Several studies also report that reasoning ability is closely related to comprehension (Ageitos et al., 2019; Owens et al., 2021; Roslina et al., 2023).

In the context of physics teacher education, scientific reasoning skills are necessary to address the complexities of modern education and develop in-depth conceptual understanding. These skills enable prospective teachers to analyze causal relationships, identify important variables, construct evidence-based arguments, and design solutions to physical problems, which are at the core of physics learning. Thus, developing scientific reasoning skills is believed to improve the quality of the learning processes they will manage in the future (Özelçi & Çaliskan, 2019; Trúsiková & Velmovská, 2022; Wahyudi et al., 2019).

This is also stipulated in Presidential Regulation of the Republic of Indonesia Number 8 of 2012 concerning the Kerangka Kualifikasi Nasional Indonesia -KKNI (the Indonesian National Qualification Framework), which requires undergraduate graduates to reach Level 6, which includes comprehensive mastery of theoretical concepts, the ability to solve complex problems through analysis, and responsibility in scientific decision-making. This requirement has direct implications for the education of prospective physics teachers, as scientific reasoning is a core competency that must be developed to meet the national qualification standards.

Despite its essential nature, previous research has shown that prospective science teachers' scientific reasoning skills are still at a low to moderate level (Lawson & Weser, 1990). Ibrahim et al. (2021) reported that more than 200,000 college graduates failed to secure employment due to limited soft skills. skills, including problem-solving, communication, and creativity. Khan and Khan et al. (2019) emphasized that most prospective science teachers are still at the basic transitional scientific reasoning level, particularly in the areas of formulating questions and developing hypotheses, and only about 20% have reached the model testing level.

Physics learning in prospective teacher education is ideally designed to develop scientific reasoning skills, so that students not only master concepts, but are also able to apply this knowledge to solve contextual problems (Docktor & Mestre, 2014; Riantoni et al., 2023). The objectives of physics learning also require integration between mastery of basic concepts and reasoning skills as a foundation for understanding and solving physics problems appropriately (Neswary & Prahani, 2023; Suryadi et al., 2022; Widodo et al., 2023). In this context, strengthening scientific reasoning needs to begin when students take basic courses, including Vibrations and Waves.

The Vibrations and Waves course covers fundamental concepts such as simple harmonic oscillations, dynamics of periodic systems, mechanical waves, superposition, interference, and resonance. This material demands critical, analytical, and causal thinking skills, where in-depth understanding requires the ability to identify variables, predict system behavior, and relate mathematical models to empirical phenomena. Previous research has shown that this topic can serve as an effective vehicle for practicing scientific reasoning through activities such as model construction, graphical analysis, data evaluation, and the development of scientific explanations (Munfaridah et al., 2021; Wittmann et al., 2003). Multiple representations of graphs, equations, diagrams, and verbal descriptions have also been shown to support the strengthening of students' scientific reasoning, which in turn leads to a deeper understanding of these concepts.

However, despite the great potential of this course in training scientific reasoning, previous research shows that students are unable to connect the concepts of vibrations and waves to everyday life contexts, have inadequate prior knowledge, and exhibit misconceptions in understanding the material (Aygün & Hacıoğlu, 2022; Eshach et al., 2016; Öztürk & Atalay, 2012). Several studies have shown that reasoning is closely related to conceptual understanding (Ageitos et al., 2019; Owens et al., 2021). Thus, students with low conceptual understanding tend to demonstrate low scientific reasoning, and vice versa. These findings indicate that the current implementation of learning in the Vibration and Waves course is not optimal in training scientific reasoning.

On the other hand, based on the analysis of articles related to scientific reasoning, it is known that in training scientific reasoning skills, researchers have focused on learning models or strategies that support the development of these skills. These models include learning that emphasizes scientific processes such as inquiry (Memiş & Çevik, 2018; Rusdiyana et al., 2024; Yulianti & Zhafirah, 2020), problem-based learning (Heron et al., 2025; Shofiyah & Wulandari, 2018), project-based learning, and STEM (Khoeriah et al., 2023). The inquiry learning used includes tiered inquiry, a combination of multiple representations, and argumentation (Memiş & Çevik, 2018; Widodo et al., 2023). However, although these models have proven effective, research specifically mapping the development needs of the Vibrations and Waves course oriented towards scientific reasoning is still very limited. Therefore, a needs analysis study is highly necessary as a basis for developing relevant teaching tools for prospective physics teachers.

Based on this urgency, this study aims to conduct a needs analysis in developing a Vibrations and Waves lecture program that is oriented towards improving the scientific reasoning abilities of prospective physics teachers, including identifying the implementation of lectures and practicums, student perceptions of learning development, and the profile of students' scientific reasoning abilities.

Method

This study uses a mixed-methods approach with a convergent design. A parallel approach was used to obtain a comprehensive overview of the development needs of a Vibrations and Waves course oriented toward scientific reasoning skills. This design selection allowed researchers to collect and analyze qualitative and quantitative data simultaneously, and then integrate the findings to produce a more robust interpretation (Creswell & Creswell, 2020). The research design is presented in Figure 1.

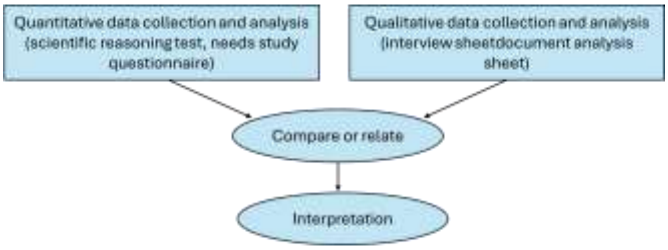

Figure 1. Convergent parallel mixed methods design

Participants in this study included 37 undergraduate physics education students who had taken the Vibrations and Waves course, along with three lecturers with at least five years of teaching experience. The study was conducted at a physics education study program in West Kalimantan that was developing an OBE-based curriculum and strengthening 21st-century skills.

Qualitative data were collected using interview guidelines and document analysis sheets. Quantitative data in this study were measured using scientific reasoning tests and needs analysis questionnaires. Semi-structured interview guidelines were used to gauge the lecturers' responses regarding learning strategies, implementation challenges, and expectations for the course. The document analysis sheet includes the suitability of learning outcome (LO), course learning outcomes (CLO), teaching materials, learning media, lecture activities, practicum implementation, and assessment instruments with scientific reasoning indicators.

The scientific reasoning test is used to measure students' scientific reasoning abilities. The test consists of 24 multiple-choice, reasoned questions. adapted from Lawson Classroom Test of Scientific Reasoning (LCTSR) (Kamaluddin et al., 2023; Lawson et al., 2000). with six aspects of reasoning including conservation reasoning, proportional reasoning, variable control, probability reasoning, correlation reasoning, and hypothetical-deductive reasoning. The LCTSR has been tested for validity by researchers and has a high internal consistency, with Cronbach's alpha ranging from 0.61 to 0.78 (Lee & She, 2010). This test is given to students online via Google Form.

The questionnaire consisted of an open and closed questionnaire with a Likert scale presented online via Google Form. The questionnaire used to measure student responses included: (1) implementation of vibration and wave lectures in the form of material relevance, conceptual difficulty, lecture process, media, assignments, and assessment; (2) student understanding of scientific reasoning skills and the need for scientific reasoning strengthening activities. The questionnaire used has met the validity criteria as assessed by three validators.

The data analysis technique in this study used descriptive statistics for quantitative data, while qualitative data were analyzed in four stages: data collection, data reduction, data presentation, and the final step, drawing conclusions and verification. Triangulation was carried out through the integration of qualitative and quantitative findings.

Results and Discussion

Qualitative Study Results

The results of the review of the RPS documents, practicum guides, and assessment tools are presented in Table 1. The results of the analysis show that the learning outcomes of the vibration and wave course have facilitated students in mastering the theoretical concepts of vibration and waves comprehensively, problem-solving skills, scientific reasoning and critical thinking skills in scientific decision-making. This means that the set course outcomes are in accordance with level 6 of the KKNI in the Presidential Regulation of the Republic of Indonesia Number 8 of 2012.

Table 1. Results of the Analysis of the Vibration and Wave Lecture Devices

Review Aspects	Description
Learning Outcomes (LO) Subject	Able to explain the concept of vibration and waves and apply them in solving physics problems logically and critically and able to verify various concepts of vibration and waves through experimental activities in the laboratory in a responsible, independent and measurable manner.
Teaching materials	Simple harmonic motion, quantities in simple harmonic motion, superposition of simple harmonic vibrations, energy of simple harmonic vibrations, damped vibrations, forced vibrations, properties of dispersion waves, properties of reflection waves, properties of refraction waves, properties of diffraction waves, properties of interference waves, properties of polarization waves, traveling waves, stationary waves, sound propagation, intensity, Doppler effect, harmonic frequencies of sound sources, sound intensity levels, electromagnetic wave spectrum, and energy density and pointer vectors.
Instructional Media	Whiteboards, handouts, reference books and lecture modules that present material, sample questions and practice questions.
Lecture activities	The learning process uses an inquiry-based method. The lesson begins with students posing problems related to everyday life, followed by a discussion to solve the problems. Students are then given the freedom to formulate wave equations in groups.
Practicum	The implementation of practical work is separated from theoretical learning and is designed to verify the concepts that have been taught.
Evaluation	The assessment instrument is in the form of essay questions in the mid-term exam and the final semester exam which cover the cognitive levels of applying, analyzing, and evaluating, although in general it still focuses on mathematical calculations.

The structure of the material in the vibration and wave course shows that the material is ordered by level of difficulty. Material with a lower level of difficulty is studied at the beginning of the lecture, followed by material with a higher level of difficulty. Furthermore, the ordering of the material is based on the interrelationships between the lecture materials.

Based on the results of the Learning Plan review, the learning media used in the vibration and wave course include a whiteboard, while the teaching materials include handouts, reference books, and modules. The media and teaching materials used are diverse and can be a reference for students in learning vibration and waves. Furthermore, the module used as a reference was developed by a team of lecturers, but it is still explanatory, with examples and practice questions that have not been integrated with the inquiry method used in the learning process. In fact, the learning method applied in the vibration and wave course generally uses the inquiry method. Learning begins with students posing problems related to everyday life, followed by discussions to solve the problems. Next, students are given the freedom to formulate wave equations in groups.

The practicum is of a verification nature. The theory learned in face-to-face classes is then verified through laboratory experiments. Assessment for the Vibrations and Waves course consists of essay- based midterm and final exams. Pre-midterm competency assessment is conducted during the midterm exam, and post-midterm competency assessment is conducted during the final exam. The questions vary in level, including applying, analyzing, and evaluating. The questions generally focus on mathematical calculations.

Interviews with the lecturers indicate that the learning outcomes of the vibrations and waves course encompass attitudes, knowledge, and skills. The attitudes developed include responsibility and independence. Knowledge includes explaining and implementing the concepts of vibrations and waves. The skills developed include logical thinking (scientific reasoning), critical thinking, problem-solving, and verification. Scientific reasoning is one of the skills targeted in the learning outcomes of the Vibrations and Waves course.

Lecturers revealed that learning about vibrations and waves has not yet facilitated the development of students' scientific reasoning skills. Lecturers employ a variety of learning methods in their lectures, including lectures, discussions, and guided inquiry, although lectures and discussions remain dominant. The learning process is still dominated by lecturer explanations, so students are not encouraged to think deeply or actively participate in the knowledge construction process. This condition is caused by students not being accustomed to independent learning with limited explanations from lecturers; on the other hand, when given more detailed explanations, students tend to understand the material more easily.

The learning media used by lecturers include handouts, modules, real-world media such as kits, and videos. Students appear to prefer real-world media, such as optical kits or resonance instruments. Enthusiasm is evident when students use media such as resonance tubes, but this does not directly improve conceptual understanding, as most students still experience difficulties when working on problems related to resonance. Thus, the media used is more functional in increasing interest, but does not effectively facilitate conceptual understanding.

The lecturer explained that the practicums are conducted in the physics laboratory once a week, with two experimental topics per session. The practicums serve to verify concepts using practical guides in the form of recipes, and are therefore always conducted after the material has been discussed in class.

The assessment instruments consist of midterm and final exam questions presented in essay format. These questions vary across cognitive levels, including application, analysis, and evaluation, but still emphasize mathematical calculations and do not yet address questions that measure students' reasoning abilities.

All lecturers also responded that there needs to be a change in the learning methods in the vibration and wave course to better facilitate students in achieving the set learning outcomes, including mastery of theoretical knowledge, scientific reasoning skills, critical thinking skills, and problem-solving. Learning methods that are considered more appropriate are those that can train students to think actively, analytically, and reflectively in understanding the concepts of vibration and waves, including problem-based learning models, project-based learning models, and inquiry learning models.

Quantitative Study Results

Scientific Reasoning Ability Test Results

Abilities of students measured using a reasoning test are presented in Table 2. A total of 37 students completed the test online using Google Form.

Table 2. Results of Students' Scientific Reasoning Skills Test

Reasoning aspects	Average Score	Category
Conservation reasoning	40.38	Low
Proportional reasoning	23.08	Very Low
Variable control	19.23	Very Low
Probabilistic reasoning	21.15	Very Low
Correlation reasoning	53.85	Low
Hypothesis-deductive reasoning	22.12	Very Low

Based on the results in Table 2, it was found that students' scientific reasoning skills are still in the low and very low category, so they need to be optimized during the lecture process. This is in line with existing research that states that these skills need to be improved (Heron et al., 2025; Mafarja & Zulnaidi, 2022).

Results of the Questionnaire on the Implementation of Vibrations and Waves Lectures

The results of the student questionnaire analysis regarding the implementation of the Vibrations and Waves lecture are presented in full in Figure 2. The results of the analysis indicate that the learning process is still dominated by the lecturer. Most students stated that the lecturer plays an important role in explaining the material (87%). Approximately 8% of students reported discussions, but they were relatively rare.

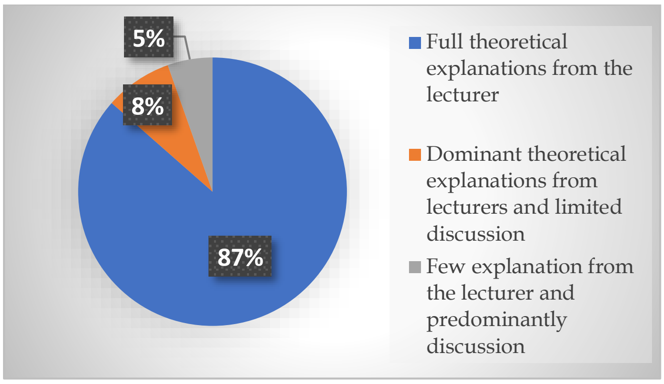

Figure 2. Percentage graph of the vibration and wave lecture process

Data regarding various learning media used by lecturers to teach vibrations and waves courses are shown in Figure 3.

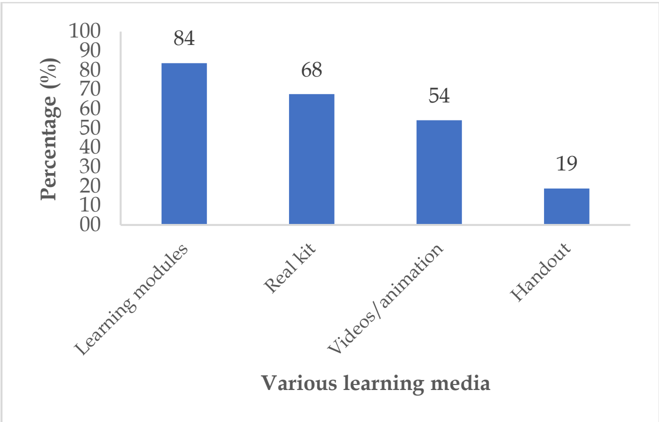

Figure 3. Percentage graph of media used in learning vibrations and waves

Based on student questionnaires, assessment methods for achievement in the Vibrations and Waves course varied, as shown in Figure 4. The most commonly used assessment methods in the Vibrations and Waves course were laboratory reports (100%); midterm exams (91.9%); and final exams (91.9%). These three methods were commonly used to assess knowledge and skills.

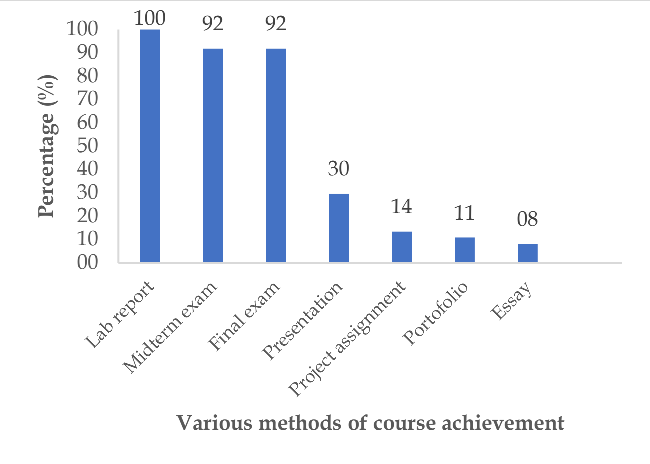

Figure 4. Percentage graph of assessment methods

Results of the Scientific Reasoning Skills Understanding Questionnaire

The results of the analysis of questionnaire data given to 37 students regarding their understanding of scientific reasoning skills showed that 31 students (83.8%) were able to define scientific reasoning skills. Students stated that scientific reasoning skills are the ability to think logically and systematically through scientific processes to solve various complex problems. However, only 12 students (32.43%) agreed that learning about vibrations and waves had facilitated the development of students' scientific reasoning skills.

In addition, 100% of students agreed that scientific reasoning skills are important to practice because they can facilitate learning physics concepts and solve physics problems. Thirty-five students agreed that project-based learning can train scientific reasoning skills, 30 students agreed that problem-based learning can train scientific reasoning skills, and 33 students agreed that problem-based learning can train students' reasoning skills.

Discussion

Research findings reveal a discrepancy between course learning outcomes and the implementation of the learning process in the field. Documented learning outcomes align with the requirements of the KKNI level 6, which emphasizes mastery of theoretical concepts, analytical skills, and scientific problem-solving (Presidential Decree No. 8 of 2012). However, the implementation of learning does not provide adequate space for students to fully develop scientific reasoning competencies.

Although the inquiry method is included in the RPS, learning practices are still dominated by lectures and direct explanations from lecturers. This learning model provides minimal opportunities for students to engage in scientific thinking processes, such as formulating hypotheses, evaluating evidence, and constructing scientific explanations (Ding et al., 2016; Fischer et al., 2014). Lecture-based physics learning tends to produce shallow procedural understanding and does not encourage higher-order thinking skills (Docktor & Mestre, 2014). This condition is consistent with the literature stating that students will have difficulty developing scientific reasoning if the learning process does not involve investigative and exploratory activities (Koenig et al., 2012; Lawson & Weser, 1990).

The modules and handouts used are explanatory and focus on delivering concepts, thus not facilitating student engagement in the scientific exploration process. In fact, multiple representations and inquiry-based activities have been shown to improve students' conceptual analysis and reasoning skills in physics learning (Syarqiy et al., 2023; Wittmann et al., 2003). Real-world media such as resonance tubes do increase student interest, but they do not automatically improve scientific reasoning if they are not integrated with analytical and argumentative activities (Memiş & Çevik, 2018).

The practicums conducted tend to be verification-based and follow procedural prescriptions. This practicum model emphasizes only the reproduction of steps, not scientific thinking. Verification-based practicums have been shown to be ineffective in developing skills in variable control, data analysis, and the formation of scientific inference (Göhner & Krell, 2022). An ideal practicum should encourage students to plan experiments, identify variables, make predictions, and evaluate evidence reflectively (Bernard & Dudek-Różycki, 2019).

The LCTSR results show that students' scientific reasoning abilities are in the very low to low category in almost all aspects, especially proportional reasoning, variable control, and hypothetico-deductive reasoning. Low scientific reasoning abilities are a common phenomenon in science students who receive expository learning (Khan & Krell, 2019; Mafarja & Zulnaidi, 2022; Suryadi et al., 2022). This low scientific reasoning ability has implications for students' difficulties in understanding mathematical models, graphs, and relationships between variables in vibration and wave material (Barniol & Zavala, 2017).

Both students and lecturers believe that the learning methods that are more suitable for training scientific reasoning are problem-based learning, project-based learning, and inquiry learning. Literature shows that students' reasoning abilities can be developed by designing appropriate activities (Bunge & Leib, 2020; Firetto et al., 2019; Widodo et al., 2023). The learning process emphasizes student involvement in discussions and problem solving that require students to put forward, assess, and evaluate their arguments, including problem-based learning, project-based learning, and inquiry learning. PBL has been shown to improve students' analytical, argumentative, and investigative abilities (Dwiningsih et al., 2024; Mutiara et al., 2024; Nicholus et al., 2024; Shishigu et al., 2018). Inquiry-based learning has also been shown to significantly improve scientific reasoning abilities including combinatorial, identifying and controlling variables, proportional, probabilistic, and correlational (Memiş & Çevik, 2018; Syarqiy et al., 2023).

The integration of qualitative and quantitative findings indicates that learning outcomes are appropriate, but learning strategies, media, and assessments do not yet support scientific reasoning-oriented learning, so students do not receive learning experiences that require active and in-depth scientific thinking. Therefore, curricular interventions are needed through the development of lecture tools that emphasize investigative activities, contextual problem- solving, multiple representations, and scientific reasoning-based assessments.

Conclusion

This study concludes that developing a scientific reasoning-oriented Vibration and Waves course is urgently needed. Learning outcomes are aligned with the KKNI standards; however, the implementation of learning is still dominated by an expository approach, the use of informative media, verification practicums, and assessments that do not assess reasoning abilities. Students' low scientific reasoning profiles confirm that learning does not facilitate the higher-order cognitive activities essential for scientific reasoning. Furthermore, it is necessary to develop learning designs, media, modules, and assessment instruments that explicitly target strengthening scientific reasoning through inquiry-based, problem-based, or project-based approaches. This development is crucial to ensure that prospective physics teachers possess adequate scientific reasoning skills to meet the demands of 21st-century professionalism and scientific literacy.

Acknowledgments
The author would like to express his gratitude to 1) the lecturer in charge of the course, 2) the students where the author conducted the research, 3) Universitas PGRI Pontianak which funded the implementation of the research.

Author Contributions
All authors contributed to the writing and revision of the article. Each author's duties are borne by DFS and NN. DFS and NN contributed to data collection by conducting the research; SLH, WW, and AP contributed to data analysis and interpretation; all authors have approved the final version.

Funding
This research was funded by Universitas PGRI Pontianak.

Conflicts of Interest
The authors declare no conflict of interest. in the publication of this scientific article.

References

Ageitos, N., Puig, B., & Colucci-Gray, L. (2019). Examining reasoning practices and epistemic actions to explore students' understanding of genetics and evolution. *Science & Education*, *28*(9), 1209–1233. https://doi.org/10.1007/s11191-019-00086-6

Aygün, B. M., & Hacıoğlu, Y. (2022). Teaching the sound concept : a review of science and physics education postgraduate theses in turkey. *Athen Journal of Education*, *9*(2), 257–275. https://doi.org/10.30958/aje.9-2-5

Barniol, P., & Zavala, G. (2017). The mechanical waves conceptual survey: An analysis of university students' performance, and recommendations for instruction. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(3), 929–952. https://doi.org/10.12973/eurasia.2017.00651a

Bernard, P., & Dudek-Różycki, K. (2019). Influence oftraining in inquiry-based methods on in-service scienceteachers' reasoning skills. *Chemistry Teacher International*, *1*(2), 1-12. https://doi.org/10.1515/cti-2018-0023.

Bunge, S. A., & Leib, E. R. (2020). How does education hone reasoning ability?. *Current Directions in Psychological Science*, *29*(2), 167–173. https://doi.org/10.1177/0963721419898818

Creswell, J. W., & Creswell, J. D. (2020). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. Los Angeles: SAGE Publications.

Demiral, Ü., & Çepni, S. (2018). Examining argumentation skills of preservice science teachers in terms of their critical thinking and content knowledge levels: An example using GMOs. *Journal of Turkish Science Education*, *15*(3), 128–151. https://doi.org/10.12973/tused.10241a

Ding, L., Wei, X., & Mollohan, K. (2016). Does higher education improve student scientific reasoning skills? *International Journal of Science and Mathematics Education*, *14*(4), 619–634. Retrieved from https://link.springer.com/article/10.1007/s10763-014-9597-y

Docktor, J. L., & Mestre, J. P. (2014). Synthesis of discipline-based education research in physics. *Physical Review Special Topics-Physics Education Research*, *10*(2), 1–54. https://doi.org/10.1103/PhysRevSTPER.10.020119

Dwiningsih, K., Sukarmin, S., Lutfi, A., Hidayah, R., Suyono, S., Azizah, U., & Alya, A. (2024). Development of e-learning based pbl-stem learning tools on students' science process skills and critical thinking ability. *Jurnal Penelitian Pendidikan IPA*, *10*(9), 7171–7178. https://doi.org/10.29303/jppipa.v10i9.7106

Eshach, H., Lin, T. C., & Tsai, C. C. (2016). Taiwanese middle school students' materialistic concepts of sound. *Physical Review Physics Education Research*, *12*(1), 1–9. https://doi.org/10.1103/PhysRevPhysEducRes.12.010119

Firetto, C. M., Murphy, P. K., Greene, J. A., Li, M., Wei, L., Montalbano, C., & Croninger, R. M. V. (2019). Bolstering students' written argumentation by refining an effective discourse intervention: negotiating the fine line between flexibility and fidelity. *Instructional Science*, *47*(2), 181–214. https://doi.org/10.1007/s11251-018-9477-x

Fischer, F., Kollar, I., Ufer, S., Sodian, B., & Hussmann, H. (2014). Scientific reasoning and argumentation: Advancing an interdisciplinary research agenda in education. *Frontline Learning Research*, *2*(3), 28–45. https://doi.org/10.14786/flr.v2i2.96

Göhner, M., & Krell, M. (2022). Preservice science teachers' strategies in scientific reasoning: The case of modeling. *Research in Science Education*, *52*(2), 395–414. https://doi.org/10.1007/s11165-020-09945-7

Heron, T. I. N., Arnyana, I. B. P., & Redhana, I. W. (2025). Critical reasoning skills of vocational high school students with problem based learning model: a systematic literature review. *Jurnal Penelitian Pendidikan IPA*, *11*(9), 17–26. https://doi.org/10.29303/jppipa.v11i9.12145

Ibrahim, N. H., Shafie, S. A., & Rahim, I. N. A. (2021). Implementation of project-based-learning through mooc in developing communication skills. *International Journal of Advanced Research in Education and Society*, *3*(2), 32–37. Retrieved from http://myjms.mohe.gov.my/index.php/ijares

Kamaluddin, K., Sani, N. K., Darmadi, I. W., & Nurgan, N. (2023). Analysis of students scientific reasoning ability and the correlation to students cognitive ability in physics learning. *Jurnal Penelitian Pendidikan IPA*, *9*(11), 10173–10179. https://10.29303/jppipa.v9i11.5657

Kambeyo, L., & Csapo, B. (2018). Scientific reasoning skills: A theoretical background on science education. *Namibia Educational Reform Forum Journal*, *26*(1), 20–29. Retrieved from https://url-shortener.me/3YWU

Khan, S., & Krell, M. (2019). Scientific reasoning competencies: a case of preservice teacher education. *Canadian Journal of Science, Mathematics and Technology Education*, *19*(4), 446–464. https://doi.org/10.1007/s42330-019-00063-9.

Khoeriah, I. A., Permana, I., & Pursitasari, I. D. (2023). STEM-AR based ecology and biodiversity e-book development for increasing students' scientific reasoning. *Jurnal Penelitian Pendidikan IPA*, *9*(10), 8837–8845. https://10.29303/jppipa.v9i10.5214

Kilinc, A., Kelly, T., Eroglu, B., Demiral, U., Kartal, T., Sonmez, A., & Demirbag, M. (2017). Stickers to facts, imposers, democracy advocators, and committed impartialists: preservice science teachers' beliefs about teacher's roles in socioscientific discourses. *International Journal of Science and Mathematics Education*, *15*(2), 195–213. https://doi.org/10.1007/s10763-015-9682-x.

Koenig, K., Schen, M., & Bao, L. (2012). Explicitly targeting pre-service teacher scientific reasoning abilities and understanding of nature of science through an introductory science course. *Science Educator*, *21*(2), 1-9. Retrieved from https://static.nsta.org/connections/college/201307Koenig.pdf.

Lawson, A. E., Clark, B., Cramer-Meldrum, E., Falconer, K. A., Sequist, J. M., & Kwon, Y. J. (2000). Development of scientific reasoning in college biology: Do two levels of general hypothesis-testing skills exist? *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *37*(1), 81–101. https://doi.org/10.1002.

Lawson, A. E., & Weser, J. (1990). The rejection of nonscientific beliefs about life: Effects of instruction and reasoning skills. *Journal of Research in Science Teaching*, *27*(6), 589–606. https://doi.org/10.1002/tea.3660270608.

Lee, C. Q., & She, H. C. (2010). Facilitating students' conceptual change and scientific reasoning involving the unit of combustion. *Research Science Education*, *40*, 479–504. https://doi.org/10.1007/s11165-009-9130-4.

Mafarja, N., & Zulnaidi, H. (2022). Relationship between critical thinking and academic self-concept: An experimental study of Reciprocal teaching strategy. *Thinking Skills and Creativity*, *45*(101), 113. https://doi.org/10.1016/j.tsc.2022.101113

Memiş, & Çevik. (2018). Argumentation based inquiry applications: small group discussions of students with different levels of success. *Journal of Turkish Science Education*, *15*(1), 25–42. https://doi.org/10.36681/.

Moore, F. M. (2008). The role of the elementary science teacher and linguistic diversity. *Journal of Elementary Science Education*, *20*(3), 49–61. https://doi.org/10.1007/bf03174708

Munfaridah, N., Avraamidou, L., & Goedhart, M. (2021). The use of multiple representations in undergraduate physics education: what do we know and where do we go from here? *Eurasia Journal of Mathematics, Science and Technology Education*, *17*(1), 1–19. https://doi.org/10.29333/ejmste/9577

Mutiara, E., Suyanto, S., Laksita, G. D., & Zamzami, Z. (2024). Improving critical thinking skills using problem based learning: systematic literature review. *Jurnal Penelitian Pendidikan IPA*, *10*(12), 988–995. https://doi.org/10.29303/jppipa.v10i12.7872

Neswary, S. B. A., & Prahani, B. K. (2023). The use of digital pocketbooks to support merdeka curriculum in physics learning: literature review. *Anatolian Journal of Education*, *8*(2), 135–146. https://doi.org/10.29333/aje.2023.829a

NGSS Lead States. (2013). *Next generation science standards: For states, by states*. The National Academy Press.

Nicholus, G., Nzabahimana, J., & Muwonge, C. M. (2024). Evaluating video-based PBL approach on performance and critical thinking ability among Ugandan form-2 secondary school students. *Cogent Education*, *11*(1), 1–16. https://doi.org/10.1080/2331186x.2024.2346040

Owens, D. C., Sadler, T. D., Petitt, D. N., & Forbes, C. T. (2021). Exploring undergraduates' breadth of socio-scientific reasoning through domains of knowledge. *Research in Science Education*, *52*(1), 1643–1658. https://doi.org/10.1007/s11165-021-10014-w

Özelçi, S. Y., & Çaliskan, G. (2019). What is critical thinking? A longitudinal study with teacher candidates. *International Journal of Evaluation and Research in Education*, *8*(3), 495–509. https://doi.org/10.11591/ijere.v8i3.20254

Öztürk, N., & Atalay, N. (2012). Analyzing pre-service teachers' misconceptions about sound. *Inönü University Journal of The Faculty of Education*, *13*(1), 43–58. Retrieved from https://url-shortener.me/3YQA

Pascaeka, L., Bektiarso, S., & Harijanto, A. (2023). Scientific reasoning skills and scientific attitudes of students in learning physics using guided inquiry model with vee map. *Jurnal Penelitian Pendidikan IPA*, *9*(11), 9610–9618. https://doi.org/10.29303/jppipa.v9i11.4467

Purwana, U., Liliasari, L., & Rusdiana, D. (2016). Profil kompetensi awal penalaran ilmiah (scientific reasoning) mahasiswa pada perkuliahan fisika sekolah. *Prosiding Simposium Nasional Inovasi Dan Pembelajaran Sains*, 753–756. Retrieved from https://ifory.id/proceedings/2016/4chQ7E9Cp/snips_2016_unang_purwana_3e6beb7ae0769e91a997aefaa2887217.pdf

Riantoni, C., Rusdi, M., & Yelianti, U. (2023). Analysis of student problem solving processes in physics. *International Journal of Education and Teaching Zone*, *2*(1), 1–12. https://doi.org/10.57092/ijetz.v2i1.107

Roslina, R., Apriana, E., Armi, A., Hakim, L., & Andalia, N. (2023). Mathematical reasoning ability and mastery of science concepts in high school students. *Jurnal Penelitian Pendidikan IPA*, *9*(10), 8934–8940. https://doi.org/10.29303/jppipa.v9i10.4931

Rusdiyana, R., Indriyanti, D. R., Hartono, H., & Isnaeni, W. (2024). The application of on-line science-based inquiry learning in primary schools. *Journal of Turkish Science Education*, *21*(2), 293–303. https://doi.org/10.36681/tused.2024.016

Sadler, T. D., & Zeidler, D. L. (2009). Scientific literacy, PISA, and socioscientific discourse: Assessment for progressive aims of science education. *Journal of Research in Science Teaching*, *46*(8), 909–921. https://doi.org/10.1002/tea.20327.

Shishigu, A., Hailu, A., & Anibo, Z. (2018). Problem-based learning and conceptual understanding of college female students in physics. *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(1), 145–154. https://doi.org/10.12973/ejmste/78035.

Shofiyah, N., & Wulandari, F. E. (2018). Model problem based learning (PBL) dalam melatih scientific reasoning siswa. *Jurnal Penelitian Pendidikan IPA*, *3*(1), 33–38. https://doi.org/10.26740/jppipa.v3n1.p33-38.

Suryadi, S., Mahardika, I. K., Sudarti, S., & Supeno, S. (2022). The effect of object-oriented physics learning on students' abilities to interpret and make reasoning about data. *Jurnal Penelitian Pendidikan IPA*, *8*(3), 1519–1523. https://doi.org/10.29303/jppipa.v8i3.1746.

Syarqiy, D., Yuliati, L., & Taufiq, A. (2023). Exploration of argumentation and scientific reasoning ability in phenomenon-based argument-driven inquiry learning in newton's law material. *Jurnal Penelitian Pendidikan IPA*, *9*(9), 7264–7272. https://doi.org/10.29303/jppipa.v9i9.4589.

Trúsiková, A., & Velmovská, K. (2022). Indicators of critical thinking and physics experiments. *Journal of Physics: Conference Series*, 1–9.

https://doi.org/10.1088/1742-6596/2297/1/012011.

Tsabari, A. ., & Lewenstein, B. V. (2013). An instrument for assessing scientists' written skills in public communication of science. *Science Communication*, *35*(1), 56–85. https://doi.org/10.1177/1075547012440634.

Wahyudi, W., Verawati, N. N. S. P., Ayub, S., & Prayogi, S. (2019). The effect of scientific creativity in inquiry learning to promote critical thinking ability of prospective teachers. *International Journal of Emerging Technologies in Learning*, *14*(14), 1–10. https://doi.org/10.3991/ijet.v14i14.9532.

Widodo, A., Huda, I. Z. N., Rochintaniawati, D., & Riandi, R. (2023). Effect of argumentation-based teaching on students understanding, reasoning and decision-making concerning food preservatives. *Jurnal Penelitian Pendidikan IPA*, *9*(3), 1418–1424. https://doi.org/10.29303/jppipa.v9i3.2951.

Wittmann, M., Steinberg, R. N., & Redish, E. F. (2003). Understanding and affecting student reasoning about sound waves. *International Journal of Science Education*, *25*(8), 991–1013. https://doi.org/10.1080/09500690305024.

Yulianti, E., & Zhafirah, N. N. (2020). Analisis komprehensif pada implementasi pembelajaran dengan model inkuiri terbimbing: aspek penalaran ilmiah. *Jurnal Penelitian Pendidikan IPA*, *6*(1), 125–130. https://doi.org/10.29303/jppipa.v6i1.341.