TPACK Implementation in Physics Textbook: Practice Problem-Solving Skill in Newton’s Law of Motion for Senior High School Students

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Abstract. One of the skills needed in the 21st century is a problem-solving skill. This article describes the result of research on the implementation of TPACK in the physics textbook. The implementation of TPACK in the physics textbook is aimed to practice the problem-solving skill of senior high school students. The research method used is Research and Development with Dick & Carey model. Has been produced a physics textbook that integrates technological knowledge, pedagogical knowledge, and physics content knowledge in multiple representations with the stage to practice a problem-solving skill in Newton’s Law of Motion concept. The stages of problem-solving in the developed physics textbook are: (a) presents the problem at the beginning of the chapter; (b) asking several questions to focus the problem; (c) formulating hypotheses on the problem; (d) present the material in multiple representations based on pedagogical and technological studies, and (e) explain phenomena based on the physics concepts of being studied. The results of this study have been validated by experts, are physics material experts, learning experts, and textbook media experts. The validation result of the physics textbook was declared feasible to practice the problem-solving skill for senior high school students.

1. Introduction
The success of education and the learning process is very important in improving students’ cognitive, psychomotor, and affective abilities [1]. Therefore, the learning process must be designed actively, innovatively, and relevant to the needs of the 21st century [2].

Physics is very widely applied in human life. Therefore, the process of learning physics must be related to the environment of everyday life [3]. One of the goals of learning physics in high school is to develop analytical thinking skills, both inductively and deductively, using the concepts and principles of physics [4]. Furthermore, in the 4.0 revolution in the 21st century, students are required to have communication skills, collaboration, critical thinking, problem-solving, and being creative and innovative [5].

The demand for skills needed to face the 21st century, namely: 1) learning and innovation skills, which include critical thinking and being able to solve problems, be creative and innovative, and able to communicate and collaborate; 2) skills to use media, technology, information and communication (ICT); 3) the ability to live life and career, including the ability to adapt, flexible, initiative, develop themselves, have social and cultural abilities, productive, trustworthy, have leadership spirit, and responsibility [6].
In 21st century problem-solving skills, students must use their experience, understanding, skills, and expertise in solving existing challenges [7, 8]. Students have high curiosity, creative ideas and use a critical mindset in making rational decisions to solve the problems they face [9, 10]. Innovation in the learning process is needed to improve students' soft skills and hard skills [11].

Textbooks have an important role in achieving mastery of students' concepts and independent learning patterns in solving problems [12, 13]. However, many physics textbooks cause misconceptions, exposure to material that lacks scientific representation and is not contextual [14]. There are many misconceptions in physics textbooks [15, 16] regarding the explanation of concepts, writing formulas, symbols, and units, presenting images, tables, and graphs [17] makes it very difficult for students to develop thinking skills to build their physics concepts [18]. The study of Newton’s law has quite a large misconception [19, 20].

The available physics textbooks only describe physics material and have not practiced scientific literacy. Therefore, physics textbooks should be displayed in multiple representations of science to minimize students' learning difficulties [21, 22, 23].

Textbooks must support the development of 21st-century competencies. Therefore, it is necessary to integrate technological and pedagogical knowledge in formulating physics concepts in textbooks needed in 21st-century learning. This integration is built within the TPACK (Technological, Pedagogical, and Content Knowledge) framework [24, 25, 26, 27]. The integration of TPACK in textbooks can optimize learning activities, improve conceptual understanding, and build students’ scientific attitudes [28, 29].

The TPACK framework can be applied to textbooks [30]. The TPACK framework will integrate technology and pedagogy into content and content presented pedagogically using technology [31, 32]. In textbooks that implement TPACK, the presentation of the material will be supported by technology, and the application of technology supports pedagogical stages, the concept of the material, the pedagogic stage will make students easier to understand the material supported by technology [33, 28].

There are five criteria for assessing the TPACK framework, namely 1) the material is presented with the support of Augmented Reality technology that can visualize abstract concepts; 2) representation to change difficult and abstract material to be real and easy for students to understand; 3) the steps of presenting the material that is arranged pedagogically will make it easier for students to build the concepts being studied; 4) the selection of appropriate technology and the use of effective pedagogies; and 5) learner-centered learning strategies combined with appropriate technology [34].

Based on the description above, this article will describe the research results on the development of physics textbooks that implement TPACK to practice problem-solving skills for 10th grade high school students on Newton's Laws of Motion.

2. Method

2.1. Research Design

This article is the result of research and development of physics textbooks that implement TPACK using the Dick & Carey approach. This textbook to be able to practice the problem-solving skills of class 10th high school students on Newton’s Laws of Motion, an R&D process has been carried out according to Dick & Carey, namely:

2.1.1. Identify learning objectives

The identification of physics learning objectives in the cognitive domain is carried out by Permendikbud No. 21 of 2016 concerning Content Standards for Primary and Secondary Education.

2.1.2. Conduct learning analysis

A learning analysis was carried out referring to the 2013 revised 2018 curriculum on Newton’s Law of Motion by identifying learning competencies 3.7, then compiling indicators of competency achievement hierarchically and systematically.

2.1.3. Analyze students and learning context

An analysis of the basic skills that students must master is carried out before studying Newton’s Law of Motion and the skills acquired by students at the end of the lesson. The results of the analysis are presented in a concept map and prerequisite materials.

2.1.4. Formulate specific learning objectives
The formulation of learning objectives is based on basic competencies and indicators of competency achievement.

2.1.5. Develop test items using textbook tools
The development of learning measuring tools is made to practice problem-solving skills that refer to learning indicators.

2.1.6. Develop learning strategies
The strategy applied in this textbook uses the TPACK framework and problem-solving learning model.

2.1.7. Developing learning materials
The development of physics textbooks was carried out by determining the scope of the material developed in the textbook, designing textbook using the TPACK framework, compiling and designing textbook, and making learning videos packaged in AR markers.

2.1.8. Develop and execute formative assessment
The product feasibility instrument was developed in the form of a questionnaire to test the physics concept feasibility, a questionnaire to test the pedagogic feasibility, and a questionnaire to test the media feasibility.

2.1.9. Review textbook
A revision was made to the physics textbook based on the criticism and suggestions given after conducting the validation test.

2.2. Instrumentation Research
To test the feasibility of the results of development research on the physics textbooks, an instrument in the form of a questionnaire is used. Thus, there are three questionnaires developed, namely a questionnaire to test the physics concept feasibility, a questionnaire to test the pedagogic feasibility, and a questionnaire to test the media feasibility.

The eligibility of physics concept in text book is assessed in 3 aspects, namely: (a) Presentation of physics concept in textbook; (b) The representation of science in physics textbook; (c) The physics concept in augmented reality media.

The eligibility of pedagogic in physics textbook is assessed in four aspects, namely: (a) Presentation of the physics concept in textbook; (b) The use of science illustrations in physics textbook; (c) The stages of problem-solving in physics textbook; (d) Implementation of TPACK in physics textbook.

The eligibility of physics textbook media is assessed in 5 aspects, namely: (a) The quality of front part of the physics textbook; (b) The quality of the content section of the physics textbook; (c) The quality of graphics aspects of the physics textbook; (d) The quality of back part of the physics textbook; (e) The quality of augmented reality media.

2.3. Data Analysis
The expert assesses the feasibility of the physics concept, pedagogic, and media instruments using four continuum scale for each aspect assessed. The interpretation of the assessment refers to the following table.

| No | Response     | Score |
|----|--------------|-------|
| 1  | Very good    | 4     |
| 2  | Good         | 3     |
| 3  | Bad          | 2     |
| 4  | Very bad     | 1     |

The result of interpretation score calculated based on the acquisition score of each item by the following formula
The range of scales on the continuum scale used in this research is 1 to 4, with a minimum score of 1 and a maximum score of 4, so the total score range is 4. This can be calculated using the following formula

\[
\text{Scale Range} = \frac{\text{maximum score} - \text{minimum score}}{\text{maximum score}} = \frac{4 - 1}{4} = 0.75
\]

The result of obtaining the score percentage is then measured using the interpretation table as follows. The scale range obtained is 0.75. The lowest interpretation is 1 to 1.75, with each range plus 0.75. Then, change the scale range in percent form. For more details, see the table below.

\[
\text{Scale Range (\%)} = \frac{\text{score}}{\text{maximum score}} \times 100\%
\]

| Scale Range          | Category of Eligibility       |
|----------------------|-------------------------------|
| 25% \( \leq SI < 43.75\%\) | Not Feasible                  |
| 43.75% \( \leq SI < 62.5\%\) | Quite Decent                  |
| 62.5% \( \leq SI < 81.25\%\) | Feasible                      |
| 81.25% \( \leq SI \leq 100\%\) | Very Feasible                 |

3. Result and Discussion

3.1 Product research

Physics textbooks that implement TPACK have been produced from this development research. The advantages of this book is on TPACK framework components are described below.

3.1.1. Technological knowledge, pedagogic knowledge, and content knowledge

![Technology Knowledge](image1)

![Content Knowledge](image2)

The technology applied in the physics textbook is augmented reality media. Newton’s law of motion phenomena explained in accordance with the concepts of physics (Figure 2).
3.1.2. Technological pedagogical knowledge

To make students easier to visualize abstract material, learning is assisted by technology-based 3-dimensional media. Augmented reality media does not just display it, but learning allows students to analyze the concept being studied. Augmented reality media in the apperception section (Figure 3). Application of Newton's law of motion packaged with augmented reality media (Figure 4).

3.1.3. Technological content knowledge

Augmented reality media have a role in conveying the abstract concept of Newton's laws of motion to make it easier for students to understand. Augmented reality media for explain magnetic field as non-touch force (Figure 5). Technology that applies Newton's first law concept (Figure 6).

3.1.4. Pedagogical Content knowledge

Newton's law of motion concept is built using the stages of problem solving learning, multiple representations and building science literation with the illustrations provided.

3.1.5. Technological, pedagogical, and content knowledge

The material is presented pedagogically by involving technology so that physics concepts are easy to understand. The physics textbook applied problem-solving stages.
3.1.5.1. Aperception, problem orientation, and hypotheses

Students watch and listen to the phenomenon of Newton's laws of motion in augmented reality media as students’ apperception (Figure 9). Students are given problems related to the concept of Newton's laws of motion that have been built from apperception and then analyze it (Figure 10). Students make hypotheses from the problems they face (Figure 11).

3.1.5.2. Students are presented with material equipped with illustrations and augmented reality media, also questions that stimulate students to think critically.

3.1.5.3. Students learn the concept of Newton's laws of motion which are equipped with phenomenons review with the help of illustrations and augmented reality media, sample questions, and simple experiment that help students to understand the concepts, summaries and competency test.

3.2. Description of formative evaluation result

The development of the physics textbook has passed the formative evaluation by material experts, pedagogic experts, and media experts. The eligibility of physics concepts in textbook is validated by material expert covering three aspects with the result as shown in Figure 20.
The eligibility of pedagogic in physics textbook is validated by pedagogic expert covering four aspects with the result as shown in Figure 21.

![Figure 21. Pedagogic eligibility in physics textbook](image)

The eligibility of physics textbook media is validated by media expert covering five aspects with the result as shown in Figure 22.

![Figure 22. Media eligibility of physics textbook](image)

### 3.3. Discussion
Implementation of TPACK and media based on augmented reality technology in physics textbooks can practice students to solve problems [28]. The contextual presentation in textbook and multiple representations make students easier to understand physics concepts [21]. The addition of augmented reality technology-based media makes students easier to understand abstract concepts to avoid misconceptions [19, 29].

Problem-solving stages in the presentation of concepts make students easier to understand the studied physics concepts [10]. The presentation of physics concepts supported by augmented reality technology and problem-solving learning stages make students understand Newton’s law of motion concept easier and students’ problem-solving skills are practiced well with this physics textbook [8, 27].
4. Conclusion
The TPACK framework implemented in the physics textbook is compiled to practice problem-solving skills on Newton's laws of motion concept. Based on formative evaluation, physics textbooks that implement TPACK are very suitable for practicing students' problem-solving skills on Newton's laws of motion concept.

References
[1] W. Syafi'i, E. Suryawati and A. R. Saputra, "Kemampuan Berpikir Kreatif dan Penguasaan Konsep Siswa Melalui Model Problem Based Learning (PBL) dalam Pembelajaran Biologi Kelas XI IPA SMAN 2 Pekanbaru Tahun Ajaran 2010/2011," Jurnal Biogenesis, vol. 8, no. 1, pp. 1-7, 2011.
[2] Sutiah, Teori Belajar dan Pembelajaran, Sidoarlo: Nizamia Learning Center, 2016.
[3] A. R. Harefa, "Peran Ilmu Fisika dalam Kehidupan Sehari-hari," Jurnal Warta, vol. 60, 2019.
[4] N. D. Permana, "Penerapan Model Pembelajaran Learning Cycle 7E Berbantuan Website Untuk Meningkatkan Keterampilan Berpikir Kritis Siswa Pada Materi Kinematika Gerak Lurus," Journal of Natural Science and Integration, vol. 1, no. 1, pp. 11-41, 2018.
[5] S. D. Aji, M. N. Hudha and A. Y. Rismawati, "Pengembangan Modul Pembelajaran Fisika Berbasis Problem Based Learning untuk Meningkatkan Kemampuan Pemecahan Masalah Fisika," Jurnal Terapan Sains dan Teknologi, vol. 1, no. 1, pp. 36-51, 2017.
[6] A. H. Subarjo, "Utilization of QR - Code in Citizenship Education," in Prosiding Seminar Nasional Teknologi Informasi dan Kedirgantaraan : Transformasi Teknologi untuk Mendukung Ketahanan Nasional, Yogyakarta, 2018.
[7] J. Carson, "A Problem With Problem Solving : Teaching Thinking Without Teaching Knowledge," The Mathematics Educator, vol. 17, no. 2, p. 7–14, 2007.
[8] N. A. P. Yaman and A. Anwar, "Terampil dalam Pemecahan Masalah: Kompetensi Matematika Siswa Abad 21," Seminar Matematika dan Pendidikan Matematika UNY, pp. PM 489-PM 496, 2017.
[9] J. A. Koenig and Rapporteur, Assessing 21st Century Skills: Summary of a Workshop, Washington, DC: The National Academies Press., 2011.
[10] T. F. Wijayanti, "Potensi Model Pembelajaran Problem Solving Disertai Argument Mapping untuk Memberdayakan Berpikir Kritis," in Prosiding Seminar Nasional Pendidikan, Palembang, 2016.
[11] A. Ayob, A. Hussain and R. A. Majid, "A Review of Research on Creative Teachers in Higher Education," International Education Studies, vol. 6, no. 6, pp. 8-14, 2013.
[12] G. Rahmawati, "Buku Teks Pelajaran Sebagai Sumber Belajar Siswa di Perpustakaan Sekolah di SMAN 3 Bandung," EduLib, vol. 5, no. 1, pp. 102-113, 2015.
[13] P. Sothayapetch, J. Lavonen and K. Juuti, "A comparative analysis of PISA scientific literacy framework in Finnish and Thai science curricula," Science Education International, vol. 24, no. 1, pp. 78-97, 2013.
[14] L. Piranti and D. Muliyati, "Pengembangan Buku Referensi Berbasis Multi Representasi dengan Pendekatan Kontekstual pada Materi Kalor dan Termodinamika," in PROSIDING SNIPS 2016, Bandung, 2016.
[15] N. Respatiningrum, Y. Radiyono and E. Wiyono, "Analisis Miskonsepsi Materi Fluida pada Buku Ajar Fisika SMA," in Prosiding Seminar Nasional Fisika dan Pendidikan Fisika (SNFPF) Ke-6, Surakarta, 2015.
[16] D. K. Gurel and A. Eryilmaz, "A Review and Comparison of Diagnostic Instruments to Identify Students' Misconceptions in Science," Eurasia Journal of Mathematics, Science and Technology Education, vol. 11, no. 5, pp. 989-1008, 2013.
[17] H. Khoiri, A. K. Wijaya and I. Kusumawati, "Identifikasi Miskonsepsi Buku Ajar Fisika SMA Kelas X pada Pokok Bahasan Kinematika Gerak Lurus," Jurnal Ilmu Pendidikan Fisika, vol. 2, no. 2, pp. 60-64, 2017.
[18] Matsun, D. F. Saputri and Triyanta, "Analisis Miskonsepsi dan Tingkat Keterbacaan Buku Ajar Fisika SMA Kelas XII pada Materi Listrik Statis," Jurnal Pendidikan Informatika dan Sains, vol. 5, no. 2, pp. 227-236, 2016.
[19] S. Wuryanti, Yennita and Fakhruddin, "Analisis Miskonsepsi Siswa pada Materi Dinamika Gerak Menggunakan Tes Diagnostik Pilihan Ganda Tiga Tingkat," *Jurnal Geliga Sains*, vol. 5, no. 2, pp. 110-118, 2017.

[20] F. Fitria and Novitriani, "Diagnostik Miskonsepsi Siswa di Lingkungan Sekolah Menengah Atas di Bandung untuk Topik Hukum Newton tentang Gerak," in *Prosiding Seminar Nasional Quantum*, 2018.

[21] D. Rosengrant, E. Etkina and A. V. Heuvelen, "An Overview of Recent Research on Multiple Representations," in *Physics Education Research Conference*, New York, 2006.

[22] B. Waldrip, "Improving learning through use of representations in science," in *Proceeding The 2nd International Seminar on Science Education*, Bandung, 2008.

[23] C. Angell, O. Guttersrud and E. K. Henriksen, "Multiple Representations as a Framework for a Modelling Approach to Physics Education," pp. 1-4, 2007.

[24] N. Baya'a and W. Daher, "The Development of College Instructors' Technological Pedagogical and Content Knowledge," *Procedia - Social and Behavioral Sciences*, no. 174, pp. 1-11, 2014.

[25] J. Rosenberg and M. J. Koehler, "Context and Technological Pedagogical Content Knowledge (TPACK): A Systematic Review," *Journal of Research on Technology in Education*, vol. 47, no. 3, pp. 186-210, 2015.

[26] P. Mishra and M. J. Koehler, "Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge," *Teachers College Record*, vol. 108, no. 6, p. 1017–1054, 2006.

[27] A. M. Ilmi, Sukarmin and W. Sunarno, "Development of Macro VBA as a TPACK Based-Physics Learning Media to Improve Critical Thinking Skills," in *The 2nd International Conference on Science, Mathematics, Environment, and Education AIP Conference Proceeding*, Surakarta, 2019.

[28] Robby, Sutrisno and W. D. Ernawati, "Pengembangan Perangkat Pembelajaran Kerangka Kerja TPACK untuk Meningkatkan Pemahaman Konsep Siswa pada Materi Kesetimbangan Kimia di Kelas XI IPA5 SMA Negeri 1 Kota Jambi," *Artikel Ilmiah Pendidikan Kimia FKIP Universitas Jambi*, 2014.

[29] S. A. Garba, T. K. Singh and N. M. Yusuf, "Integrating Technology in Teacher Education Curriculum and Pedagogical Practices: the Effects of Web-based Technology Resources on Pre-service Teachers’ Achievement in Teacher Education Training.," in *International Conference on Information Science and Technology Application (ICISTA)*, Paris, 2013.

[30] A. Y. A. Putranti, "Analisis TPACK Buku Guru Kelas 5 Tema 1 Edisi Revisi 2017 pada Muatan IPA," FKIP Universitas Muhammadiyah Surakarta, Surakarta, 2020.

[31] N. Brouwer, P. J. Dekker and J. V. D. Pol, E-Learning Cookbook. TPACK in Professional Development in Higher Education, Amsterdam: Amsterdam University Press, 2013.

[32] M. J. Koehler, P. Mishra and W. Cain, "What Is Technological Pedagogical Content Knowledge (TPACK)?:, "*Journal of Education*, vol. 193, no. 3, pp. 13-19, 2013.

[33] S. Cox and C. R. Graham, "Diagramming TPACK in Practice: Using An Elaborated Model of The TPACK Framework to Analyze and Depict Teacher Knowledge," *Tech Trends*, vol. 53, no. 5, pp. 60-69, 2009.

[34] C. Angeli and N. Valanides, "Epistemological and Methodological Issues for the Conceptualization, Development, and Assessment of ICT-TPCK: Advances in Technological Pedagogical Content Knowledge (TPCK)," *Computers & Education*, vol. 52, no. 1, pp. 154-168, 2009.