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The Implementation of E-books Based on Technological Pedagogical Content Knowledge (TPACK) to Improve Multi-Representation Ability and Physics Students' Conceptual Understanding

Masrifah[1,a)], Dewi Amiroh[1], Achmad Samsudin[2], Suryani Taib[1], Nasrun Balulu[1], Bayram Costu[3]

[1]*Physics Education Study Program, Universitas Khairun, Gambesi, Ternate, Maluku Utara, Indonesia*
[2]*Physics Education Study Program, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No.229, Isola, Bandung, Jawa Barat 40154, Indonesia*
[3]*Department of Science Education, Yildiz Technical University, 34220 Esenler, İstanbul, Turkiye*

✉: [a)]masrifah.fisika@gmail.com

Abstract

The aim of the research is to examine the multi-representation abilities and conceptual understanding of physics students as the impact of implementing e-books based on TPACK. The reality on the field shows that the representation ability of students at various education levels is still inadequate. The research design used in this research is a group pretest-posttest design. The subjects involved in this research were 30 students from the Physics Education Study Program at Universitas Khairun (Unkhair) and 34 students from the Physics Education Study Program at the Universitas Pendidikan Indonesia (UPI). The instrument used in this research, namely multi-representation questions, was adopted from the Representation-Force Concept Inventory (R-FCI) instrument with a modified presentation in the form of Google Form so that it is more in line with current developments in educational technology. The results of the research show that the multi-representation abilities and conceptual understanding of in-service physics teachers at Unkhair have increased respectively by 0.43 and 0.56 in the moderate category. after the learning process using e-books based on TPACK. Meanwhile, in-service physics teachers at UPI have increased respectively by 0.89 and 0.87 in the high category. This shows that the physics e-book based on TPACK developed can improve students' multi-representation abilities and understanding of concepts as expected.

Keywords: e-book, TPACK, multi-representation

INTRODUCTION

Physics is a subject that develops along with advances in science and technology related to everyday life. Students can develop their thinking skills to solve problems in everyday life through physics learning. The characteristics of physics, which contain many calculations and abstract concepts, require students to master various types of representations, known as multi-representations (Puspitaningrum et al., 2021). Multi-representation is a model representing the same concept in several formats, such as text, graphs, mathematical equations, images, and diagrams (Widianingtiyas et al., 2015). Students can understand a concept from various representative perspectives to build a deeper, more meaningful, and

sustainable understanding. Mastery of various forms of representation also contributes to improving students' cognitive abilities, especially in connecting abstract concepts with concrete reality (Taqwa et al., 2020).

The importance of multiple representations in physics learning, namely: (1) physical concepts can often be visualized and understood better by using representations; (2) helps in constructing other, more abstract representations; (3) trains quantitative reasoning in finding answers through abstract mathematical representations; and (4) can accommodate optimal learning opportunities for each type of intelligence.

The ability to describe a concept in various forms of representation is known as multi-representational ability. This ability is the key to success in learning physics (Kohl & Finkelstein, 2004) because it plays a role in completing students' cognitive processes. In addition, multi-representation helps students build a better understanding of a concept, allowing them to achieve a deeper understanding (Fatimah, 2016).

Based on this study, it can be stated that using representations in physics learning can influence a person's understanding (Latifah et al., 2024; Sari, Feranie, & Karim, 2015). So, the ability to represent physics concepts in various forms of representation is crucial for in-service physics teachers because one type of representation that is considered most appropriate by the teacher may not necessarily be understood by all students (Masrifah et al., 2020; Suhandi & Wibowo, 2012).

But the reality in the field shows that until now the objectives of Physics learning have not been achieved optimally. It can be seen from the quality of Indonesian education, which has not shown a satisfactory increase in learning outcomes, especially in understanding physics concepts, and students' scientific performance that still relatively low. The low physics learning outcomes are indicated by the results of the ability representation of students at various levels of education is currently still inadequate (Smeets & Bus, 2015; Humairoh et al., 2015; Zakiya et al., 2017; Mulyadi et al., 2020; Brantley-Dias & Ertmer, 2013). Prospective teachers still do not have adequate multi-representational skills (Latifah et al., 2024; Sezen et al., 2012; Bunawan et al., 2015; Mäntylä & Hämälainen, 2015). The low multi-representation ability follows the results of field observations, which show that students' understanding of physics concepts, especially particle dynamics, is still not optimal. Efforts are needed to improve students' representation and understanding of physics concepts. Understanding various types of representations facilitates one in gaining a deep understanding of physics concepts (Masrifah et al., 2018). Influence the understanding of concepts (Latifah et al., 2024; Sari et al., 2015) and increase the ability to solve problems (Mohammed et al., 2015).

There are many ways to innovate in physics learning by designing teaching materials that follow learning objectives, such as implementing plans, modules, student worksheets, and appropriate media according to the characteristics of the teaching materials and students (Wati et al., 2018). One of the alternative solutions to finishing the problem representation in physics learning namely by using e-books. E-books can help students practice the various representations to present electronic content in the form of sound, images, graphics, animations, and videos, making e-books more attractive and interactive than printed books (Handayani et al., 2015). Interactive e-books accompanied by animations and videos make it easier for students to grasp the contents of reading materials than regular e-books (Hand, Gunel & Ulu, 2009). The use of e-books during the learning process has been proven to improve conceptual understanding (Simbolon, Sinaga & Utari, 2017). The same thing applied to the use of multiple representations in learning media, which can improve students' scientific literacy (Humairoh et al. 2015) and conceptual understanding and can increase student representation ability (Zakiya et al. 2017) and critical thinking skills (Mulyadi et al. 2020). The importance of multi-representations is because the structure of physics knowledge requires multiple representations to be well understood. Physics learning always uses mathematical models to explain a phenomenon and the relationship between variables (Smeets & Bus 2015). Ineffective physics learning, teachers must master professional competence, pedagogy, and technology are important components for successful learning (Brantley-Dias & Ertmer, 2013; Durdu & Dag, 2017). For this reason, prospective teachers must master the three teaching competencies known as Technological Pedagogical and Content Knowledge (TPACK), which is a teacher framework for teaching effectively using technology (Masrifah et al., 2022; Ammade et al., 2020; Brantley-Dias & Ertmer, 2013).

The 21st-century learning requires students to not only be able to apply concepts but also to be able to think at a high level. High-level thinking requires critical, logical, and systematic thinking skills in processing knowledge. Students must be able to develop and master different representations or multi-representation abilities to solve a problem. When students are faced with a physics problem situation in classroom learning, they will try to understand the problem by solving the problem in a way that the students understand. In this paper, we will explain how the representations used by students when solving Newton's law problems. Newton's law is one of the physics materials that require multi-representation to solve the problem. The ability to solve problems that are quite complex is needed in Newton's law material, so students not only memorize formulas but students must also develop their multi-representation abilities mathematically, pictorially, and verbally. If students are not strong in representing their concepts in various forms, they will find solving these Newton's law physics problems difficult.

Based on the problems, realities, and expectations described above, this research aims to examine multi-representation ability and physics students' conceptual understanding as an impact of the implementation of e-books based on Technological Pedagogical and Content Knowledge TPACK, which is a result of development from previous studies.

METHODS

The research method used was a quasi-experiment, with the research design used being one group pre-test-post-test design, as shown in TABLE 1. This study used two sample groups: experimental class 1 and class 2. Both groups were given the same treatment (X) (use of e-books in corporate flip pdf format). Tests were conducted before and after the learning process to analyze the description of multi-representation abilities and conceptual understanding of pre-service physics teachers.

TABLE 1. One group pre-test post-test design

Group	Pre-test	Treatment	Post-test
Experiment 1	O1	X	O2
Experiment 2	O1	X	O2

This study was conducted in the Physics Education Study Program at Universitas Khairun (Unkhair) as Experimental Class 1 and at the Universitas Pendidikan Indonesia (UPI) as Experimental Class 2. The research sample consisted of 30 students in Experimental Class 1 and 34 students in Experimental Class 2, selected randomly based on their enrollment in the same course, Basic Physics I. Both experimental classes received the same treatment: learning using a multi-representation approach assisted by an e-book. The learning process lasted for three meetings, with a pretest conducted in the first meeting before instruction began and a posttest conducted in the third meeting after the student had completed the learning process. The e-book was in Flip PDF Corporate format, covering Newton's Laws. The content was presented in various formats, including text, images, mathematical equations, graphs, animations, and videos, to accommodate students with different learning styles. Additionally, the e-book was accessible offline, allowing students to study anytime and anywhere. The e-book was distributed to all students during the learning process and accessed via their smartphones. Students were given 30 minutes to study the e-book independently before continuing with the multi-representation approach, guided by the lecturer as a facilitator and motivator.

The instrument used in this study was a multi-representation question adopted from the Representation-Force Concept Inventory (R-FCI). This instrument was developed by (Nieminen, Savinainen, & Viiri, 2010) in the form of multiple-choice questions on Gravity and Newton's Third Law, which have been standardized and used internationally. The researcher only took 9 questions related to Newton's laws: verbal representations, motion diagrams, graphs, and vectors. Modifications were only made to the packaging of questions using Google Forms because it is more practical and per the latest educational technology developments. Furthermore, to measure students' conceptual understanding, a conceptual understanding question instrument was used, which was developed by the researcher in the form of Multiple Choice Questions of 10 questions about Newton's 1st, 2nd, and 3rd laws, which 3 physics content experts had validated. After going through the validation and revision

process, the question instrument was declared valid and suitable for use in research. The data obtained from the research are in the form of percentage data on analyzing students' multi-representation abilities and conceptual understanding. Furthermore, a prerequisite analysis test was carried out, namely the homogeneity and normality tests, before testing the hypothesis. The results of the prerequisite test state that both the data on multi-representation ability and the data on students' conceptual understanding are homogeneous and normal. Therefore, it can be continued with hypothesis testing using a paired sample t-test to determine the significance of the increase in students' multi-representation ability and conceptual understanding of Newton's law. Hypothesis testing is carried out using a significance level of α = 0.05 with the help of SPSS 22. Furthermore, to see the magnitude of the increase in students' multi-representation ability and conceptual understanding, the normalized n-gain test <g> is used using the following equation.

$$\langle s \rangle = \frac{\% \langle s_f \rangle - \% \langle s_i \rangle}{100 - \% \langle s_i \rangle} \quad (1)$$

where <g> is the average of normalized gain, $<s_f>$ is the average of the post-test score, and $<s_i>$ is the average of the pre-test score.

Next, the results of the n-gain data analysis of students' multi-representation abilities and conceptual understanding are interpreted according to TABLE 2.

TABLE 2. N-gain Criterion (Hake, 1998)

Normalized Gain	Criteria
gain > 0.7	High
0.3 < gain < 0.7	Moderate
0.3 < gain	Low

RESULTS AND DISCUSSION

This research was conducted at the tertiary level involving physics students at one of the Education and Teacher Training Institutions (LPTK) in Ternate City (as experimental class 1) and one of the LPTK in Bandung City (as experimental class 2). The learning process was carried out by applying a physics e-book based on TPACK to Newton's law concept developed in previous studies. The results of the study are presented as follows.

Multi-Representation Ability

Data on the multi-representation abilities of physics students on the concept of Newton's laws were obtained using multi-representation questions adopted from the Representation-Force Concept Inventory (R-FCI) instrument with a modified presentation in the form of Google Form so that it is more in line with current developments in educational technology. The results of the pretest and posttest of students' multi-representation abilities are presented in the form of a diagram in FIGURE 1.

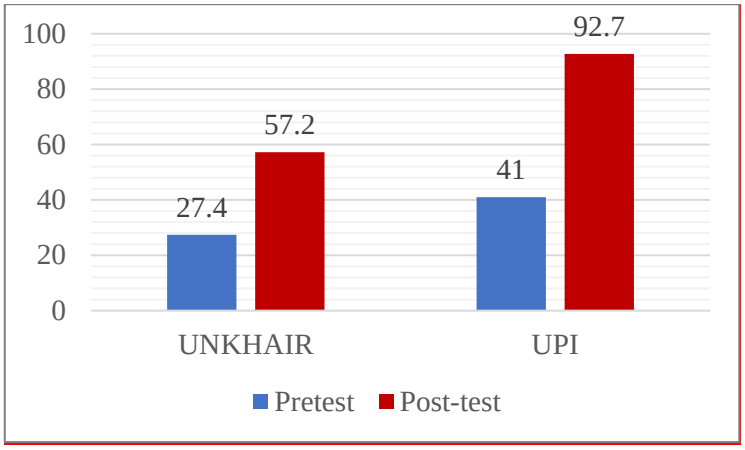

FIGURE 1. Pretest and posttest scores of students on Multi-Representation

The diagram in FIGURE 1 shows that the multi-representation ability of physics students in the Physics Education study program at Universitas Khairun (Unkhair) as experimental class 1 has increased. This can be seen from the average test results after the learning process using physics ebooks (posttest) of 57.2, which shows an increase compared to the test score before the learning process (pretest) of 27.4. However, the multi-representation ability of Unkhair physics students is generally still relatively low for both pretest and posttest scores. This happens because they have not received any introduction to multi-representation, an approach to studying physics concepts through various forms of representation. Generally, teachers only teach mathematical equations in solving physics problems about Newton's Laws.

Meanwhile, the multi-representation ability of physics students in the physics education study program at the Universitas Pendidikan Indonesia (UPI) as experimental class 2 also increased, as seen from the average pre-test (41.0) and post-test (92.7) scores. These results indicate that the multi-representation ability of UPI's students after the learning process increased and was in the high category. Factors that influence the effectiveness of TPACK-based ebooks in improving students' multi-representation abilities and conceptual understanding, namely the development of ebook content, are carried out creatively using the TPACK approach that combines technological, pedagogical, and content knowledge. Using technology through the TPACK framework is an important condition in creating effective and innovative classroom teaching (Abbit, 2011). The ebook content used in this study is presented in various static representation modes (such as verbal, images, pictorial diagrams, tables, graphs, and mathematical equations) and dynamic representations (learning videos) that are relevant and complementary to each other to produce more precise and easier-to-understand descriptions. The content is presented in the form of an ebook to make it more interesting and practical so that it is in great demand because it can be accessed anytime and anywhere (Mashfufah et al.,2019). The use of appropriate videos and animations can help students understand concepts and motivate them to explore information related to the phenomena presented so that learning is more meaningful (Chen, Fan & He, 2012). This is supported by Mayer (1997) and Clark & Paivio (1991), who explain that the technique of using various multimedia elements with animated and video displays can move verbal and visual channels in memory, which is an effective strategy for obtaining, storing, and remembering information in the learning process.

Furthermore, to test the significance of the improvement of multi-representation ability, it is necessary to conduct a mean difference test or t-test for paired samples. The results can be seen in TABLE 3.

TABLE 3. Results of paired sample t-test analysis on multi-representation ability

Pretest – Posttest	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence interval of the difference				
				Lower	Upper			
Unkhair	52.0000	25.85488	3.33785	45.32098	58.67902	15.579	59	.000
UPI	73.2142	23.27273	2.78162	67.66510	78.76347	26.321	69	.000

Based on the results of the t-test analysis of the data on the multi-representation abilities of in-service physics teachers at Universitas Khairun (UNKHAIR) using SPSS 22 software, a significance value (Sig. 2-tailed) of 0.000 was obtained, which is below the significance level of $\alpha = 0.05$. This finding indicates that the increase in students' multi-representation abilities is statistically significant. A similar thing also happened to in-service physics teachers at the Universitas Pendidikan Indonesia (UPI), which showed a significant increase in multi-representation abilities, as indicated by the Sig. (2-tailed) value, which is also smaller than 0.05. Furthermore, an analysis was carried out using the normalized N-gain test to determine the effectiveness of the increase. The results of the N-gain analysis are presented in FIGURE 2.

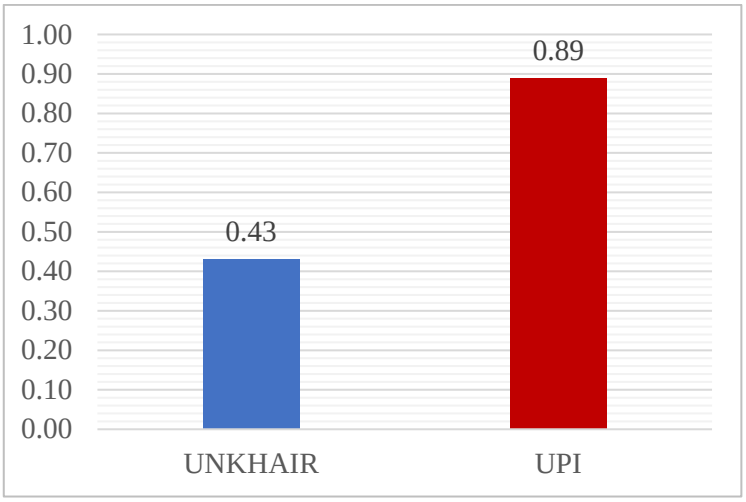

FIGURE 2. N-gain Value of Students' Multi-representation Ability

Based on the N-gain results as seen in FIGURE 2, it shows that the multi-representation abilities of physics students at both Unkhair and UPI have both increased, where for Unkhair students, the increase was 0.43 which is in the moderate category, and for UPI students, it was 0.89 with a high category.

Multi-representation ability is applying several types of representations to Physics concepts. The multi-representation ability of prospective Physics teachers increased after learning using multimodal ebooks. This is because the developed ebook provides various representations such as text, images, diagrams, and equations so that it can have a positive impact on students. This is in accordance with the research results stating that multiple representations in learning materials can positively impact students (Titin S, 2022). If only one representation is used, multi-representation ability does not improve students' understanding of Physics concepts. For example, if students get a concept presented only with mathematical representation, then the ability to represent graphics verbally and images will experience difficulties. Multi-representation ability can help students' cognitive processes, reduce the possibility of misinterpretation, and strengthen deep understanding of concepts (Kassiavera et al., 2019). This representation ability is supported by Johnson-Laird's cognitive framework theory, namely three main categories of mental representation. First, the mental representation of a proposition consists of a series of symbols, such as equations, formulas, numbers, and abstract and meaningful syntactic structure definitions. Both mental models are built by perception or imagination and tentative analogical representations where the results of thinking can be refined with existing knowledge. Third, mental images are based on observations and experiences from the real world, coherent and integrated representations of events or objects from the observer's point of view (Ibrahim & Rebello, 2013).

The multi-representation ability of the post-test scores of the two universities differs significantly, namely, Unkhair is in the low category, and UPI is in the high category. Firstly, Unkhair students' have never been introduced to multi-representation or how to learn a physics concept through different forms of representation. Generally, teachers only teach mathematical equations in solving physics problems about Newton's laws. Meanwhile, UPI students have long studied physics concepts with a multirepresentation approach. Students' multirepresentation ability can increase along with the frequency of the learning process using multirepresentation (Sabella, Henderson & Singh, 2009). Students will use multirepresentation and apply the abilities they have previously obtained in subsequent learning.

In addition, the second cause of the difference in students' multi-representation abilities is the student's initial abilities. It can be seen from the results of the Unkhair students' pretest, which is lower than that of UPI students' where the Unkhair students' pretest score was 27.4 and UPI's was 41. So even though the learning methods used for students at these two universities are the same, they will produce different multi-representation abilities. The initial ability level will significantly affect students' multi-representation abilities (Vogt et al., 2020), where initial knowledge affects learning engagement through cognitive load and students' problem-solving strategies (Dong, Jong & King, 2020).

The third possible cause of the difference in multi-representational ability results is the learning gap between Unkhair in North Maluku and UPI in West Java. This learning gap can be seen from the Word Bank study conducted on 12th-grade high school students who will later become college students. 12th-grade high school students in North Maluku have lower scores on the PISA and the National Examination than students in West Java (World Bank, 2020).

Furthermore, the results of students' multi-representational abilities for each type of representation are shown in FIGURE 3.

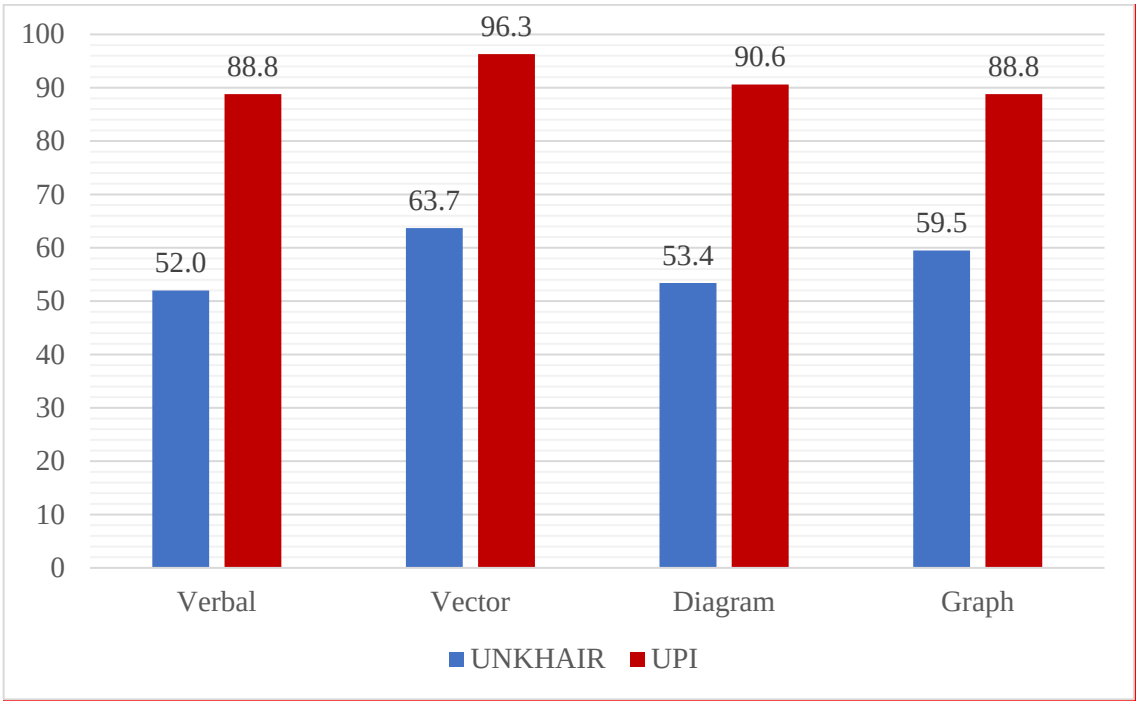

FIGURE 3. Students' multi-representation abilities in each type of representation

The results of the analysis of students' multi-representation abilities in each type of representation, as seen in FIGURE 3, show that the multi-representation abilities of physics students at both Unkhair and UPI are highest in the vectorial representation type, with values of 63.7 and 96.3, respectively. This is because students at both universities, Unkhair and UPI, are accustomed to using vector descriptions in teaching the concept of Newton's laws, so students are accustomed to solving Newton's law problems using vectorial forms. This is in accordance with the research of Mladovichi that the teaching approach influences students' learning conceptions (Mladenovici et al., 2022).

In particle dynamics, the vectors are the center of representation, usually used in two forms: algebraic representation as a formula equation and visual representation depicted by a vector field diagram or image representation. Algebraic representation is useful for quantitative calculations, and vector field diagrams are helpful in describing force components in a field. These two things complement each other, namely, students try to extract vector representation information into algebraic representations, which are continued with an understanding of Physics concepts (Malone et al., 2023). Image representation can visualize data that can reduce the burden on working memory when analyzing data, thereby helping students understand the Physics concepts (Susac et al. 2017).

Meanwhile, the lowest achievement was in Unkhair physics students, namely the verbal representation type of 52. In contrast, UPI physics students had the lowest achievement in the verbal and graphic representation types with the same value, namely 88.8. This is because students have difficulty understanding the meaning of Newton's law problems in the form of text. Students do not have a meaningful understanding of the concept of Newton's laws but only memorize the concept of Newton's laws (Furwati, Sutopo, & Zubaidah, 2017).

The pretest and posttest scores for each representation category all increased. It was indicated that TPACK-based e-books are able to help students improve their multi-representation abilities. The increase in scores for each representation had different increases, where the representation that experienced the highest increase was the diagram representation at 37.2, and the lowest increase in representation ability was the graph, with a value of 29.3.

Conceptual Understanding

The data on students' conceptual understanding of physics students on the concept of Newton's law was obtained using ten conceptual understanding questions in the form of Google Form so that it is more in line with current developments in educational technology. The results of the pretest and posttest of students' conceptual understanding are presented in the form of a diagram in FIGURE 4.

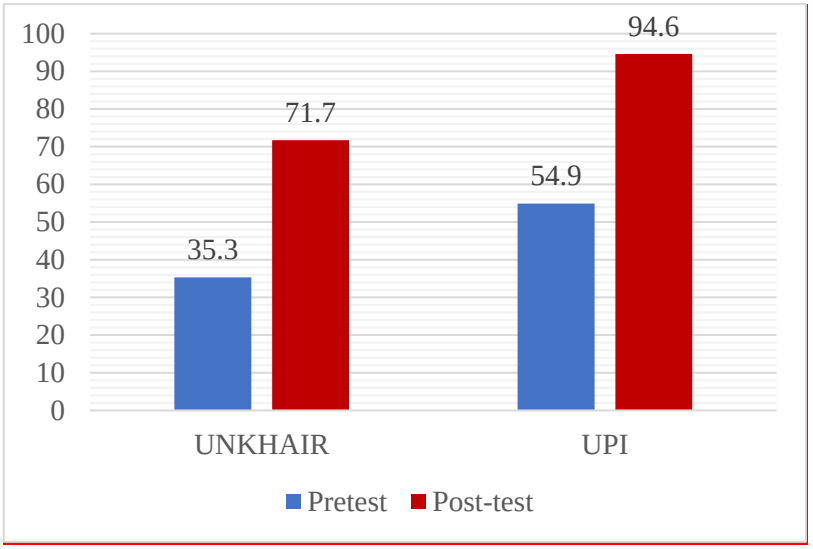

FIGURE 4. Pretest and posttest score of students' conceptual understanding

The diagram in FIGURE 4 shows that the conceptual understanding of physics students in the physics education study program at Universitas Khairun (Unkhair) as experimental class 1 has increased. It can be seen from the average test results after the learning process using physics ebooks (post-test) of 54.9, which shows an increase compared to the test score before the learning process (pretest) of 35.3. Likewise, the conceptual understanding of physics students in the physics education study program at the UPI as experimental class 2 experienced an increase, as seen from the average pretest score (71.7) and post-test (94.6).

Furthermore, to test the significance of the improvement of conceptual understanding that occurs, it is necessary to conduct a mean difference test or t-test for paired samples. The results can be seen in TABLE 4.

TABLE 4. Results of paired sample t-test analysis on Conceptual Understanding

Pretest – Posttest	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence interval of the difference				
				Lower	Upper			
Unkhair	40.80433	27.54483	3.55602	33.68875	47.9199	11.475	59	.000
UPI	65.32500	30.69241	3.66844	58.00665	72.6433	17.807	69	.000

The results of the t-test analysis of the conceptual understanding data of physics students at Unkhair using SPSS 22 showed that the Sig. (2-tailed) score was smaller than the alpha significance level or 0.000 < 0.05 so that it can be concluded that the improvement of students' conceptual understanding

was significant. Likewise, the conceptual understanding of physics students at UPI also increased significantly. This can be seen from the Sig. (2-tailed) score, which is smaller than the specified alpha significance level (0.05).

Furthermore, the extent of the improvement of students' conceptual understanding can be seen from the results of the normalized N-gain test, the results of which can be seen in FIGURE 5.

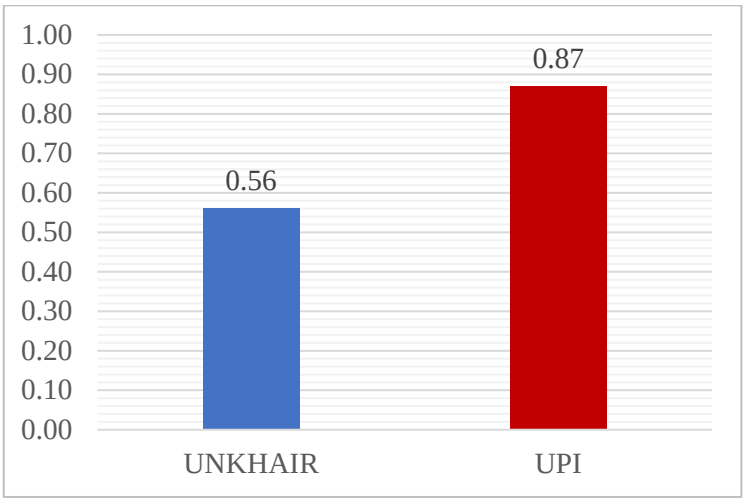

FIGURE 5. N-gain Score of Students' Concept Understanding

Based on the N-gain results as seen in FIGURE 5, it shows that the conceptual understanding of physics students at both Unkhair and UPI has increased, where for Unkhair students' the increase was 0.56, which is in the moderate category, and for UPI students' it was 0.87 which is in the high category.

The improvement of conceptual understanding of physics students is influenced by the Physics e-book on the concept of Newtons law's. Using multiple representations supports students' success in understanding Physics concepts (Titin S, 2022). This Physics E-book is developed with various representations such as images, equations, diagrams, and texts. This interpretation plays an important role in Physics and Physics learning, because it can facilitate the learning and understanding the substantially (Malone et al., 2023). This is in accordance with the findings that understanding of Physics concepts can increase after learning using a multiple representation approach (Campos et al., 2020; Kassiavera et al., 2019; Klein et al., 2018; Von Korff & Rebello, 2012; La Sahara et al., 2020; Sutopo & Waldrip, 2023; Amiroh et al., 2021). The existence of a multi-representation e-book that provides diagrammatic representations can help students to understand and analyze Physics problems easily. It can positively impact the correctness of students' answers in answering Physics problems (Susac et al., 2019). In addition, the combination of concepts and symbolic reasoning in e-books can help Physics students learn (Kuo et al., 2013).

CONCLUSION

Based on the research and data analysis results, the application of TPACK-based physics e-books on the concept of Newton's law that has been developed can improve students' multi-representation abilities and conceptual understanding. This can be seen from the n-gain value of multi-representation abilities and conceptual understanding of pre-service physics teachers at Universitas Khairun of 0.43 and 0.56, with a moderate category for both. Likewise, for the multi-representation abilities and conceptual understanding of the pre-service physics teacher at Universitas Pendidikan Indonesia, the N-gain was obtained respectively of 0.89 and 0.87 with a high category for both. According to the findings, the multi-representation abilities and conceptual understanding of students at both universities were increased, although the magnitude of the increase was different. It is because the initial abilities possessed by students at the two universities are indeed different so it affects the final results achieved even though they are given the same treatment. In addition, the involvement of Unkhair students' when studying e-books is not optimal because they still need direction to consider e-books that they have

never studied before. TPACK-based physics e-book on Newton's law concept can improve students' multi-representation ability and conceptual understanding because the content in the e-book is presented in various forms of representation such as text, images, tables, graphs, and videos so that it is more interesting and easy to understand for students with any learning style. However, there are still weaknesses in the e-book where interactive simulations for practical activities and practice questions are not yet available. For that, there is still an opportunity for further researchers to develop the e-book to make it more perfect.

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