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Science and Engineering Practices Elements on Physics Textbook: A Comparison Between Indonesia and Malaysia

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Abstract

Many countries are revitalizing science subjects by strengthening the integration of science content with engineering, technology, and mathematics content and skills, creating STEM learning. However, the availability of textbooks capable of facilitating this integration remains limited.This study aims to analyze the Science and Engineering Practice content in high school physics textbooks used by Indonesian and Malaysian schools. This study is qualitative descriptive research with content analysis. The analysis was conducted on two samples of Indonesian and Malaysian books each. Content analysis is based on the SEPAR (Science and Engineering Practice Assessment Rubric) that divides Science and Engineering Practice into 8 elements. The analysis showed that Indonesian textbooks' Science and Engineering Practice content is still lacking compared to Malaysian books in all elements. The most common aspects found in Indonesian books are asking questions and defining problems. These results show that Malaysian high school physics textbooks represent many elements of Science and Engineering Practices, but there are still several elements that are not optimal. This research highlights the importance of improving representation of Science and Engineering Practice in Physics textbook.

Keywords: STEM, Science and Engineering Practice, Physics Textbook

Abstrak

Berbagai negara merevitalisasi mata pelajaran IPA dengan memperkuat integrasi konten IPA dengan konten dan keterampilan Engineering, *Teknologi dan Matematika menjadi pembelajaran STEM. Namun ketersediaan buku tet yang mampu memfasilitasi integrasi ini masih terbatas. Penelitian ini bertujuan untuk menganalisis konten* Science and Engineering Practice *dalam buku pelajaran fisika Sekolah Menengah Atas (SMA) yang digunakan oleh sekolah-sekolah di Indonesia dan Malaysia. Penelitian ini merupakan penelitian deskriptif kualitatif dengan analisis konten. Analisis dilakukan terhadap dua buku sampel dari Indonesia dan Malaysia. Analisis konten dilakukan berdasarkan SEPAR* (Science and Engineering Practice Assessment Rubric) *yang membagi* Science and Engineering Practices *menjadi 8 elemen. Hasil analisis menunjukkan bahwa konten* Science *dan* Engineering Practices *pada buku teks Indonesia masih kurang dibandingkan dengan buku-buku Malaysia. Hasil analisis menunjukkan elemen yang banyak ditemukan pada buku Indonesia adalah pertanyaan awal dan definisi masalah. Buku-buku Indonesia belum memadai dalam menyajikan konten* Science *dan* Engineering Practices. *Hasil ini menunjukkan bahwa buku Fisika SMA Malaysia banyak merepresentasi elemen* Science *dan* Engineering Practices *namun masih terdapat beberapa elemen yang belum maksimal. Penelitian ini menyoroti pentingnya peningkatan kualitas dan kuantitas konten Science dan Engineering Practices dalam buku teks Fisika*.

***Kata kunci**: STEM*, Science and Engineering Practice*, Buku Teks Fisika*

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INTRODUCTION

The era of Society 5.0 is a challenge for Indonesia in various fields, including education. Teachers need to prepare and equip students through learning models that are oriented towards improving the ability to search and analyze information, think critically, be creative, innovative, and communicate (Nurhaddi & Budiyanto, 2020). These expected abilities are part of the 4C skills: Creativity, Critical thinking, Communication, and Collaboration (Anagün, 2018). In the learning process, teachers need to gain 4C skills to improve the quality of learning and develop hidden skills when dealing with problems (P. Winarni, 2021). There is a relation between 4C skills or 21st century skills and the Science-Technology-Engineering-Mathematics (STEM) approach. The activity of designing 21st century skills instruction begins with identifying themes and fundamental concepts that combine several subject contents.

STEM education has been widely adopted by several countries around the world. Malaysia, for example, has collaborated with the United States by involving children aged 13-14 years to apply STEM to compete in improving 21st century skills(J. Winarni et al., 2016). In the case of Malaysia, all of these initiatives are focused at transforming STEM so that career aspirations among students increase and their motivation to continue learning Science and can compete globally (Abd et al., 2020). In addition, STEM has also taken a central role in a project implemented in Turkey where the project aims to improve technical knowledge and skills using science concepts (Aryati et al., 2020). In the learning process in Indonesia itself, STEM education has been incorporated since 2014. On the other hand, STEM education in Indonesia has become the commitment of all stakeholders in the field of science education in the last several years that focus on teacher and lesson preparations (Permanasari et al., 2021). STEM education has been used as learning strategies and techniques, combined with other learning models, assessed, and produced into teaching materials, modules, and learning media. Currently, STEM education has been implemented at all levels of education and is most focused on being used at the senior high school level (Farwati et al., 2021).

The application of STEM can be observed in school textbooks, which are learning resources that are compiled based on the curriculum and presented systematically to create a supportive learning environment. It is necessary to change the paradigm of thinking when STEM is considered difficult to implement (Sulaeman et al., 2022). School textbooks have a direct impact on student learning when students engage with the book, as well as an indirect impact through the influence of teachers who can explain the textbook during the teaching process. Books or teaching materials are essential in a student's learning process because they are intellectual, enlightening and can arouse students' reasoning and spirituality to become more creative and innovative (Asikin et al., 2021). STEM-based learning resources are helpful and can encourage students to think creatively. Research suggests that children exposed to STEM topics will have more meaningful learning and can develop their 21st century skills (Sakata & Kumano, 2018). Moreover, if STEM occupations or vocations are mentioned in their textbooks, children who study STEM will have a favorable impression of STEM careers (Amalia et al., 2023).

Physics is one of the science subjects that frames problems related to phenomena, conducts experiments, evaluates ideas, principles, and laws of physics (Pisano, 2025). Students can also develop basic projects or make simple products related to topics while learning physics. Through the application of STEM in physics learning, students are required to understand the ideas of science as well as the technical utilization of a technology that is useful to develop and improve critical thinking skills (Putra et al., 2021). Therefore, it is necessary to find out whether or not Physics textbooks represent Science and Engineering Practices. The purpose of this study is to determine whether the presentation of Indonesian and Malaysian high school Physics textbooks and which elements are represented more. In addition, researchers also want to examine what elements still need improvement in the Physics textbook.

METHOD

This research is descriptive research with content analysis. The purpose of this study is to analyze

how is the representation of Science and Engineering Practice in Indonesian high school physics textbooks and Malaysian. The samples were Indonesian Grade 10 and 11 high school physics textbooks equivalent to Malaysian Form 4 and 5 high school physics textbooks, published by each government. From the preliminary analysis, the chapters about Newtonian mechanics and Fluid are suitable for analysis because both books have these two chapters. The list of books used can be seen in Table 1.

Table 1. The identification of Indonesian and Malaysian physics high school textbooks on fluid material

Code	Book Title	Year	Publisher
1	Buku Siswa Fisika Kelompok Peminatan Matematika dan Ilmu-Ilmu Alam untuk SMA-MA Kelas 11 Kurikulum 2013 Edisi Revisi (Sunardi, P, & Darmawan, 2021)	2021	Yrama Widya
2	Buku Siswa Fisika Kelompok Peminatan Matematika dan Ilmu-Ilmu Alam untuk Siswa SMA/MA Kelas 10 Kurikulum 2013 Edisi Revisi 2016 (Sunardi et al., 2016)	2016	Yrama Widya
3	Buku Fizik Tingkatan 5 Kementerian Pendidikan Malaysia Kurikulum Standar Sekolah Menengah (Chuan, Choy, Bongkek, Kasron, & Anuar, 2020)	2020	Bestari SDN. BHD.
4	Buku Fizik Tingkatan 4 Kementerian Pendidikan Malaysia Kurikulum Standar Sekolah Menengah (Choy et al., 2019)	2019	Pustaka Sarjana SDN. BHD.

The instrument used in this study is the Science and Engineering Practice Analysis Rubric (SEPAR) (Papakonstantinou & Skoumios, 2021), to evaluate the level at which students engage in science and practice contained in the four textbooks without any change to the original version. The instrument consists of 4 levels with 8 assessment elements. The levels are organized based on the level of conformity of the textbook with the level of science and engineering practices in the textbook. Level 0 indicates that the school textbook does not allow students to engage in the assessed aspects. While Levels 1, 2, and 3 indicate if the textbook suggests that the book will enable students to engage in the assessed aspects.

This research is divided into 4 stages. The first was to find two Indonesian and Malaysian high school physics textbooks each. The textbooks consisted of grade 10 and 11 in Indonesian while Malaysian are form 4 and 5 and have the subject matter of Newtonian mechanics and Fluids. Secondly, the researchers looked at the sub-chapters of Newtonian and fluid mechanics and then analyzed the science and engineering practice content in the book. Each sub-chapter was assessed according to the level based on the assessment indicators of each level. If there were SEPAR aspects in the textbook, the level chosen was between 1-3, and if not found, the level chosen was 0. Thirdly, two researchers from the author observed all eight aspects contained in the two books and discussed them to reach a final agreement. Lastly, the results of the analysis were calculated using descriptive statistical analysis. Observations were processed in the form of scores and analyzed using Microsoft Excel. The following equation was used (Arikunto, 2021):

$$R = \frac{f}{n} \times 100\% \quad (1)$$

R = score percentage
f = aspect value score
n = minimum score of aspect value

RESULTS AND DISCUSSION

Results

The results of the data analysis identified the level of practice involved in the content on Newtonian

Mechanics and Fluids.

1. Indonesian and Malaysian Physics Textbooks

   The high school physics textbooks analyzed were Indonesian grade 10 and 11 equivalent to Malaysian form 4 and 5. Each of physics textbooks are currently used by schools and have Newtonian mechanics and fluid material selected. Based on our analysis, both books apply Science and Engineering Practice content in each Newtonian and fluid mechanics sub-chapters.

Table 2. Content of Indonesian and Malaysian Physics Textbooks on Newtonian Mechanics

SUB-CHAPTER	MATERIAL
1	Uniform Speed
2	Uniform Acceleration
3	Free Fall Motion
4	Inertia
5	Momentum and Impulse
6	Power
7	Newton's Gravity
8	Kepler's Law

Table 3. Content of Indonesian and Malaysian Physics Textbooks on Fluids

SUB-CHAPTER	MATERIAL
1	Fluid Pressure
2	Atmosphere Pressure
3	Gas Pressure
4	Archimedes Law
5	Bernoulli's Principle

2. Science and Engineering Content Analysis in Indonesian Grade 11 High School Physics Textbook and Malaysian Form 5 High School Physics Textbook.

Table 4. Identification of Science and Engineering Practice Content

Aspect	Indonesian Textbook	Malaysian Textbook
Asking questions and defining problems	33%	24%
Developing and using models	53%	73%
Planning and carrying out investigation	40%	80%
Analyzing and interpreting data	58%	91%
Using mathematics and computational thinking	44%	100%
Constructing explanations and designing solutions	42%	73%
Engaging in argument from evidence	53%	67%
Obtaining, evaluating, and communicating information	56%	69%

Discussion

Asking questions and defining problems

Based on Table 3. The percentage of scores obtained on asking questions and defining problems is 33% in the Indonesian books and 24% in the Malaysian books. This number shows that applying aspects of asking questions and defining problems in Indonesian books is slightly higher over Malaysian books. Both textbooks are equally lacking in providing opportunities for students to ask questions that

are scientific or non-scientific in nature. Overall, both textbooks are explicit in telling a problem, so they lack opportunities for students to define problems that can be solved by themselves through experiments or tools they design. Based on these results, textbooks that can stimulate students were needed to increase their curiosity and enthusiasm in finding problems. The ability to identify good questions and express them well is not only an exercise for students but also an essential skill for becoming a successful scientist (Farland-Smith, 2009). An example of the application of activities in this aspect is the literature study task to find out in advance related to the possible problems given.

Developing and Using Models

Based on Table 3. The percentage of scores obtained in the aspects of developing and using models is 53% in the Indonesian book and 73% in the Malaysian book. This number shows that applying aspects of developing and using models in Malaysian books has an advantage over Indonesian books. Each book has provided opportunities for students to create or use models in the form of projects or tools designed to solve the problems given. This aspect corresponds with the goal of technology education, which is to engage students through challenges when creating models and products to find new solutions (Hirsch et al., 2017). However, the fundamental difference that causes Malaysian books to have an advantage over Indonesian books is the opportunities to predict or explain natural phenomena through these models. In the mechanics material of the Malaysian book, students are allowed to analyze the advantages and limitations of the model that should be evaluated, while in Indonesian books, there needs to be an explanation of whether the benefits and regulations of the designed tool need to be evaluated. An example of the application of activities in this aspect is creating something to answer the problem presented in the "project task" of the Indonesian textbook and "aktiviti" in the Malaysian textbooks.

Planning and Carrying Out Investigations

Based on Table 3. The percentage of scores obtained in the aspects of planning and carrying out investigations is 38% in the Indonesian book and 73% in the Malaysian book. This number shows that applying aspects of planning and carrying out investigations in the Malaysian book has an advantage over the Indonesian book. In designing and carrying out investigations, both textbooks provide opportunities to develop or carry out investigations for data collection. This opportunity allows students to determine the experimental variables, controls, and investigation methods. What makes Indonesian textbooks lacking in this aspect compared to Malaysia is that the process of planning and conducting investigations is still primarily guided by the teaching materials. Engaging in investigations designed to make choices and decisions during planning and execution allows students to discover what works and does not work in their experiments (Zhou, 2024). Examples of the application of activities in this aspect are collecting experimental and managing data in practicum or project in Indonesian textbooks and experiments in Malaysian textbooks.

Analyzing and Interpreting Data

Based on Table 3. The percentage score obtained in the aspect of analyzing and interpreting data is 58% in the Indonesian book and 91% in the Malaysian book. This number shows that analyzing and interpreting data in the Malaysian book has an advantage over the Indonesian book. In practice, both textbooks provide opportunities for students to explore and classify data in tables and graphs. Analyzing and interpreting data is needed in learning because it requires students' thinking activities to decide to deal with a problem (Abdulwahed & Hasna, 2017). The significant difference between Indonesian and Malaysian books is that in Indonesian books, there are only a few project tasks that require organizing data in the form of tables and graphs. In contrast, in Malaysian books, many examples of jobs need students to analyze data referring to the charts and tables produced. An example of application in this aspect is analyzing data in tables or graphs marked by the command or question "Based on the table

or graph obtained, the conclusions that can be drawn". This activity is in the practicum or project in Indonesian textbooks and experiments in Malaysian textbooks.

Using Mathematics and Computational Thinking

This aspect has the most significant difference between Indonesian and Malaysian physics books compared to other aspects. Based on table 3, the percentage score obtained in the aspect of using mathematics and computational thinking is 44% in the Indonesian book and 100% in the Malaysian book. This shows that applying aspects of using mathematics and computational thinking in Malaysian books has an advantage over Indonesian books. In the Malaysian book, students can determine the results and conclusions based on appropriate mathematical skills to solve a problem or scientific question in each task or project. In the Indonesian book, problem solving tends to be observed directly after the experiment without using mathematical or computational thinking. It can be observed in figure 2, representing the use of mathematics and computational thinking in the mechanics material in the Malaysian book. The task given in Activity 2.6 of the Malaysian book presents a similar job to Activity 5.5 in the Indonesian book, which can be seen in figure 3. However, the difference is that in the Malaysian book, students are given an additional task in the form of Experiment 2.2 on the same material. Whereas in the Indonesian book, only Activity 5.5 applies concepts without applying mathematical skills.

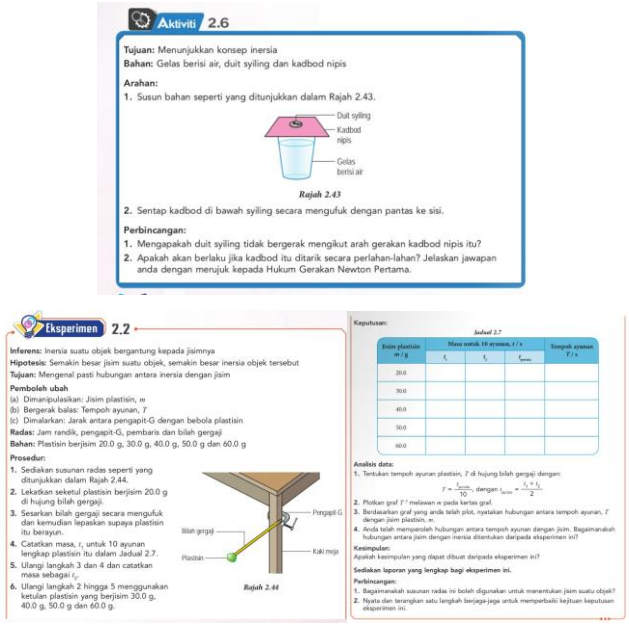
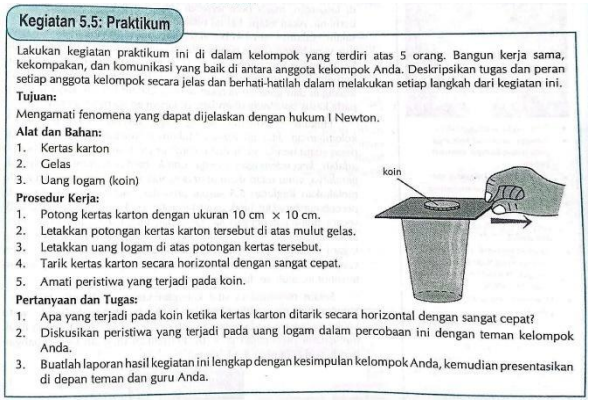


Figure 1. Examples of practical tasks in Malaysian textbook



Kegiatan 5.5: Praktikum

Lakukan kegiatan praktikum ini di dalam kelompok yang terdiri atas 5 orang. Bangun kerja sama, kekompakan, dan komunikasi yang baik di antara anggota kelompok Anda. Deskripsikan tugas dan peran setiap anggota kelompok secara jelas dan berhati-hatilah dalam melakukan setiap langkah dari kegiatan ini.

Tujuan:

Mengamati fenomena yang dapat dijelaskan dengan hukum I Newton.

Alat dan Bahan:

1. Kertas karton
2. Gelas
3. Uang logam (koin)

Prosedur Kerja:

1. Potong kertas karton dengan ukuran 10 cm × 10 cm.
2. Letakkan potongan kertas karton tersebut di atas mulut gelas.
3. Letakkan uang logam di atas potongan kertas tersebut.
4. Tarik kertas karton secara horizontal dengan sangat cepat.
5. Amati peristiwa yang terjadi pada koin.

koin

Pertanyaan dan Tugas:

1. Apa yang terjadi pada koin ketika kertas karton ditarik secara horizontal dengan sangat cepat?
2. Diskusikan peristiwa yang terjadi pada uang logam dalam percobaan ini dengan teman kelompok Anda.
3. Buatlah laporan hasil kegiatan ini lengkap dengan kesimpulan kelompok Anda, kemudian presentasikan di depan teman dan guru Anda.

Figure 2. Examples of practical tasks in Indonesian textbook

Using mathematical context means being able to introduce mathematical concepts through certain problems or situations to make learning more meaningful (Sengupta-Irving & Agarwal, 2017). So it is essential to provide opportunities for students to sharpen their mathematical skills through tasks provided in books or teaching materials.

Constructing Explanations and Designing Solutions

Based on Table 3. The percentage of scores obtained on the aspects of constructing explanations and designing solutions is 42% in the Indonesian book and 73% in the Malaysian book. This number shows that implementing aspects of constructing explanations and designing solutions in the Malaysian book has an advantage over the Indonesian book. The previous research states that scientific reasoning and physics synthesis problem solving ability have a mutual relationship, where the higher the category of reasoning patterns owned by students, the higher the ability to solve physics synthesis problems, and vice versa (Nurhayati et al., 2016). Both textbooks provide opportunities for learners to construct scientific explanations related to why and how a phenomenon can occur based on the tasks or projects that have been given. The significant difference between Malaysian and Indonesian books is that in Malaysian books, the tasks presented encourage learners to group data in graphs, analyze the resulting data, then continue the aspect of building explanations and designing solutions so it will look more systematic because the data obtained is sorted. Indonesian high school physics textbooks tend not to provide opportunities for learners to compare several solutions to a problem.

Engaging in Argument from Evidence

Based on Table 3, the percentage score obtained on the aspect of engaging in arguments from evidence is 53% in the Indonesian book and 67% in the Malaysian book. This number shows that the application of engaging in arguments from evidence in the Malaysian book has an advantage over the Indonesian book. Both books provide opportunities for students to engage in arguments from the evidence they obtain. Students are allowed to propose arguments built on evidence, reasoning, and assessments of opposing views to support and emphasize the ideas submitted. This aspect can be seen in each question presented; learners must complete their answers with explanations to support their arguments. Argumentation skills can be empowered if the claim supports a statement or states evidence implicitly, so the argumentation made is logical and acceptable (Nuryadin et al., 2024).

Obtaining, Evaluating, and Communicating Information

Based on table 3, the percentage of scores obtained on the aspects of obtaining, evaluating, and

communicating information results is 56% in the Indonesian book and 69% in the Malaysian book. This number shows that the application of obtaining, evaluating, and communicating information in Malaysian books has an advantage over Indonesian books. Malaysian and Indonesian books provide opportunities for learners to obtain, evaluate, and communicate information from the data sets obtained. Evidently, in both books analyzed, students can read and evaluate texts to get scientific information. In addition, students are motivated to compare or combine information sourced outside the book. Then, at the end of the task is always accompanied by the sentence "Present it in front of your friends and teachers" to encourage students to combine information not only through writing but in communicating information directly in front of their friends and teachers. This aspect is essential for all professions because the first thing often seen from individuals is their communication skills fluently and understandably. Therefore, students' communication skills are critical to evaluate to know the scientific communication skills possessed and mastered by students (Fuadah et al., 2017).

CONCLUSION

This study concluded that there are differences in Science and Engineering Practice content in Indonesian and Malaysian high school Physics textbooks. The most common aspects found in Indonesian books are asking questions and defining problems. The lowest aspects in Indonesia, compared to Malaysian books, are the aspects of using mathematics and computational thinking. The Malaysian book has an advantage in seven aspects compared to the Indonesian book, especially in using mathematics and computational thinking with a percentage of 100%. This study analysed limited textbooks only for the books that were published by the government. In the future research, content analysis for more massive textbooks sampling will be valuable to explore the coherency with our sample textbooks. In addition, this analysis is expected to be a reference for further researchers to design textbooks or teaching materials that can ultimately facilitate aspects of science and engineering practice.

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