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Development of A STEM-Based Introduction to Quantum Physics Module on the Sub-Subject of Potential Variations in the Physics Education Study Program

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Abstract: A valid and practical STEM-based introduction to quantum physics module has been successfully developed. The module development uses a modified Rowntree development model consisting of three stages: the planning stage, the development stage, and the evaluation stage. Tessmer's formative evaluation was carried out at the evaluation stage, including self-evaluation, expert review, one-to-one evaluation, and small group evaluation. Data collection techniques used walkthrough data and questionnaire data. The results of the expert review show that the EVR value from the experts is 88.1%. In the one-to-one evaluation stage, the HEOS value from student responses to the use of this module is 88.6% (efficient type). The module was revised into prototype two and re-tested apart from these two stages. In the small group evaluation trial, the HEOS score from student responses using this module is 93.0%. Thus, based on the study results, it is concluded that the developed module (teaching material) is valid and practical.

Keywords: Development; STEM; Quantum physics; Module; Potential variations

Introduction

Teaching material is critical to learning implementation as it helps educators and students find a solid pathway to enhance their understanding. It also allows instructors to improve the quality of teaching and learning. Teaching material is systematic content, typically found as unwritten or written materials, which assists students in exploring their learning process and developing individual potential. Furthermore, teaching material roles to smoothen the learning process, particularly in physics content in higher education. In this modern era, physics teaching and learning in tertiary education significantly contribute to the development and process of science and technology as advanced concepts and compartmentalized learning at the university level can benefit students to think creatively and critically and enable integrated learning with other disciplines. This integration refers to STEM (Science, Technology, Engineering, and Mathematics) founded by the National Science Foundation (NSF) (Ring-Whalen et al., 2018). This learning approach lets students discover conceptual knowledge by examining each aspect of STEM (Syahirah et al., 2020). Similarly, Shanta et al. (2020) argue that STEM learning aims to produce students with high critical thinking skills so they can solve complex problems thoroughly and compete as a qualified workforce in human capital. However, through a lens of actuality, teaching and learning in tertiary education only utilizes materials that cover two aspects of STEM: science and mathematics.

This reality challenges the system as most students only acknowledge two aspects of the STEM approach. The problem is that most students understand either science or mathematics or science and mathematics (Desfitri, 2018). The demand for STEM education in

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science learning is notable, particularly in physics, because this approach significantly impacts students' learning interests (Wahyu et al., 2020). STEM can also construct conceptual knowledge of natural science and mathematical principles, which is critical for technical and technological skills (Yata et al., 2020). The most compelling part of STEM is that it can prepare students to face the global economic challenges in the 21st century (McGunagle & Zizka, 2020).

These reflections play a significant role in the importance of the STEM approach in university teaching and learning, as tertiary education (specifically in physics education study program) must prepare students for a wider range of challenging course material, such as the Introduction to Quantum Physics course. This course mainly consists of potential variation and one-dimensional Schrödinger equation as a prerequisite for students to advance to the next level of understanding. The content of potential variation intersects with all four aspects of the STEM approach and also opens the opportunity to include engineering and technology aspects as part of learning. An identical previous study proves that the learning materials with a STEM integration approach create more meaningful learning than the common materials (Riandry et al., 2017). By reflecting on the previous study, this research implies the purpose of creating the teaching material for STEM-based Introduction to Quantum Physics course materials to make learning more sustainable and meaningful for students in physics education.

Method

This research was development-based (development research), as this study aimed to produce a new product and improve the existing product (Linda et al., 2018). This development research modified the Rowntree development model, which mainly consists of three stages: planning, development, and evaluation. The Rowntree model indicates a product/output-oriented model, mainly to make accurate and practical teaching material (Nisa et al., 2020). Furthermore, during the evaluation stage, Tessmer's formative evaluation model will be used, which consists of four steps: (1) self-evaluation; (2) expert review; (3) one-to-one evaluation; (4) small group evaluation (Akhsan et al., 2020). This evaluation stage does not include a field test because this study only investigates the validity and practicality without going further to find the effect of the implementation. For more details, see Figure 1.

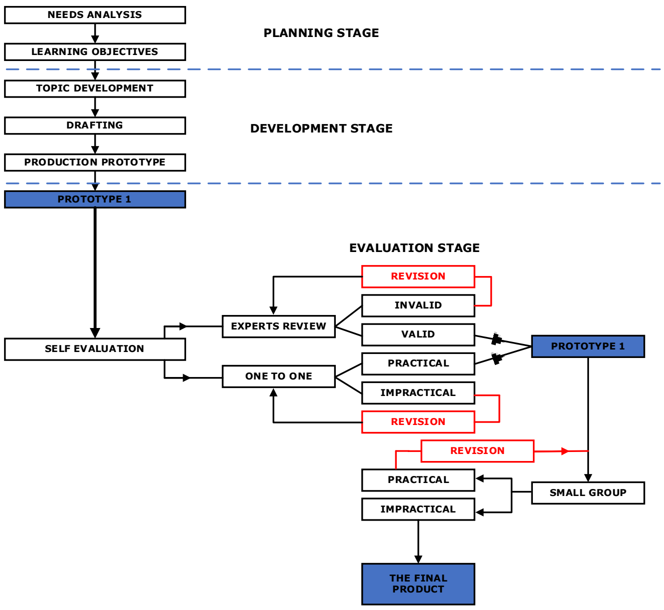

Figure 1. The research process

Data Collection Techniques

Walkthrough

The walkthrough is a validation process involving experts to develop an initial product (Prototype 1). This expert validation includes content, design, and language validation. At this stage, we collect the data using a validation sheet, aiming to compile expert responses and suggestions as the basis of the initial product.

Questionnaire

At this stage, we used a questionnaire to determine the students' opinions about the practicality of using the STEM-based module (teaching materials). This technique was used at the one-to-one (three students) and small group evaluation stage (nine students) with suggestions and comments from the students chosen for each stage. We chose the students from three groups: upper, median, and lower level. Their suggestions and comments will reflect on the product's current quality, and later, we improve the content based on those suggestions and comments.

Walkthrough Data Analysis

The analysis of the collected data from a walkthrough stage later became an input for improvement in the module (teaching material). We used the Likert scale: 1 to 5, one represents the worst scale, and 5 represents a perfect quality. This Likert scale aims to represent the range of overall validity. The module validity is calculated using EVR (Expert Validation Results) (Wiyono, 2015).

$$EVR = \frac{total\ score}{max\ overall\ score} x\ 100\ \% \quad (1)$$

with categories shown in table 1 as follows.

Table 1. Category Validity Level

Percentage (%)	Category
$86 \leq EVR \leq 100$	Very Valid
$70 \leq EVR < 86$	Valid
$56 \leq EVR < 70$	Less Valid
$EVR < 56$	Invalid

Questionnaire Data Analysis

The results from the one-to-one and small-group evaluation stages are used to quantify the practicality of the overall prototype. Similar to obtaining the validity data, in this process, we also used the Likert scale to measure students' opinions based on the current module prototype. We converted the quantified questionnaire data to a percentage to investigate the practicality of the module (Wiyono, 2015).

$$HEOS = \frac{Questionnaire\ score}{Questionnaire\ maximum\ score} x\ 100\ \% \quad (2)$$

with categories shown in table 2 as follows.

Table 2. Category Level of Practicality

Percentage (%)	Category
$86 \leq HEOS \leq 100$	Very Practical
$70 \leq HEOS < 86$	Practical
$56 \leq HEOS < 70$	Less Practical
$HEOS < 56$	Not Practical

Result and Discussion

Planning and Development Stage Results

The planning stage commences through demand analysis (Akhsan et al., 2020). We conducted the demand analysis through informal interviews and questionnaire distribution to physics education of the Faculty of Teacher Training and Education of Sriwijaya University students of the 2014 cohort. This demand analysis aims to acknowledge the initial conceptualization of STEM conception (Hang, 2021). Based on the result of demand analysis, we found that the Introduction to Quantum Physics course is considered one of the most difficult courses for students; hence, there is a demand for STEM-based teaching material (module) development to assist students in learning the course. As the main part of the Introduction of Quantum Physics course consists of the sequence of potential variation content, we decided to create the STEM-based module for the potential variation topic.

The syllabus analysis, indicators, and learning objectives are strengthened in the development stage. This process also aims to ensure the quality of the teaching materials in tertiary education (Schiering et al., 2023) and represents the implementation process of the STEM approach (Nasrudin et al., 2020). At this stage, we also developed the outline of the contents and the overall design as an initial product development (Jambi, 2019).

Evaluation Stage Results

Based on the validation results in the Expert Review stage, the validity results are shown in Table 3. Table 3 shows that the EVR score (Expert Validation Results) is 88.1% (very valid category). Meanwhile, in the one-to-one evaluation stage, the HEOS value is 88.6%, and in the small group stage, the HEOS value is 93.0%. Thus, the module development is very practical.

Table 3. EVR Recapitulation

Expert Validation Results	Score
Total content validation score	180
Total design validation score	52
Total language validation score	41
Total Score	273
Maximum Total Score	310
EVR	88.1%

Based on the overall result, the STEM-based module and learning approach may create meaningful understanding (Kocakaya & Ensari, 2018; Michaluk et al., 2018). This objection is aligned with tertiary education's goal, where teaching and learning content should be more contextual (Ozcan & Gercek, 2015) and facilitate knowledge construction through learning varieties (Aalto & Mustonen, 2022; Ozkizilcik & Cebesoy, 2023) to enhance information-seeking skills (Reuter & Leuchter, 2023). "The current role of universities is not exclusively to train professionals, but also competent citizens able to face future environments and contexts demanded by new societies" (Hernández del Barco et al., 2022). This notion implies that the development of STEM-based modules might facilitate students to face the 21st-century workforce (Rifandi et al., 2020; Fakhrudin et al., 2021; Wu & Li, 2023) through vocational interests based on six aspects: Realistic, Investigative, Artistic, Social, Enterprising, and Conventional (Hartmann et al., 2022). Thus, there is also a need to transform the university learning to reinforce STEM practice (Jun-On & Kaya, 2021).

Conclusion

Based on the research results on developing a STEM-based introduction to quantum physics module on the sub-subject of potential variations, it can be concluded that the final product of the module is considered very valid based on validation by experts at content/material and module design. This result can be seen from the overall EVR value at the expert review stage of 88.1 % (very valid). This module is also very practical in terms of utilization of the module. Based on the one-to-one evaluation stage results, the research shows that the student's impression of using this module is 88.6% (very practical). In addition, at the small group evaluation stage, the results of student responses using the module based on HEOS is 93.0% (very practical category). Thus, based on the results of the one-to-one evaluation and small group evaluation, it can be stated that the STEM-based introduction to quantum physics module on the subject of potential variations has been tested for its practicality. Therefore, a STEM-based introduction to the quantum physics module on potential variations in the Physics Education Study Program of Sriwijaya University has been produced and proven valid and practical.

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Author Contributions
Hamdi Akhsan: Conceptualized the research idea, methodology design, validated, Guruh Sukarno Putra: data analysis, manuscript writing, Ketang Wiyono: Muhammad Romadoni, M. Furqon : reviewed, and edited.

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Conflicts of Interest
The author declares no conflict of interest in this research.

References

Aalto, E., & Mustonen, S. (2022). Designing knowledge construction in pre-service teachers' collaborative planning talk. *Linguistics and Education*, *69*. https://doi.org/10.1016/j.linged.2022.101022

Akhsan, H., Wiyono, K., Ariska, M., & Melvany, N. E. (2020a). Development of Higher-order Thinking Test Instrument on Fluid Material for Senior High School Students. *Journal of Physics: Conference Series, 1467*(1). https://doi.org/10.1088/1742-6596/1467/1/012046

Akhsan, H., Wiyono, K., Ariska, M., & Melvany, N. E. (2020b). Development of HOTS (higher order thinking skills) test instruments for the concept of fluid and harmonic vibrations for high schools. *Journal of Physics: Conference Series, 1480*(1). https://doi.org/10.1088/1742-6596/1480/1/012071

Desfitri, R. (2018). Pre-service teachers' challenges in presenting mathematical problems. *Journal of Physics: Conference Series*, *948*(1). https://doi.org/10.1088/1742-6596/948/1/012035

Fakhrudin, I. A., Wicaksana, E. J., Nastiti, A. R., Saljadziba, E., & Indriyanti, N. Y. (2021). Pre-Service Teachers' Perspectives: STEM as a Solution to Promote Education for Sustainable Development. *Journal of Physics: Conference Series*, *1842*(1). https://doi.org/10.1088/1742-6596/1842/1/012082

Hang, N. T. T. (2021). Vietnamese pre-service teachers and in-service teachers' conception of STEM Education. *Journal of Physics: Conference Series*, *1957*(1). https://doi.org/10.1088/1742-6596/1957/1/012021

Hartmann, F. G., Mouton, D., & Ertl, B. (2022). The Big Six interests of STEM and non-STEM students inside and outside of teacher education. *Teaching and Teacher Education*, *112*. https://doi.org/10.1016/j.tate.2021.103622

Hernández del Barco, M. A., Cañada, F. C., Cordovilla Moreno, A. M., & Airado-Rodríguez, D. (2022). An approach to epistemic emotions in physics' teaching-learning. The case of pre-service teachers. *Heliyon*, *8*(11). https://doi.org/10.1016/j.heliyon.2022.e11444

Jambi, U. (2019). Development of E-Modules Based on Local Wisdom in Central Learning Model at Kindergartens in Jambi City. *European Journal of Educational Research, 8*(4), 1137–1143. https://doi.org/10.12973/eu-jer.8.4.1137

Jun-On, N., & Kaya, J. (2021). Pre-service teachers' integrated curriculum approaches to STEM education in classrooms. *Journal of Physics: Conference Series*, *1957*(1).https://doi.org/10.1088/1742-6596/1957/1/012022

Kocakaya, S., & Ensari, O. (2018). Physics pre-service teachers' views on STEM activities Copyright (C). In *Asia-Pacific Forum on Science Learning and Teaching* (Vol. 19, Issue 1). Retrieved from https://www.eduhk.hk/apfslt/download/v19_issue1_files/ensari.pdf

Linda, R., Herdini, H., S, I. S., & Putra, T. P. (2018). Interactive E-Module Development through Chemistry Magazine on Kvisoft Flipbook Maker Application for Chemistry Learning in Second Semester at Second Grade Senior High School. *Journal of Science Learning, 2*(1), 21. https://doi.org/10.17509/jsl.v2i1.12933

McGunagle, D., & Zizka, L. (2020). Employability skills for 21st-century STEM students: the employers' perspective. *Higher Education, Skills and Work-Based*

Learning, 10(3), 591–606. https://doi.org/10.1108/HESWBL-10-2019-0148

Michaluk, L., Stoiko, R., Stewart, G., & Stewart, J. (2018). Beliefs and Attitudes about Science and Mathematics in Pre-Service Elementary Teachers, STEM, and Non-STEM Majors in Undergraduate Physics Courses. *Source: Journal of Science Education and Technology*, 27(2). https://doi.org/10.1007/s10956-017-9711-3

Nasrudin, D., Rochman, C., Suhendi, H. Y., Helsy, I., Rasyid, A., Aripin, I., Utami, W., & Mayasri, A. (2020). STEM education for pre-service teacher: Why and how? *Journal of Physics: Conference Series*, *1563*(1). https://doi.org/10.1088/1742-6596/1563/1/012039

Nisa, W. L., Ismet, I., & Andriani, N. (2020). Development of E-Modules Based on Multi-representations in Solid-State Physics Introductory Subject. *Berkala Ilmiah Pendidikan Fisika, 8*(2), 73. https://doi.org/10.20527/bipf.v8i1.7690

Ozcan, O., & Gercek, C. (2015). What are the Pre-service Physics Teachers' Opinions about Context Based Approach in Physics Lessons? *Procedia - Social and Behavioral Sciences*, *197*, 892–897. https://doi.org/10.1016/j.sbspro.2015.07.269

Ozkizilcik, M., & Cebesoy, U. B. (2023). The influence of an engineering design-based STEM course on pre-service science teachers' understanding of STEM disciplines and engineering design process. *International Journal of Technology and Design Education*. https://doi.org/10.1007/s10798-023-09837-7

Reuter, T., & Leuchter, M. (2023). Pre-service teachers' latent profile transitions in the evaluation of evidence. *Teaching and Teacher Education*, *132*. https://doi.org/10.1016/j.tate.2023.104248

Riandry, M. A., Ismet, I., & Akhsan, H. (2017, September). Developing Statistical Physics Course Handout on Distribution Function Materials Based on Science, Technology, Engineering, and Mathematics. In *Journal of Physics: Conference Series* (Vol. 895, No. 1, p. 012047). IOP Publishing. https://doi.org/10.1088/1742-6596/895/1/012047

Rifandi, R., Rahmi, Y. L., Widya, & Indrawati, E. S. (2020). Pre-service teachers' perception on science, technology, engineering, and mathematics (stem) education. *Journal of Physics: Conference Series*, *1554*(1). https://doi.org/10.1088/1742-6596/1554/1/012062

Ring-Whalen, E., Dare, E., Roehrig, G., Titu, P., & Crotty, E. (2018). From conception to curricula: The role of science, technology, engineering, and mathematics in integrated STEM units. *International Journal of Education in Mathematics, Science and Technology, 6*(4), 343–362. https://doi.org/10.18404/ijemst440338

Schiering, D., Sorge, S., Tröbst, S., & Neumann, K. (2023). Course quality in higher education teacher training: What matters for pre-service physics teachers' content knowledge development? *Studies in Educational Evaluation*, *78*. https://doi.org/10.1016/j.stueduc.2023.101275

Shanta, S., & Wells, J. G. (2022). T/E design based learning: assessing student critical thinking and problem solving abilities. *International Journal of Technology and Design Education, 32*(1), 267-285. https://doi.org/10.1007/s10798-020-09608-8

Syahirah, M., Anwar, L., & Holiwarni, B. (2020). Pengembangan Modul Berbasis Stem (Science, Technology, Engineering and Mathematics) Pada Pokok Bahasan Elektrokimia. *Jurnal Pijar Mipa, 15*(4), 317. https://doi.org/10.29303/jpm.v15i4.1602

Wahyu, Y., Suastra, I. W., Sadia, I. W., & Suarni, N. K. (2020). The effectiveness of mobile augmented reality assisted STEM-based learning on scientific literacy and students' achievement. *International Journal of Instruction, 13*(3), 343–356. https://doi.org/10.29333/iji.2020.13324a

Wiyono, K. (2015). Pengembangan model pembelajaran fisika berbasis ICT pada implementasi kurikulum 2013. *Jurnal Inovasi Dan Pembelajaran Fisika, 2*(2), 123-131. https://doi.org/10.36706/jipf.v2i2.2613

Wu, X., & Li, J. (2023). Becoming competent global educators: Pre-service teachers' global engagement and critical examination of human capital discourse in glocalized contexts. *International Journal of Educational Research*, *119*. https://doi.org/10.1016/j.ijer.2023.102181

Yata, C., Ohtani, T., & Isobe, M. (2020). Conceptual framework of STEM based on Japanese subject principles. *International Journal of STEM Education, 7*(1). https://doi.org/10.1186/s40594-0

Zainuddin, Z., & Perera, C. J. (2018). Supporting students' self-directed learning in the flipped classroom through the LMS TES BlendSpace. *On the Horizon, 26*(4), 281–290. https://doi.org/10.1108/OTH-04-2017-0016