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Development of an E-book based on Multimode Representation and Technological Pedagogical and Content Knowledge (TPACK)

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abstract

This research aimed to develop an e-book for physics teachers based on multimode representation and Technological Pedagogical and Content Knowledge (TPACK)Thus, it was expected to improve pedagogical, professional, and ICT literacy competencies have been carried out. This research employed Educational Research and Development (R&D) by Borg and Gall, but the steps were limited only to the initial product revision. The instrument used was a questionnaire to evaluate the quality and understanding of the e-book. This study involved five expert validators in pedagogy, IT, and physics content. After the e-book draft was validated and revised, it was tested on a limited basis to 16 in-service physics teachers and eight pre-service teachers. The development eligibility of the e-book for physics teachers was seen from the results of the quality and readability tests of the content. The results of the expert validation regarding the quality of the developed e-book are in the excellent category with an average percentage of 88%. The test results show that the average percentage of physics teachers' e-book understanding is 80.3%. The test results conclude that the multimode and TPACK-based e-books developed for high school physics teachers are feasible to apply. However, it should be tested more extensively before being used further in the learning process.

1. Introduction

Teachers refer to professional educators with the main task of educating, teaching, guiding, directing, training, appraising, and evaluating students. Meanwhile, physics teachers have a central role in the physics learning process. Therefore, efforts to increase competence are necessary to produce professional and qualified teachers and fulfill the required competencies. The quality and professionalism of teachers are the keys to improving student learning outcomes and ensuring the quality of world education (Rutkowski et al., 2013).

Since teacher professionalism is significant to the quality of a country's education, the government has made efforts to improve teacher competence to produce professional teachers, as expected. One of the policies carried out by the government is the Continuous Professional Development (CPD) program, which is expected to produce professional teachers who have substantial knowledge and can assist and guide students to develop and navigate the world of

science and technology rapidly evolving. Change is a feature of 21st-century society (Mendikbud, 2019). However, in reality, teachers have many activities of the main tasks at schools, which spend time and can become an obstacle for the implementation of this program. Since the teachers have limited time and place, they need quickly, and flexibly accessible learning possibly carried out anywhere. In other words, teachers need training strategies accessible anytime and anywhere (Bayar, 2014; Mulhayatiah et al., 2021).

One solution to overcome these obstacles is providing teaching materials for the continuous professional development program of the government by creating quality teacher guidebooks to improve teacher competence which will directly impact the quality of students. Some opinions state that teacher quality can be enhanced by teacher professional preparation and development programs and human resource policies. These programs tend to be more challenging, expensive, and time-consuming. Therefore, a better choice is to provide relatively easy, cheap, and fast teaching materials (Chingos & Whitehurst, 2012). However, teachers must effectively and efficiently use the required teaching materials anytime and anywhere. Thus, it is expected to improve teachers' educational and professional competence and follow the demands of the 2013 curriculum and 21st-century education.

However, the field study results showed that teachers generally used printed guide books that are less effective and efficient to carry and learn everywhere. The research on senior high school physics teachers' perceptions of using guide books was circulated and used at schools. This research instrument was a questionnaire distributed to 30 physics teachers from ten schools in Mojokerto City, Cimahi City, Bandung City, and Ternate City. The results also showed that the teachers' guidebook still had content, pedagogy, and presentation (Masrifah et al., 2018a).

Moreover, other studies conducted on the physics teachers' guide book of senior high schools at X Class of the 2013 curriculum discovered that the pedagogical and professional competencies of the four analyzed books were generally in the adequate category with an average percentage of 66% and 65%. Each book has different advantages and limitations (Masrifah et al., 2019).

The research results showed a gap between reality and expectations. Physics teachers' professional and educational competence cannot be improved if the guidebooks do not provide the competencies required in 21st-century learning. It is necessarily emphasized that the 21st-century generation needs skills to access, evaluate, use, manage, and enrich information through various available media at this time. Technological literacy can strengthen the digital generation's capabilities to think, learn, communicate, collaborate, and create (Trilling & Fadel, 2009). Therefore, it is necessary to conduct research that develops a guidebook for senior high school physics teachers' to overcome the problems or gaps due to the demands of the 2013 curriculum, the 21st-century learning paradigm, and the facts that occur in the field.

This research developed a multimode representation and TPACK-based guide book. The book was available in the electronic version, in an e-book, to make it more effective and interesting. Considering the integration of Information and Communication Technology (ICT) in the learning process is very important for physics teachers because they were born and developed in the digital era. Therefore, they must have high technological literacy. Professional educators should have TPACK competencies, including four main educator competencies: pedagogy, professionalism, personality, and social; these competencies follow global education trends in 21st-century learning and integrate learning skills of communication, collaboration, creativity, and critical thinking (Nofrion et al., 2012). The TPACK learning can be an alternative to improve teachers' competence and professionalism, especially technological literacy because it is an open-source for learning through technology (Blevins, 2018; Rufaida & Nurfadilah, 2021).

The reality shows that the physics teachers' TPACK skills are insufficient. This explanation denotes that educational institutions necessary conduct learning and training for prospective

physics teachers to integrate technology in the teaching; thus, their TPACK skills can be improved (Masrifah et al., 2018b; Efwinda & Mannan, 2021). This study aimed to produce a multimode representation and TPACK-based e-book for physics teachers to improve their academic, professional, and ICT literacy competencies

2. Method

This research employed Educational Research and development (R&D) to produce certain products, and test their effectiveness. Meanwhile, R&D development research is a systematic process to develop, improve, and evaluate educational programs and products (Borg & Gall, Joyce. Gall, 2003). The research development consists of ten steps. However, the steps in this study were limited to the fifth stage: the revision of the initial product. The development design is as shown in Figure 1.

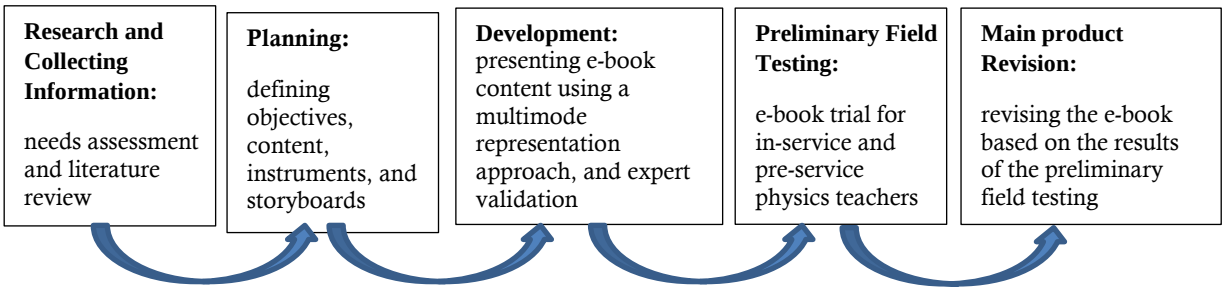

Figure 1. Diagram of the development of based on multimode representation-based e-book

This study involved five expert validators in pedagogy, IT, and physics content. After the multimode representation and TPACK-based e-book draft for high school physics teachers was validated and revised based on the quality test results the e-book was tested on a limited basis to 16 in-service physics teachers and eight pre-service teachers. The instrument of this research was a questionnaire to evaluate the quality and understanding of the e-book. The e-book of the quality instrument consisted of 30 statement items developed by adapting the assessment instrument from the BSNP and the TPACK framework which included content, pedagogy, technology, and graphics (Sinaga et al., 2014). Meanwhile, the understanding test instrument consisted of several questions related to discourse, which included (a) the main idea of the discourse, (b) information supporting the main idea of the reading, (c) foreign words or not understandable meaning, and (d) difficultly coherent sentences. The discourse was arranged according to the components in the e-book for physics teachers. These components include general instructions, content, experimentation, learning strategies, and assessment. The validity and reliability of the instrument were tested before being used. The feasibility of the developed e-book was seen from analyzing the quality test of the e-book content and the comprehension test. The average results of analyzing two tests were then interpreted based on the category of book eligibility adapted from the rubric to assess the feasibility of text-books of (Mendikbud, 2014), as shown in Table 1.

Table 1. Criteria of quality of book

Interval (%)	Criteria
81 – 100	Very good
61 – 80	Good
41 – 60	Enough
21 – 40	Poor
0 – 20	Very poor

3. Result and Discussion

Research and information collection

At this stage, the researcher obtained information from the existing books commonly used by physics teachers at schools. The books did not optimally provide pedagogic and professional competencies for teachers because they did not discuss competency standards Therefore, the teacher' books was necessarily improved and developed to assist teachers to improve their pedagogic and professional competencies concerning Standards of Academic Qualification and Teacher Competence (Mendiknas, 2007). In addition, the teacher's used printed books at schools, and thus, this method was less effective and efficient for them.

Planning

The analysis results in the preliminary stage denote that planning was conducted to design the developed products, as follows. 1) Developing teacher books aimed to assist teachers in improving their educational and professional competencies according to the demands of the Minister of National Education No. 16 of 2007 concerning the standards of academic qualifications and teacher competencies. 2) Physics content necessarily developed according to the results of teacher needs analysis is particle dynamics topic because the content of this topic is very applicable in students' real life. 3) This research designed instruments, namely the quality book and comprehension book. 4) The e–book storyboard was designed by integrating technology and combining content and pedagogy.

Development

The book was developed using the Technological Pedagogical and Content Knowledge (TPACK) framework, which is the intersection of three types of knowledge domains: technological knowledge, pedagogics, and content. Therefore, the development of physics teacher books focused on three domains of knowledge: content, pedagogy, and technology. Furthermore, to provide content knowledge, the researchers applied a multimode representation approach to develop physics content. Book content in this approach was presented in various forms of representation, including texts, images, pictorial diagrams, mathematical equations, tables, graphs, animations, virtual labs, and videos. However, this approach was inseparable from pedagogic knowledge and technology in the teacher's book because the three domains of knowledge were indeed interrelated and inseparable. Furthermore, the book content was available in an e-book with an e-pub format which is phenomenal recently.

Table 2. Quality of physics teacher e-books

Component	Average (%)	Category
Content	87	Very Good
Pedagogy	90	Very Good
Technology	88	Very Good
Graphics	88	Very Good

To determine the quality of the developed multimode representation and TPACK-based e-book for high school physic teachers, the researcher conducted a quality test by validating five experts in the fields of physics content, pedagogy, and learning technology. The results of the quality test of the physics teacher e-book are presented in Table 2.

The quality analysis results of the teacher e-books denoted that the average percentage scores of four components, namely content, pedagogy, technology, and graphics, were in the very good category. Likewise, the average percentage of the content quality of the book from all assessment components is in the very good category by 88%. These tests concluded that the quality of the

developed multimode representation and TPACK-based e-books for high school physics teachers was classified as very good.

The research findings showed that the quality of teacher e-books on the pedagogical component reached the highest average percentage value by 90%. The quality of these components was improved because the teacher book was presented several learning strategies based on scientific approaches (Discovery, PBL, and PjBL) and described clearly and comprehensively by exemplifying concrete application in learning physics for each topic. These strategies enabled teachers to understand the book easily. The explanations in the e-book also helped the teachers design and prepare the physics learning process, and thus, the learning became more fun. The developed teacher e-book also provided experimental activities with several approaches: cookbooks, guided inquiry, video, and animation simulations clearly and completely. Therefore, they could further facilitate the potentials and creativity of teachers. Teachers could choose learning strategies and experimental activities following the contexts of the school and their abilities.

Furthermore, the content quality of teacher e-books was in the very good category with an average percentage of 87%. The content component was also crucially considered one of the characteristics of a teacher book that could help teachers develop content or subject knowledge (Mohammadi & Abdi, 2014). The developed content in the teacher book was appropriate, accurate, and relevant because the e-book content had been developed based on the results of curriculum analysis, needs analysis, and field studies. The book's content was also considered contextual because the content combined theory and application in real life. This content considered the concept of Newton's law closely related to the phenomena of daily life. In addition, content is considered innovative because it describes static representations in texts, images, tables, graphs, mathematical equations, and learning videos. Therefore, the content become more interesting and clearer and was easily understood. Furthermore, the teacher e-book was revised several times.

Likewise, the quality of teacher e-books on the ICT component was in a very good category. The assessment indicator on the technology component with the highest percentage value was the technology in the e-book to facilitate information literacy and ICT for teachers. This was because the physics teacher book was available in an e-book with the e-Pub format. This format was one of the most popular digital book formats to present information more completely, efficiently, and interestingly, and it was easy to learn. The technology component was not less important for the development of teacher books because teachers are nowadays required to have high information and technology literacy, and students are currently facing access to good information and are technology literate. ICT can be integrated into learning through the Technological pedagogical and content Knowledge (TPACK) framework. TPACK combines three knowledge domains: content, pedagogy, and technology in teaching (Cahyani et al., 2021). The integrated technology- of learning material can impact teachers' pedagogical and professional competencies (Srisawasdi et al., 2018).

Furthermore, the quality of the graphic component was very good because the graphic component in this book included the use of language, physical terms and symbols, presentation designs, layouts, and display quality of images, graphics, and videos. The quality of the graphic component the improved teacher e-book because it used good language, was easily understood and followed the readers' level of understanding. The use of language is pivotal because it is a communication tool that enables readers to understand a book (Hufana & Casta, 2016). Moreover, the use of simple, smooth, and easy language can attract readers' interest and motivation. In addition to language, the teacher book was also interesting because it had an attractive and fun design and layout. Thus, the book was interesting to read and easily

understood by the teachers. This condition is reinforced by (Kasmaienezhadfard et al., 2015), who state that illustrations in textbooks affect the quality of the textbooks and can contribute to the science learning process.

Five validators stated that the developed physics teacher e-book had very good quality. However, it still required improvements by considering suggestions and inputs from the validators to further refine the e-book. Furthermore, the Physics teacher e-book was revised based on suggestions and inputs from the validators before being used for field trials.

Preliminary field testing

This stage referred to an initial field trial stage conducted on a limited scale because it only involved 16 in-service physics teachers and eight pre-service teachers. At this stage, the multimode representation and TPACK-based e-book for high school physics teachers was validated by experts. Consequently, the teachers could read and understood it. After that, the teacher was asked to fill out the readability test instrument to examine if the readers could easily understand the contents of the e-book. The readability test results included the paragraphs of main ideas and the supporting information to developed teacher e-book. These results are summarized in Figure 2.

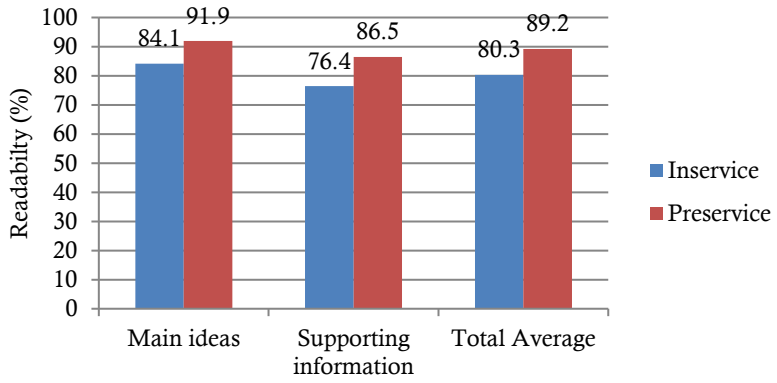

Figure 2. Average percentage of in-service and pre-service teacher readability test

The results of analyzing in-service and pre-service teachers'comprehension of the main ideas for the discourse and supporting information for the main ideas. It shows that the average percentage of comprehending each component and the average value of the combined percentage between the two components is in the high category. Thus, it can be concluded that the overall draft of the developed teacher e-book could be easily understood by in-service and pre-service teachers. A book is considered to have a good level of understanding if it is easily understood by readers. Understanding is one of the main requirements for selecting textbooks used as learning resources. The textbooks should not be too difficult to read; thus, they are easy to understand (Kusuma, 2018; Yulianto, 2019). For this reason, it is recommended to use easily understood texts.

The comprehension test results also showed that in-service and pre-service teachers still had not recognized some terms, and such a condition possibly impacted paragraph understanding. Therefore, the e-book is still revised to allow readers, especially in-service and pre-service teachers, to easily understand it. The terms the teachers did not understand are summarized in Table 3.

Table 3. Unrecognized words or terms

Participants	Unrecognized terms	Revision/solution
In-service and pre-service teachers	Multimodal representation	Different types of representation
	Cohesive	Integrated
	ill-structured	Un-structure
	Open-ended	Free description
	Timeline	Deadline
	Metacognitive	Ability to control one's knowledge
	Pictorial Diagram	Flowchart of the state of an object
	Cookbook	As per instructions
	Misconception	Wrong concept

Main product revision

Based on the limited trial results, the next step was improving the developed e-book. The improvement was made to produce physics teacher e-books readily tested in a wide field to determine the effectiveness of multimode representation and TPACK-based e-books for senior high school physics teachers and improve pedagogical and professional competencies and teachers' ICT literacy.

The book was developed using the Technological Pedagogical and Content Knowledge (TPACK) framework which referred to the intersection of three types of knowledge domains: technological knowledge, pedagogy, and content. Therefore, the development of physics teacher books focused on these three knowledge domains. Furthermore, to provide content knowledge, the researchers employed a multimode representation approach to develop physics content. However, this approach is inseparable from pedagogic knowledge, and technology is inseparable from the teacher book. Such conditions occur because the three domains of knowledge are interrelated and inseparable. Physics content in this teacher book was developed by considering the multimodal approach model. The content was developed using multiple representation modes and included static representations (text, images, pictorial diagrams, tables, graphs, and mathematical equations) and dynamic (learning videos). Learning materials providing real objects included images, audio, texts, animation, or detail learning videos; these methods make learning practical and interesting (Bal & Bicen, 2016). Physics content in the teacher's book was also developed contextually by considering daily real phenomena of physic content discussed. Therefore, the learning process became more meaningful, and the teacher could easily understand the physics content is easier to understand. The general differences between the developed multimode representation and TPACK-based book and teacher guide books for senior high school physics teachers are summarized in Table 4.

Table 4. Difference between developed teacher book and the teacher books used by teachers

Developed teacher e-book	Teacher book used at school
Physics content was explained clearly and comprehensively.	Physics content only presented necessary topics. Thus, not every topic or sub-topic was provided with a material description.
The book consisted of at least two modes: static representation (texts, images, pictorial diagrams, tables, graphs, and mathematical equations), and dynamic representation (simulation videos and animations).	The teachers had to use a package of student books to study the material. For example, the topic of particle dynamics only discussed the sub-topic of frictional force and briefly explained texts, mathematical equations, and images. Unfortunately, the explanation of the images was not presented.
The explanation of each representation was complementary.	
Teacher books were flexible; thus, it applied to any relevant student books.	

Developed teacher e-book	Teacher book used at school
The teacher book presented learning strategies with several active learning models according to the demands of the 2013 curriculum. The teacher book was available with examples of their application of learning physics. Thus, the teachers had choices according to their school conditions, students, and abilities.	The book only exemplified steps of a scientific approach without any explanations. The book only exemplified learning models applicabled to teach the material. Thus, the teachers were still constrained in applying the model.
Experiment activities were presented with several approaches: cookbooks, guided inquiry, and simulation videos, and animation. Thus, the teachers could understand various experimental approaches and have choices according to the conditions of the school, students, and their abilities. The book eliminated more obstacles or reasons for not providing experimental activities during the learning process.	Experiment activities are not presented specifically but only seen from scientific approaches. Therefore, there was no clear and complete guide for teachers. The book only exemplified experimental activities with the cookbook approach in the general instructions section of the book. The teacher still difficultly understood the experimental activities.
The teacher book is presented in an e-book with the e-pub format, the most popular digital book format today. This format enabled the book to present videos possibly accessed offline.	Teacher books were available in a printed form.

4. Conclusion

This study concludes that the developed e-book for high school physics teachers was based on multimode representation and TPACK and was categorized as feasible. The e-book was considered feasible because its quality and the understanding of the contents were tested. In addition, the teacher e-book was improved by considering the research findings and suggestions from the validators. The limitation of this study was not testing the effectiveness of the developed product to improve the competence of physic teachers. Therefore, further research was necessarily conducted.

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