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Development of STEM-Based Physics Teaching Materials Integrated 21st Century Skills (4C) and Characters

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Abstract

Teaching materials currently available are mostly centered on textbook and tasks. Moreover, it is rarely implanted with 21st century skills and character values so that students find it difficult when solving problems related to life. STEM-based teaching materials developed are presented with characteristics of fluid information which is complemented by discussions, practicum, and project activities related to STEM aspects and integrated with 21st century skills (4C) and character values so that students are encouraged to be more active in solving problems. This study aims to describe characteristics and identify feasibility, readability, student responses to STEM-based physics teaching materials, integrated 21st century skills (4C), and characters. The method used in this research was Research and Development (R&D) with producers adapted from the research and development steps of Borg and Gall, which are modified into seven stages. Data collection techniques in this study were carried out in several ways, namely interviews, tests, and questionnaires placed on a Likert scale. The results of the feasibility test showed that the teaching materials were in a very worthy category. The readability test results showed that the teaching materials were presenting in the class easily understood. The assessment of students' responses to teaching materials showed an excellent category to be used by the second-year student at high school as a supporting learning source in the fluid subject learning process.

Keywords: teaching material, STEM, 21st century skills, character.

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INTRODUCTION

Education is an essential asset for a nation's sustainability and progress, especially to prepare a generation that can compete in the 21st century. Science and technology which are increasingly developing demands that students have abilities that are in accordance with the times. The 4C skills in the 21st century are critical thinking skills, creativity, communication, and collaboration. The government continuously made an effort to improve the quality of education in Indonesia. One of them is through changes to the national education curriculum, starting from the 1947 Lesson Plan Curriculum to the revised 2013 Curriculum used to date. The main focus of the 2013 Curriculum is the activeness of students, the integration of 21st century skills, and character education in learning. Through the currently implemented 2013 Curriculum, the expected competence after studying physics at the high school level is to live a life with a positive attitude with critical, creative, innovative, and collaborative thinking, along with honesty and openness based on the potential of the product process and understanding the impact of developments in technology (Kemendikbud, 2016).

One of the government's efforts to improve the quality of education in Indonesia, according to Bappenas (2013), is through the development of teaching materials to support the learning process. The research is in line with the research results by Ariyani & Wangid (2016), which states that innovative teaching materials developed can instill certain characters embedded in students. According to Widayoko et al. (2018), to face the times' demands, teaching materials are needed that can help students understand the material. Also, its application in technology can raise students' curiosity in engineering technology with the concepts being studied. As a result, students master scientific literacy competencies and have broad insights. Learning with the STEM approach integrates science, technology, engineering, and mathematics learning to help 21st century skills by focusing on solving real problems related to everyday life. The use of the STEM approach to learning could be applied in models, teaching materials, and LKPD as well as improving students' problem-solving skills (Chien & Lajium, 2016; Fitriani et al., 2017). The results of Yıldırım & Altun's (2015) research shows that the STEM approach can lead to effective and quality learning, relates to everyday life experiences, and develops problem solving skills such as creativity and critical thinking.

In reliance on the suitability between the learning objectives with the STEM approach and the learning objectives in secondary schools listed in the 2013 Curriculum, it can be concluded that the 2013 Curriculum learning provides opportunities for the development and implementation of STEM. It can also develop students' critical thinking skills, creativity, innovation, and problem-solving and development skills of the students' character. In this case, it means that the teaching materials are oriented to the material and practice questions. Teaching materials should be oriented towards environmental problems and application of technology using the STEM approach and prioritizing multi and transdisciplinary integration of S, T, E, and M and the development of 4C and character development of students.

Regarding the results of observations in the works of monitoring at SMA Negeri 1 Patikraja, it was found that the learning resources of students were in the form of textbooks and student worksheets, which indicated that these learning resources were still centered on cognitive aspects without an emphasis on affective and applicable aspects that encouraged mastery of 21st century skills and character education. The above problems provide an overview of the urgency of the need for learning resources that support learning physics to improve 21st century skills and students' character. Therefore, research is needed on the development of STEM-based teaching materials integrated 21st century skills and the character of students in high school physics learning. The purpose of this study was to describe the characteristics, feasibility level, readability level, and students' responses to the teaching materials developed.

METHODS

The method used in this research was Research and Development (R&D). This research was conducted in January - May 2020 at SMA Negeri 1 Patikraja, located at Jalan Adipura No. 3, Patikraja District, Banyumas Regency, Central Java Province. The subjects in this study were lecturers of material experts and media experts, physics teachers of SMA Negeri 1 Patikraja, and students of class XI MIPA 3 and XI MIPA 5 SMA Negeri 1 Patikraja.

The data collected in this research used interview methods, questionnaires, and tests. Interviews were conducted at the information gathering stage of the physics teacher and some students of SMA Negeri 1 Patikraja to obtain data about physics teaching materials used by students at the school and to find out directly the students' responses to

the teaching materials. The research instruments used were the gaps test and questionnaire. The gap test was used to determine the teaching material's readability. Then it was tested for its validity using the validator's expert judgment techniques. The reliability test for the intercept test instrument was not carried out.

The feasibility level, readability level, and student responses are expressed as the percentage score (P) and calculated by looking for the percentage of the score obtained compared to the maximum score. Data brought conclusions about students' feasibility, legibility, and responses to teaching materials linked to the Likert scale from the data analysis results.

The procedure used in this study was adapted from the research and development steps by Borg & Gall (1989), as shown in Figure 1.

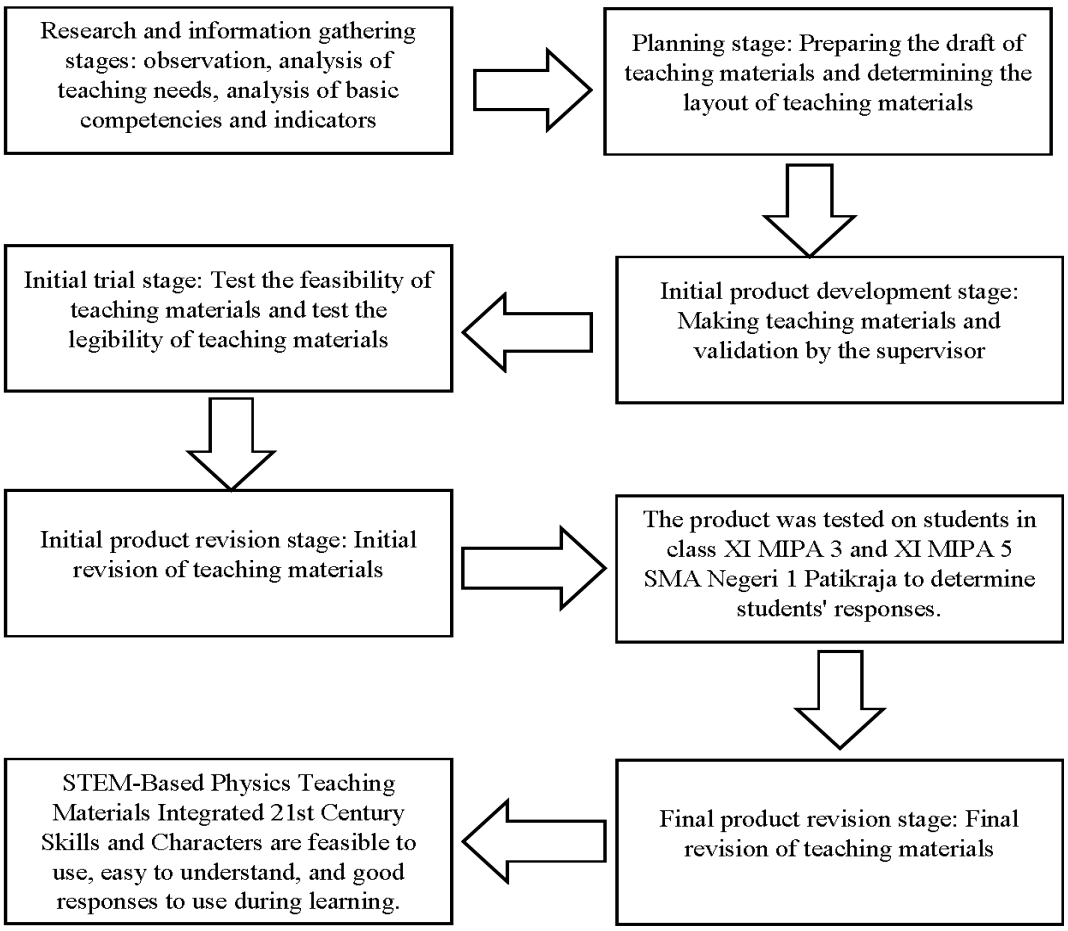


Figure 1. The research procedure used

RESULTS & DISCUSSION

Characteristics of Teaching Materials

This research's product was in the form of STEM-based physics teaching materials integrated with 21st century skills (4C) and character. The teaching material contained fluid material related to science, technology, engineering, and mathematics and, in its presentation, also integrates 21st century skills (4C) and character education. Teaching

materials were made from Microsoft Word 2016 software to compile the material and assisted with CorelDraw X7 software for making graphic designs of teaching materials. The text in the teaching material was written in Times New Roman font and font size of 12-16. The use of writing teaching materials above aimed to make teaching materials visible and easy to read. The statement was in line with Nurhadryani et al.'s (2013) research results, which stated that the appropriate type and size of letters would make it easier for students to learn the material in teaching materials. Also, on each side of the teaching material, pictures were given following the material's discussion. The picture aimed to provide a sense of comfort and make it easier for students to understand the material so that there was no misunderstanding about Situmorang (2014) research, which stated that suitable teaching materials present pictures that could motivate learners to support problem-solving activities.

STEM-based physics teaching materials integrated 21st century skills and character content were divided into three parts: the initial element, the content part, and the final part. The total number of teaching materials is 69 pages and was printed using A4 paper (21 cm × 29.7 cm). The content was so that the school's learning needed developed physics teaching materials and outside school (Prastowo, 2015).

The initial section consisted of covers, introductions, a brief profile of teaching materials, a table of contents, instructions for using teaching materials, essential competencies and indicators of competency achievement, and a concept map. The content section consisted of two chapters, namely static fluid and dynamic fluid. In each chapter, there was a discussion activity integrated 21st century skills (4C), which was contained in the content "*Come on, observe!*" and "C*ome on, Discuss!*". Before explaining the material, the content "*Come on, learn!*" contained keywords and the importance of studying the material. The descriptions of the material in the developed teaching materials are presented in detail and arranged systematically to make it easier for students to understand the material. Also, there is the content "*Come on, Try It!*" and "*Come on, Project!*" which contains experimental activities and project activities (making a prototype of a tool that applies a particular concept) equipped with student worksheets. Contextual elements and STEM linkages appear in the "*STEM Rubric*" content. "*Character Values*" contained religious, curiosity, discipline, and social care character. Other contents used were "*Our Figures*", which contains historical figures who contributed to discovering physics concepts. Also, "*Sample Questions*", which included examples of questions from the material that has been presented. This teaching material also included the "*Competency Test*", which contained items to determine students' ability regarding fluid material included in this developed physics teaching material. The format for arranging the content of teaching materials developed was also made consistently from beginning to end. In line with Arsyad's (2014) statement, print-based media must pay attention to the consistency of the format in which it was prepared.

The teaching materials developed have the characteristics of STEM-based learning. The integration of each aspect of STEM in the teaching materials developed can be explained as follows.

a. The scientific aspect is the central aspect of the teaching materials developed. This was because the subject of physics is one of the main domains in science. Each chapter presented scientific aspects, especially on static and dynamic fluids, such as Pascal's law, Archimedes law, continuity law, Bernoulli's law, and other subsections in a fluid material.
b. The technological aspects of the teaching materials developed were applying concepts to fluid material in everyday life such as water pumps, hydraulic jacks, infusions, showers, airplane wings, and other technologies related to liquid materials. This aspect

was presented in the form of supporting information about the use of technology in a concept.

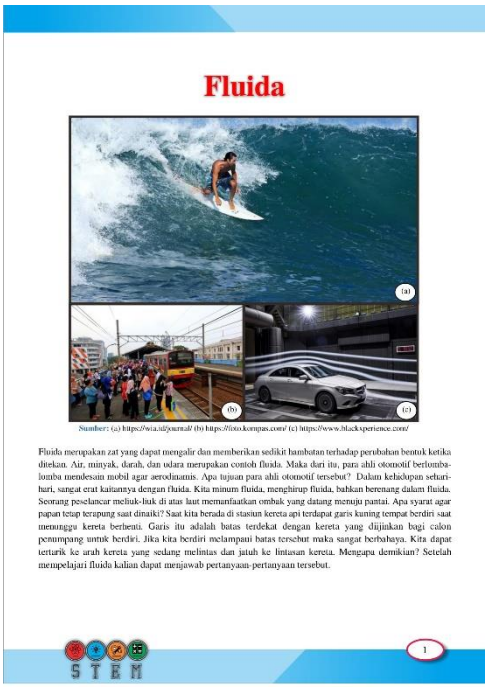
c. Engineering aspects in the developed teaching materials are integrated into an explanation of the working principles of technology. It also used concepts in a fluid material, simple project activities (making a prototype of a tool that applies a particular concept), and questions about how a design supports a technology to maximize its utilization.
d. Mathematical aspects can be found in almost all parts of the teaching material. This was because definitions, theories, and physical models were always expressed in mathematical relationships. In mathematical information presented mathematical aspects of the developed teaching related to mathematical formulas/symbols/quantities/operations on the fluid material being discussed.

The physics teaching materials developed also have the integrated characteristics of 21st century skills (4C). The integration of each 4C skill in the teaching materials developed can be explained as follows.

a. Critical thinking skills (critical thinking) in the developed teaching materials are integrated into the form of STEM-based learning activities. It was also related to problem-solving. As Saputra et al. (2019) stated, critical thinking skills could be developed through learning that actively engages students in discussion activities to solve a problem.
b. Communication skills (communication) in the developed teaching materials are integrated into learning activities related to problem-solving in group activities and presentation of discussion results. Therefore, Choridah (2013) stated that problem-based learning involving group activities and presentations could spur students to communicate with friends and teachers.
c. Collaboration skills (collaboration) in the developed teaching materials are integrated into group work activities and discussion results. As Scott (2015) stated, problem-based learning and projects involving group activities or work collaboratively could spur students to develop collaborative skills.
d. Creativity skills (creativity / creative thinking) in the developed teaching materials are integrated into the form of STEM-based learning activities related to problem-solving. As the results of their research, Irfana et al. (2019) state that STEM-based learning can improve students' creative thinking skills. The physics teaching materials developed also have the integrated characteristics of 21st century skills (4C). The integration of each 4C skill in the teaching materials developed can be explained as follows.

In addition to being integrated 21st century skills (4C), the teaching materials developed also have characteristics loaded with character values, including religion, curiosity, discipline, and social care. These characters were selected based on an analysis of their needs and the material context (Nurgiyantoro & Efendi, 2013). Integrating these character values was reflected in the instructions in discussion activities, practicum, and projects in teaching materials. This was in line with Khusniati's (2012) results, which stated that independently discovering concepts such as practicum activities could foster students' various kinds of characters. Also, to further maximize character cultivation in the developed teaching materials, there was "*Character Values*" content containing instructions or information about the relationship between the material and the four-character values developed to motivate students to increase their character values further. The content of "*Character Value*s" was presented in a separate box column. Based on Arsyad's opinion (2014), emphasis using boxes could be used to mark important information in teaching materials. Based on the results of Pala's (2011) research, character planting in students could be useful if it was done repeatedly and continuously. Thus, in the learning process, the teacher could instill character values continually.

Some examples of the results of product development for teaching materials in the content section are presented in the image below.

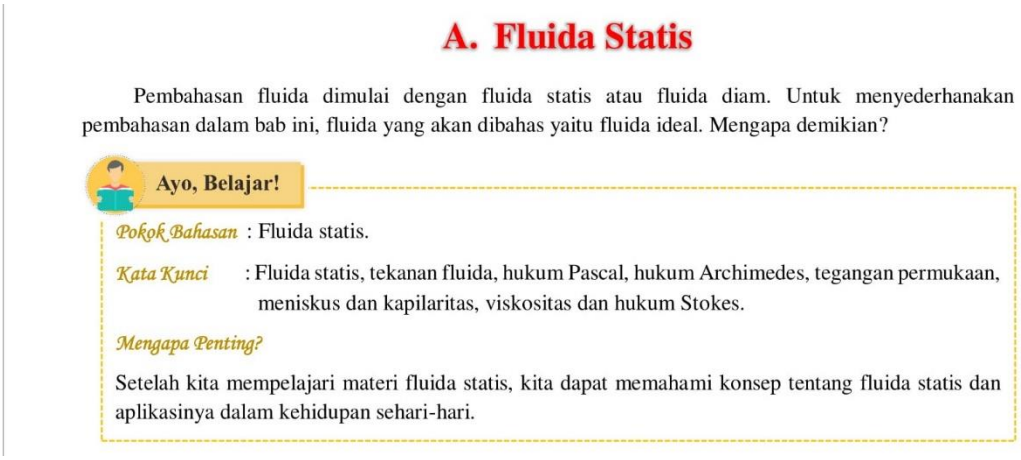


Fluida

Fluida merupakan zat yang dapat mengalir dan memberikan sedikit hambatan terhadap perubahan bentuk ketika ditekan. Air, minyak, darah, dan udara merupakan contoh fluida. Maka dari itu, para ahli otomotif berlomba-lomba mendesain mobil agar aerodinamis. Apa tujuan para ahli otomotif tersebut? Dalam kehidupan sehari-hari, sangat erat kaitannya dengan fluida. Kita minum fluida, menghirup fluida, bahkan berenang dalam fluida. Seorang peselancar meluk-luk di atas laut memanfaatkan ombak yang datang menuju pantai. Apa syarat agar papan tetap terapung saat dinaiki? Saat kita berada di stasiun kereta api terdapat garis kuning tempat berdiri saat menunggu kereta berhenti. Garis itu adalah batas terdekat dengan kereta yang diijinkan bagi calon penumpang untuk berdiri. Jika kita berdiri melampaui batas tersebut maka sangat berbahaya. Kita dapat terturik ke arah kereta yang sedang melintas dan jatuh ke lintasan kereta. Mengapa demikian? Setelah mempelajari fluida kalian dapat menjawab pertanyaan-pertanyaan tersebut.

STEM

Figure 2. Introduction to teaching materials



A. Fluida Statis

Pembahasan fluida dimulai dengan fluida statis atau fluida diam. Untuk menyederhanakan pembahasan dalam bab ini, fluida yang akan dibahas yaitu fluida ideal. Mengapa demikian?

Ayo, Belajar!

Pokok Bahasan : Fluida statis.

Kata Kunci : Fluida statis, tekanan fluida, hukum Pascal, hukum Archimedes, tegangan permukaan, meniskus dan kapilaritas, viskositas dan hukum Stokes.

Mengapa Penting?

Setelah kita mempelajari materi fluida statis, kita dapat memahami konsep tentang fluida statis dan aplikasinya dalam kehidupan sehari-hari.

Figure 3. The content section "*Come on, Learn!*" on teaching materials

4. Hukum Archimedes

Pada sub bab sebelumnya kalian telah mempelajari mengenai tekanan hidrostatis dan pemanfaatannya. Pada sub bab ini, kalian akan mempelajari hukum Archimedes. Sebelum mempelajari lebih lanjut tentang hukum Archimedes, mari lakukan kegiatan berikut.

Ayo, Mengamati!

Perhatikan gambar kapal selam pada Gambar 18!

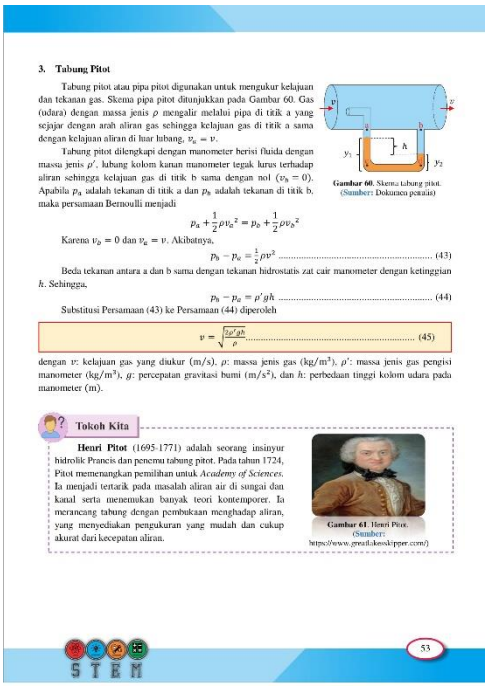
Salah satu teknologi canggih yang memanfaatkan prinsip mengapung, melayang, dan tenggelam adalah teknologi kapal selam. Kapal selam memiliki ruang khusus penampung air. Jumlah air yang ditampung dapat ditambah dan dikurangi.

Jawablah pertanyaan-pertanyaan berikut ini!

1. Bagaimana cara kerja kapal selam tersebut?
2. Berikan tanggapan kalian terhadap desain kapal selam tersebut!
3. Analisis faktor-faktor apa saja yang menyebabkan kapal selam mampu mengapung, melayang, dan tenggelam!
4. Setelah kalian menjawab pertanyaan di atas, buatlah kesimpulan sesuai dengan jawaban kalian!

Gambar 18. Teknologi kapal selam. (**Sumber:** https://www.penamerdeka.com/)

Figure 4. The content section "*Come on, Observe!*" on teaching materials



3. Tabung Pitot

Tabung pitot atau pipa pitot digunakan untuk mengukur kelajuan dan tekanan gas. Skema pipa pitot ditunjukkan pada Gambar 60. Gas (udara) dengan massa jenis ρ mengalir melalui pipa di titik a yang sejajar dengan arah aliran gas sehingga kelajuan gas di titik a sama dengan kelajuan aliran di luar lubang, $v_a = v$.

Tabung pitot dilengkapi dengan manometer berisi fluida dengan massa jenis ρ', lubang kolom kanan manometer tegak lurus terhadap aliran sehingga kelajuan gas di titik b sama dengan nol ($v_b = 0$). Apabila p_a adalah tekanan di titik a dan p_b adalah tekanan di titik b, maka persamaan Bernoulli menjadi

$$p_a + \frac{1}{2}\rho v_a^2 = p_b + \frac{1}{2}\rho v_b^2$$

Karena $v_b = 0$ dan $v_a = v$. Akibatnya,

$$p_b - p_a = \frac{1}{2}\rho v^2 \quad \ldots\ldots (43)$$

Beda tekanan antara a dan b sama dengan tekanan hidrostatis zat cair manometer dengan ketinggian h. Sehingga,

$$p_b - p_a = \rho' g h \quad \ldots\ldots (44)$$

Substitusi Persamaan (43) ke Persamaan (44) diperoleh

$$v = \sqrt{\frac{2\rho' g h}{\rho}} \quad \ldots\ldots (45)$$

dengan v: kelajuan gas yang diukur (m/s), ρ: massa jenis gas (kg/m^3), ρ': massa jenis gas pengisi manometer (kg/m^3), g: percepatan gravitasi bumi (m/s^2), dan h: perbedaan tinggi kolom udara pada manometer (m).

Gambar 60. Skema tabung pitot. (**Sumber:** Dokumen penulis)

Tokoh Kita

Henri Pitot (1695-1771) adalah seorang insinyur hidrolik Prancis dan penemu tabung pitot. Pada tahun 1724, Pitot memenangkan pemilihan untuk *Academy of Sciences*. Ia menjadi tertarik pada masalah aliran air di sungai dan kanal serta menemukan banyak teori kontemporer. Ia merancang tabung dengan pembukaan menghadap aliran, yang menyediakan pengukuran yang mudah dan cukup akurat dari kecepatan aliran.

Gambar 61. Henri Pitot. (Sumber: https://www.greatlakeskiipper.com/)

STEM

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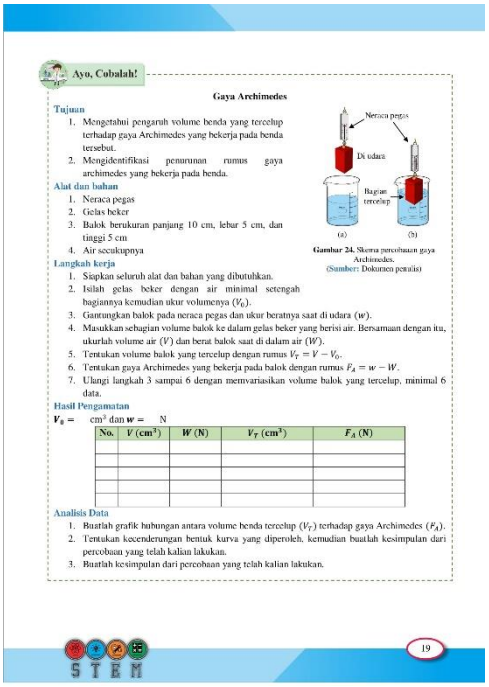
Figure 5. Section description of teaching materials



Ayo, Cobalah!

Gaya Archimedes

Tujuan

1. Mengetahui pengaruh volume benda yang tercelup terhadap gaya Archimedes yang bekerja pada benda tersebut.
2. Mengidentifikasi penurunan rumus gaya archimedes yang bekerja pada benda.

Alat dan bahan

1. Neraca pegas
2. Gelas beker
3. Balok berukuran panjang 10 cm, lebar 5 cm, dan tinggi 5 cm
4. Air secukupnya

Neraca pegas
Di udara
Bagian tercelup
(a) (b)

Gambar 24. Skema percobaan gaya Archimedes.
(**Sumber:** Dokumen penulis)

Langkah kerja

1. Siapkan seluruh alat dan bahan yang dibutuhkan.
2. Isilah gelas beker dengan air minimal setengah bagiannya kemudian ukur volumenya (V_0).
3. Gantungkan balok pada neraca pegas dan ukur beratnya saat di udara (w).
4. Masukkan sebagian volume balok ke dalam gelas beker yang berisi air. Bersamaan dengan itu, ukurlah volume air (V) dan berat balok saat di dalam air (W).
5. Tentukan volume balok yang tercelup dengan rumus $V_T = V - V_0$.
6. Tentukan gaya Archimedes yang bekerja pada balok dengan rumus $F_A = w - W$.
7. Ulangi langkah 3 sampai 6 dengan memvariasikan volume balok yang tercelup, minimal 6 data.

Hasil Pengamatan

$V_0 =$ cm³ dan $w =$ N

No.	V (cm³)	W (N)	V_T (cm³)	F_A (N)

Analisis Data

1. Buatlah grafik hubungan antara volume benda tercelup (V_T) terhadap gaya Archimedes (F_A).
2. Tentukan kecenderungan bentuk kurva yang diperoleh, kemudian buatlah kesimpulan dari percobaan yang telah kalian lakukan.
3. Buatlah kesimpulan dari percobaan yang telah kalian lakukan.

S T E M

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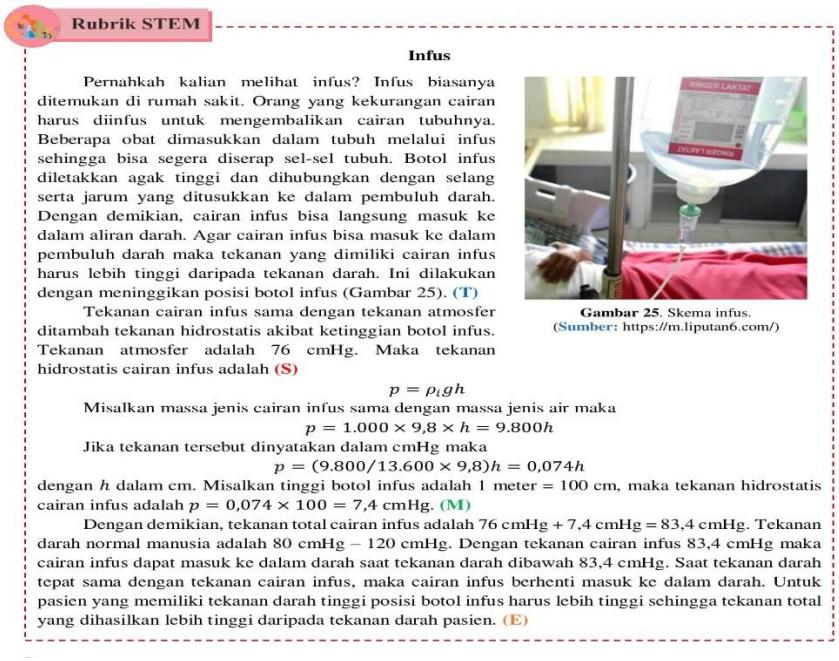
Figure 6. The content section "*Come on, Try It*!" on teaching materials



Rubrik STEM

Infus

Pernahkah kalian melihat infus? Infus biasanya ditemukan di rumah sakit. Orang yang kekurangan cairan harus diinfus untuk mengembalikan cairan tubuhnya. Beberapa obat dimasukkan dalam tubuh melalui infus sehingga bisa segera diserap sel-sel tubuh. Botol infus diletakkan agak tinggi dan dihubungkan dengan selang serta jarum yang ditusukkan ke dalam pembuluh darah. Dengan demikian, cairan infus bisa langsung masuk ke dalam aliran darah. Agar cairan infus bisa masuk ke dalam pembuluh darah maka tekanan yang dimiliki cairan infus harus lebih tinggi daripada tekanan darah. Ini dilakukan dengan meninggikan posisi botol infus (Gambar 25). **(T)**

Gambar 25. Skema infus.
(**Sumber:** https://m.liputan6.com/)

Tekanan cairan infus sama dengan tekanan atmosfer ditambah tekanan hidrostatis akibat ketinggian botol infus. Tekanan atmosfer adalah 76 cmHg. Maka tekanan hidrostatis cairan infus adalah **(S)**

$$p = \rho_l g h$$

Misalkan massa jenis cairan infus sama dengan massa jenis air maka

$$p = 1.000 \times 9{,}8 \times h = 9.800h$$

Jika tekanan tersebut dinyatakan dalam cmHg maka

$$p = (9.800/13.600 \times 9{,}8)h = 0{,}074h$$

dengan h dalam cm. Misalkan tinggi botol infus adalah 1 meter = 100 cm, maka tekanan hidrostatis cairan infus adalah $p = 0{,}074 \times 100 = 7{,}4$ cmHg. **(M)**

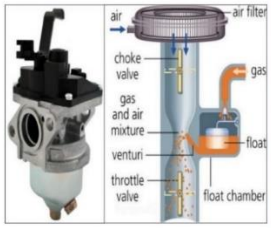
Dengan demikian, tekanan total cairan infus adalah 76 cmHg + 7,4 cmHg = 83,4 cmHg. Tekanan darah normal manusia adalah 80 cmHg – 120 cmHg. Dengan tekanan cairan infus 83,4 cmHg maka cairan infus dapat masuk ke dalam darah saat tekanan darah dibawah 83,4 cmHg. Saat tekanan darah tepat sama dengan tekanan cairan infus, maka cairan infus berhenti masuk ke dalam darah. Untuk pasien yang memiliki tekanan darah tinggi posisi botol infus harus lebih tinggi sehingga tekanan total yang dihasilkan lebih tinggi daripada tekanan darah pasien. **(E)**

Figure 7. Content section "*STEM Rubric*" on teaching materials

Ayo, Diskusi!

Karburator dan Injektor

Karburator adalah alat pencampur bahan bakar dan udara. Pencampuran tersebut bertujuan untuk mempermudah pembakaran pada silinder mesin. Cara kerja dari karburator adalah sebagai berikut. Perhatikan Gambar 59 penampang bagian atas pipa venturi menyempit sehingga udara yang bergerak pada bagian tersebut mempunyai kelajuan yang tinggi dan berakibat tekanan pada bagian tersebut rendah. Tekanan dalam tangki bensin sama dengan tekanan atmosfer. Adanya tekanan atmosfer menyebabkan bahan bakar tersembur keluar sehingga bahan bakar bercampur dengan udara sebelum memasuki silinder mesin. Semburan bahan bakar cair yang bercampur dengan udara menghasilkan gas yang disebut *manzel* dan bersifat mudah terbakar. Gas *manzel* inilah yang dibakar sehingga memiliki tekanan yang tinggi dan menekan piston. Demikian seterusnya sehingga roda akan bergerak seiring dengan gerakan naik turun piston tersebut.



Gambar 59. Mesin karburator. (**Sumber:** https://fastnlow.net/)

Namun, saat ini penggunaan karburator sudah mulai digantikan dengan teknologi injeksi. Teknologi injeksi memiliki komponen penting yang disebut injektor. Secara sederhana, karburator dan injektor mirip dengan alat semprot yang berisi bahan bakar. Pada karburator memanfaatkan tekanan atmosfer, sedangkan pada injektor dibantu dengan pompa elektronik untuk mengatur daya isap dan semprotnya. Teknologi injeksi terbukti lebih irit bahan bakar dan menurunkan emisi gas buang sehingga lebih ramah lingkungan.

Jawablah pertanyaan-pertanyaan berikut ini!

1. Berdasarkan penjelasan di atas, bagaimanakah Hukum Bernoulli diterapkan?
2. Analislah bagaimana pompa elektronik pada teknologi injeksi mampu lebih menghemat bahan bakar dan menurunkan emisi gas buang dari pada karburator!
3. Kesimpulan apakah yang dapat kalian ambil dari bacaan di atas?

Figure 8. The content section "*Come on, Discussion!*" on teaching materials

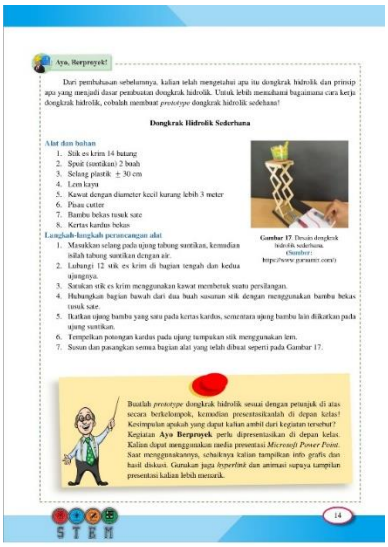


Figure 9. The content section "*Come on, Project!*" on teaching materials

Nilai Karakter

Disiplin

Sahabat, lakukanlah kegiatan proyek ini dengan penuh ketekunan dan kedisiplinan! Dengan mengikuti prosedur proyek ini, kalian akan mendapat pemahaman yang lebih dalam mengenai materi ini jika kalian bersungguh-sungguh.

Figure 10. The content section "*Character Values*" in teaching materials

Contoh Soal

Contoh 4

Seorang anak bermassa 56 kg sedang berenang dalam kolam renang. Anak tersebut merasa tubuhnya menjadi lebih ringan. Pada saat dalam air anak tersebut menggelantung di neraca dan terbaca massa tubuh anak tersebut menunjukkan angka 32 kg. Berapakah gaya angkat Archimedes pada tubuh anak tersebut? Berapa volume tubuh anak tersebut yang tercelup dalam air saat penimbangan? (massa jenis air 1.000 kg/m^3)

Penyelesaian

Berat tubuh anak tersebut saat di luar kolam renang adalah $w_1 = m_1 g = 56 \text{ kg} \times 10 \text{ m/s}^2 = 560 \text{ N}$. Berat tubuh anak tersebut saat penimbangan dalam air adalah $w_2 = m_2 g = 32 \text{ kg} \times 10 \text{ m/s}^2 = 320 \text{ N}$. Perbedaan berat ini disebabkan oleh adanya gaya angkat Archimedes. Jadi gaya angkat Archimedes adalah

$$F_A = w_1 - w_2 = 560 \text{ N} - 320 \text{ N} = 240 \text{ N} = 240 \text{ kg m/s}^2$$

Jumlah air yang dipindahkan tubuh sama dengan volume bagian tubuh yang tercelup. Gaya angkat Archimedes sama dengan berat air yang dipindahkan, atau $F_A = m_a g = \rho_a V_c g$ dengan V_c adalah volume bagian tubuh yang tercelup. Jadi

$$V_c = \frac{F_A}{\rho_a g} = \frac{240 \text{ kg m/s}^2}{1.000 \text{ kg/m}^3 \times 10 \text{ m/s}^2} = 0{,}024 \text{ m}^3 = 0{,}024 \times 10^6 \text{ cm}^3 = 24 \times 10^3 \text{ cm}^3$$

Figure 11. The content section "*Sample Questions*" on teaching materials

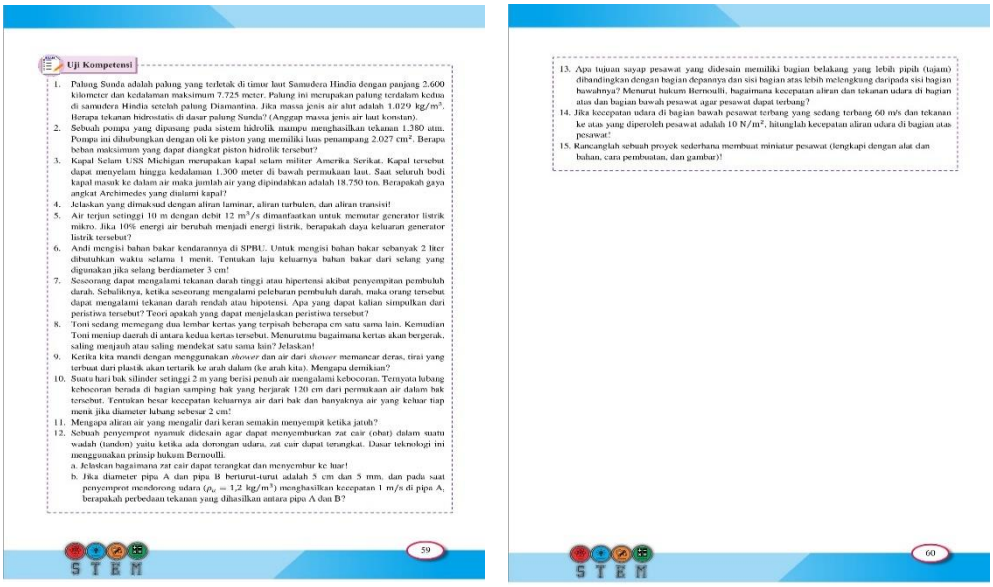
Tokoh Kita

Prof. Dr. Ing. H. Bacharuddin Jusuf Habibie, FREng. (1936-2019) adalah Presiden Republik Indonesia yang ketiga. Dimasa kecil Habibie telah menunjukkan kecerdasan dan semangat tinggi pada ilmu pengetahuan dan teknologi khususnya fisika. Hingga memasuki usia 40 tahun, karir Habibie sudah sangat cemerlang, terutama dalam desain dan konstruksi pesawat terbang. Beberapa rumusan teorinya dikenal dalam dunia pesawat terbang seperti *"Habibie Factor"*, *"Habibie Theorem"*, dan *"Habibie Method"*. Pada tahun 1976, Lembaga Industri Pesawat Terbang Nurtanio (LIPNUR) yang dipimpin Nurtiano dan kawan-kawan berubah nama menjadi Industri Pesawat Terbang Nurtanio (IPTN) yang dipimpin oleh Habibie.

Gambar 64. B. J. Habibie.
(**Sumber:** https://celebestopnews.com/)

Sejak kepemimpinannya, Habibie mengembangkan sejumlah teknologi dan kerja sama dengan negara lain dalam membuat sejumlah pesawat terbang, seperti CN235 (diproduksi massal tahun 1983), N250, dan N2130. Industri pesawat terbang yang pertama dan satu-satunya di Asia Tenggara ini kemudian berganti nama menjadi Industri Pesawat Terbang Nusantara (IPTN) pada 11 Oktober 1985.

Figure 12. The content section "*Our Figures*" in teaching materials



Uji Kompetensi

1. Palung Sunda adalah palung yang terletak di timur laut Samudera Hindia dengan panjang 2.600 kilometer dan kedalaman maksimum 7.725 meter. Palung ini merupakan palung terdalam kedua di samudera Hindia setelah palung Diamantina. Jika massa jenis air alut adalah 1.029 kg/m^3. Berapa tekanan hidrostatis di dasar palung Sunda? (Anggap massa jenis air laut konstan).
2. Sebuah pompa yang dipasang pada sistem hidrolik mampu menghasilkan tekanan 1.380 atm. Pompa ini dihubungkan dengan oli ke piston yang memiliki luas penampang 2.027 cm^2. Berapa beban maksimum yang dapat diangkat piston hidrolik tersebut?
3. Kapal Selam USS Michigan merupakan kapal selam militer Amerika Serikat. Kapal tersebut dapat menyelam hingga kedalaman 1.300 meter di bawah permukaan laut. Saat seluruh bodi kapal masuk ke dalam air maka jumlah air yang dipindahkan adalah 18.750 ton. Berapakah gaya angkat Archimedes yang dialami kapal?
4. Jelaskan yang dimaksud dengan aliran laminar, aliran turbulen, dan aliran transisi!
5. Air terjun setinggi 10 m dengan debit 12 m^3/s dimanfaatkan untuk memutar generator listrik mikro. Jika 10% energi air berubah menjadi energi listrik, berapakah daya keluaran generator listrik tersebut?
6. Andi mengisi bahan bakar kendaraannya di SPBU. Untuk mengisi bahan bakar sebanyak 2 liter dibutuhkan waktu selama 1 menit. Tentukan laju keluarnya bahan bakar dari selang yang digunakan jika selang berdiameter 3 cm!
7. Seseorang dapat mengalami tekanan darah tinggi atau hipertensi akibat penyempitan pembuluh darah. Sebaliknya, ketika seseorang mengalami pelebaran pembuluh darah, maka orang tersebut dapat mengalami tekanan darah rendah atau hipotensi. Apa yang dapat kalian simpulkan dari peristiwa tersebut? Teori apakah yang dapat menjelaskan peristiwa tersebut?
8. Toni sedang memegang dua lembar kertas yang terpisah beberapa cm satu sama lain. Kemudian Toni meniup daerah di antara kedua kertas tersebut. Menurutmu bagaimana kertas akan bergerak, saling menjauh atau saling mendekat satu sama lain? Jelaskan!
9. Ketika kita mandi dengan menggunakan *shower* dan air dari *shower* memancar deras, tirai yang terbuat dari plastik akan tertarik ke arah dalam (ke arah kita). Mengapa demikian?
10. Suatu hari bak silinder setinggi 2 m yang berisi penuh air mengalami kebocoran. Ternyata lubang kebocoran berada di bagian samping bak yang berjarak 120 cm dari permukaan air dalam bak tersebut. Tentukan besar kecepatan keluarnya air dari bak dan banyaknya air yang keluar tiap menit jika diameter lubang sebesar 2 cm!
11. Mengapa aliran air yang mengalir dari keran semakin menyempit ketika jatuh?
12. Sebuah penyemprot nyamuk didesain agar dapat menyemburkan zat cair (obat) dalam suatu wadah (tandon) yaitu ketika ada dorongan udara, zat cair dapat terangkat. Dasar teknologi ini menggunakan prinsip hukum Bernoulli.
    a. Jelaskan bagaimana zat cair dapat terangkat dan menyembur ke luar!
    b. Jika diameter pipa A dan pipa B berturut-turut adalah 5 cm dan 5 mm, dan pada saat penyemprot mendorong udara ($\rho_u = 1{,}2$ kg/m^3) menghasilkan kecepatan 1 m/s di pipa A, berapakah perbedaan tekanan yang dihasilkan antara pipa A dan B?

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13. Apa tujuan sayap pesawat yang didesain memiliki bagian belakang yang lebih pipih (tajam) dibandingkan dengan bagian depannya dan sisi bagian atas lebih melengkung daripada sisi bagian bawahnya? Menurut hukum Bernoulli, bagaimana kecepatan aliran dan tekanan udara di bagian atas dan bagian bawah pesawat agar pesawat dapat terbang?
14. Jika kecepatan udara di bagian bawah pesawat terbang yang sedang terbang 60 m/s dan tekanan ke atas yang diperoleh pesawat adalah 10 N/m^2, hitunglah kecepatan aliran udara di bagian atas pesawat!
15. Rancanglah sebuah proyek sederhana membuat miniatur pesawat (lengkapi dengan alat dan bahan, cara pembuatan, dan gambar)!

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Figure 13. The content section "*Competency Test*" on teaching materials

The final part of the teaching materials developed consisted of a summary glossary and bibliography. The summary contained a summary of the material that has been studied in the teaching materials to make it easier for students to review the material. This was in line with the opinion of Daryanto & Dwicahyono (2014), which states that the summary in teaching materials was prepared by examining the main things contained in the teaching material. The glossary contains explanations of newly introduced terms in teaching materials arranged alphabetically (Daryanto & Dwicahyono, 2014). The bibliography included a list of reference sources for the material used in teaching materials.

The Feasibility of Teaching Materials

The feasibility test was carried out by giving a feasibility questionnaire to 3 validators consisting of one material expert lecturer, one media expert lecturer, and one physics teacher. The eligibility questionnaire referred to the test instrument that has been made based on the modified BSNP rules. The feasibility questionnaire consisted of four aspects, namely, content, presentation, language, and geography. The recapitulation of the feasibility test results on each element of the assessment in teaching materials was shown in Table 1.

Table 1. Review of the Results of Feasibility Test for Teaching Materials for Each Aspect

Eligibility Aspects	*P*(%)	Criteria
Content	92,54	Very worthy
Presentation	93,75	Very worthy
Language	91,67	Very worthy
Graphic	87,50	Very worthy
Average	91,36	Very worthy

The validator's analysis of the feasibility test has met the very worthy criteria with a value percentage of 91.36%. It also meant that STEM-based physics teaching materials integrated 21st century skills (4C) and character have met the standard of eligibility of printed teaching materials applied by BSNP for learning with some improvements according to validator suggestions. This was in line with Budiawati & Kantun (2016) opinion, which stated that the feasibility of teaching materials was seen from the teaching materials' ability to meet the feasibility assessment standards set by BSNP.

The teaching material products developed are also compiled based on the preparation guidelines in the 2013 Revised Edition of the Curriculum 2013, a STEM approach, and integrated 21st century skills and character content. This added value of the teaching materials developed compared to the textbooks and LKPD used by students at SMA Negeri 1 Patikraja.

The analysis results on the feasibility aspect of the content of teaching materials, which consisted of six sub aspects, were presented in Table 2.

Table 2. Results of Content Feasibility Aspect Analysis

Sub aspects	*P*(%)	Criteria
Material suitability	94,44	Very worthy
Material accuracy	91,67	Very worthy
Contemporary material	100	Very worthy
STEM based	93,75	Very worthy
21st Century Skills Integration (4C)	95,83	Very worthy
Integration of character values	87,50	Very worthy

In reliance on the analysis of the results of the content feasibility aspect test presented in Table 2, it was found that the teaching materials developed got an average percentage of 92.54% with very worthy criteria in the content feasibility aspect. STEM-based physics teaching materials integrated 21st century skills, and character content was compiled through the presentation of material that has been adjusted to the Core Competencies (KI), and Basic Competencies (KD) of the 2013 Revised 2017 Curriculum for physics subjects' class XI SMA / MA. This was in line with Prastowo's (2015) opinion which states that the material in teaching materials is very dependent on the basic competencies to be achieved.

The material in the developed teaching materials was also compiled regarding technological developments to facilitate students to construct their knowledge according to the times. As stated by Izzati et al. (2019), utilizing the latest technology currently running in this century can enrich material development. Examples of contextual physics in the teaching materials developed can also help students understand existing concepts easily (Oktaviani et al., 2017). The presentation of STEM-based learning is suitable for physics subjects, develops life skills, creates career awareness, attracts students' attention, and makes learning fun (Kanadli, 2019).

The integration of 21st century skills (4C) in the developed teaching materials was presented with concrete problems around the latest technology to become more enthusiastic in learning them. STEM-based learning has proven effective in helping students develop 21st century (4C) skills because 4C skills were also skills developed in the STEM curriculum to allow students to choose a future career (Beers, 2011; Sarı et al., 2018).

Instructions on teaching materials activities were presented by integrating religious character values, curiosity, discipline, and social care. Character education could be delivered through instruction in teaching material activities to improve students' character development (Larasati & Yulianti, 2014; Wahyuni et al., 2017).

The analysis results on the feasibility aspect of presenting teaching materials, which consisted of three sub aspects, were shown in Table 3.

Table 3. Results of the Analysis of Presentation Feasibility Aspects

Sub Aspects	*P*(%)	Criteria
Presentation technique	100	Very worthy
Learning presentation	94,44	Very worthy
Presentation completeness	91,67	Very worthy

Regarding the analysis of the results of the presentation feasibility aspect test presented in Table 3, it was found that in the presentation feasibility aspect, the teaching materials developed got an average percentage of 93.75% with very worthy criteria.

The material in the developed teaching materials was presented coherently from general/basic concepts to more specific/complex concepts. The developed teaching materials consistently showed a pattern of activity sequences and components of STEM-based learning offerings always presented, making it easier for students to understand them. Teaching materials that were arranged with coherent and consistent concepts could advance students more interested in learning and make it easier for students to understand a concept (Parmin & Peniati, 2012; Rahmayantis, 2017).

STEM-based physics teaching materials were presented by paying attention to active and interactive student involvement, which was shown through discussion activities, practicums, and projects carried out in groups. Therefore, Pangesti et al. (2017) stated that STEM-based teaching materials that were equipped with discussion activities, practicum, and project creation could improve students' mastery of concepts. STEM-

based learning can have a positive impact on student learning outcomes in school, such as student interest and motivation, student attitudes towards lessons, improve science process skills, and can help students lead to independent discovery of a concept by students (Herak & Lamanepa, 2019; Yildirim, 2016). The presentation completeness of the developed teaching materials was divided into three parts: the beginning, the content, and the end, according to Depdiknas (2008).

Table 4 presented the results of the analysis on the linguistic feasibility aspect of teaching materials, which consist of six sub-aspects.

Table 4. Results of the Analysis of Language Feasibility Aspects

Sub Aspects	*P*(%)	Criteria
Legibility	95,83	Very worthy
Conformity with Indonesian language rules	83,33	Worthy

Table 4 presented the analysis of the test results on the feasibility of the linguistic aspects. In language eligibility, the teaching materials developed got an average percentage of 91.67% with very worthy criteria. The rate was because the terms, symbols, and icons used in the teaching materials developed were arranged consistently to avoid confusion. According to Purnanto & Mustadi (2018), consistent use of terms from beginning to end could make it easier for students to understand the book's contents. Also, teaching materials were prepared by paying attention to the structure of the SPO / SPOK in a sentence according to the General Guidelines for Indonesian Spelling (PUEBI) and adjusted to the reader (high school education level students), so that students can easily understand them. As stated by Sorraya (2014), teaching materials developed according to the level of cognitive development of students could make it easier for students to understand every activity in the teaching material.

Table 5. presented the analysis results on the feasibility of the graphic aspects of teaching materials, which consisted of three sub-aspects.

Table 5. Results of the Analysis of the Feasibility of the Graphic Aspects

Sub Aspects	*P*(%)	Criteria
Teaching material size	91,67	Very worthy
Cover design of teaching materials	87,50	Very worthy
Design content of teaching materials	83,33	Worthy

The analysis of the test results of the feasibility aspect of the graphic presented in Table 5 showed that in the aspect of graphics feasibility, the teaching materials developed to get an average percentage of 87.50% with very worthy criteria. The number was because the teaching materials used A4 paper (21 cm × 29.7 cm), corresponding to ISO standards. The standard was regarded to develop physics teaching materials at school and outside of school (Prastowo, 2015). Furthermore, the cover for teaching materials developed was designed with proportional attention to the composition of the color and the size of the layout. The illustration image on the cover of teaching materials was an example of fluid application in everyday life. Pattashiki & Hakim (2016) stated that the colors and design illustrations on the cover of attractive teaching materials could clarify the concepts, messages, and materials in teaching materials. The text in the developed teaching material is written in Times New Roman typeface and font size of 12-16 to clearly and quickly read it. As the research results, Nurhadryani et al. (2013) states that

the appropriate type and size of letters will make it easier for students to learn the material contained in teaching materials.

Readability of Teaching Materials

Table 6 presented the results of the readability analysis of teaching materials.

Table 6. Teaching Material Readability Test Results

Grade	*P*(%)	Criteria
XI MIPA 3	85,48	Intelligible
XI MIPA 5	88,29	Intelligible
Average	86,88	Intelligible

Based on the data obtained from the readability test of teaching materials in class XI MIPA 3 and XI MIPA 5, the average percentage of teaching material readability was 86.88%. These results indicated that students easily understand the teaching material. Dewi & Arini (2018) stated that the results of a good teaching material legibility test could increase the interest in learning and the reader's memory. One of the factors supporting students' success in understanding the content of teaching materials was visual images/illustrations that support the learning material. Neina et al. (2015) stated that using photos / graphic drawings to keep learning materials can affect teaching materials' readability.

In general, the teaching materials developed to use a sentence structure following the General Guidelines for Indonesian Spelling (PUEBI). It was adapted to the reader (high school students) so that students easily understand it. The teaching materials developed were packaged in simple vocabulary to make it easier for students to understand the material. The same thing was expressed by Larasati & Yulianti (2014) in their research which stated that teaching materials arranged using simple sentences and letters would be easier for students to understand.

Student Responses to Teaching Materials

The operational field test aimed to determine students' response to teaching materials as users regarding the display aspects of teaching materials, grammar and sentence structure, content, use, and functions of teaching materials. Also, 35 students of class XI MIPA 3 and 34 students of class XI MIPA 5 at SMA Negeri 1 Patikraja carried out assessment of students' responses to teaching materials. The choice of class XI MIPA as a respondent was due to the assumption that class XI MIPA already knew fluid material obtained in class XI in the odd semester to respond to teaching materials and questionnaires that have been compiled.

Table 7 presented the results of the student response questionnaire analysis on the display aspects of teaching materials.

Table 7. Results of Display Aspect Analysis

Sub Aspects	*P*(%)
The display of STEM teaching materials integrates 21st century skills and a load of interesting characters	87,34
The pictures contained in the teaching materials are clear and easy to understand	88,44
Average	87,88

Table 7 presented the display aspects. The teaching materials developed got an average percentage of 87.88% with excellent criteria in the display aspect. The rate was because the teaching materials developed could visualize the material clearly and attractively through the support of picture explanations that helped students interact to increase students' understanding (Khamidah et al., 2019). Based on students' responses in the reason/input column, it was stated that overall, the teaching materials developed have an attractive appearance and design. The images and descriptions of the ideas presented are easy to understand to motivate students to read them.

The analysis of students' questionnaire responses to teaching materials on the grammar and sentence structure aspects was based on an indicator, namely using language in teaching materials that is easy to understand. The average percentage is 88.44%, with an excellent category. The rate was because the developed teaching materials present fluid material with grammar and sentence structure that has been adjusted to the General Guidelines for Indonesian Spelling (PUEBI). It also adapted to the reader's cognitive development (high school students) and has gone through material experts' validation stage. It made it easier for students to understand the fluid material in teaching materials. In line with the results of students' responses given in the reason/input column. It stated that the entire of the teaching materials developed use standard Indonesian, straightforward, and understood by students. As Rahmawati (2016) said, in the preparation of teaching materials, students must pay attention to standard, effective, and consistent sentences so that students easily understand them. Also, the choice of language in teaching materials, according to Qostantia (2017), must be adjusted to the age development of students by paying attention to sound and correct Indonesian rules.

Table 8 presented the results of the student response questionnaire analysis on the aspects of the content of teaching materials.

Regarding the analysis of the content aspects presented in Table 8, it was found that the teaching materials developed got an average percentage of 90.16% with excellent criteria in the display aspect. These results indicated that students could know the relationship between fluid material and science. They could also know various technologies that utilize the principles in a fluid material, know-how the engineering process is (designing or creating a technology) and understood aspects of mathematics as a language for science, engineering, and technology after studying fluid material the developed teaching materials. In reliance on the results of student responses given in the reason/input column, it was stated that the overall content of the material in the developed teaching materials presented material under what students have learned. The learning was in odd semesters and had many features that support the completeness of learning in class, one of which is "STEM Rubric," which contains the relationship between fluid material and aspects of science, technology, engineering, and mathematics. The multi and transdisciplinary integration of the S, T, E, and M aspects in this teaching material can improve students' conceptual mastery (Pangesti et al., 2017).

Questionnaire students' responses to teaching materials on aspects of use were based on an indicator, namely the material in teaching materials systematically arranged and easy to understand. Based on the student response analysis results, the average percentage was 88.48%, with the excellent category. The ratio was because the teaching materials developed present fluid materials packaged with STEM-based learning integrated 21st century skills (4C) and character content to give students a sustainable and robust willingness to learn (Beers, 2011; Sartika, 2019). Based on the results of students' responses given in the reason/input column, it was stated that the teaching materials developed are practically used in learning, presenting complete material about fluids, and easy to understand. As the research results of Irwandani et al. (2017) stated, material that

is arranged systematically, logically, easily understood, and is easy to use by both educators and students has good quality and feasibility.

Table 8. Results of Content Aspect Analysis

Sub Aspects	*P*(%)
The material contained in the teaching material is following the fluid subject matter	93,14
The material contained in teaching materials relates fluid to scientific aspects	90,22
The material contained in teaching materials relates fluids to technological aspects	89,14
The material contained in teaching materials relates fluids to engineering aspects (design/engineering)	87,34
The material contained in teaching materials relates fluids to mathematical aspects	90,94
Average	90,16

Table 9 presented the results of the student response questionnaire analysis on the functional aspects of teaching materials.

Based on the analysis of the functional aspects presented in Table 9, it was found that the teaching materials developed to get an average percentage of 86.60% in the display aspect. These results indicated that the developed teaching materials function in excellent criteria. Based on the results of students' responses given in the reason/input column, it was stated that the entire of teaching materials developed are practically used in learning and are suitable if used as handbooks for students to study at school and outside of school. As the results of research by Afriana et al. (2016) states, STEM-based learning could provide a memorable experience, giving rise to motivation and interest in education.

Overall, students' responses to physics teaching materials based on STEM integrated 21st century skills (4C) and character get reactions in the excellent category with a percentage of 88.32%.

Table 9. Results of Function Aspect Analysis

Sub Aspects	*P*(%)
STEM-based physics teaching materials integrated 21st century skills and practical character content used in learning	88,07
STEM-based physics teaching materials integrated with 21st century skills and character content help you understand the subject of fluids in more depth from the aspect of science	87,34
STEM-based physics teaching materials integrated with 21st century skills and character content help you understand the subject of fluids in more depth from the technological aspects	86,24
STEM-based physics teaching materials integrated with 21st century skills and character content help you understand the subject of fluids in more depth from the engineering aspect (design/engineering)	83,34
STEM-based physics teaching materials integrated with 21st century skills and character content help you understand the subject of fluids in more depth from the aspects of mathematics	88,04
Average	86,60

Interview Students' Responses to Teaching Materials

Interviews were conducted to explore students' responses to physics teaching materials based on STEM integrated 21st century skills (4C) and character. As the opinion of Asriningtyas et al. (2018), which stated that the data of a study could be strengthened through interviews with students. In this study, the interview respondents were six students, each consisting of three students of class XI MIPA 3 and 3 students of class XI MIPA 5 SMA Negeri 1 Patikraja.

Overall, an analysis of the results of interviews with students found that STEM-based physics teaching materials integrated with 21st century skills and character content could provide new learning experiences for students, especially concerning fluid material with science, technology, engineering, and mathematics. Students showed an interest in the teaching materials being developed. The images and language presented have helped students understand the problems presented in the teaching materials. However, there were still parts of the formula that need to be emphasized to be more visible. 21st century skills (4C), presented in the form of problems around technology related to fluids in discussion questions, have also been understood by students. Also, the presentation of character values related to the material has been understood by students. The findings from the analysis of physics teaching materials' test results based on STEM integrated 21st century skills (4C) and character. It showed that this teaching material was practically used in learning. It could be seen from the attractive appearance, grammar, and sentence structure that is easy to understand. The content of STEM-based material integrated 21st century skills (4C) and characters that students could accept and understand their practical use. Also, the function of teaching materials that make students more interested in studying the material more deeply.

CONCLUSION

Based on the results of research conducted at SMA Negeri 1 Patikraja, several conclusions were obtained. They were that the characteristics of STEM-based physics teaching materials were integrated with 21st century skills (4C). Also, the characters in fluid material contained the latest problems, discussion activities, practicum, and simple projects related to aspects of STEM in daily life and integrated with 21st century (4C) skills and character. The feasibility test results based on the content, presentation, language, and graphic aspects show that the teaching materials in the category are very suitable for use in learning. The legibility test results showed the teaching materials were in the easy-to-understand type. The assessment results of students' responses to teaching materials received responses in the excellent category for use by students of class XI SMA/MA as a source of supporting teaching materials in the learning process of fluid material. Overall, the teaching materials developed provide new learning experiences from cognitive and affective aspects compared to previously used teaching materials that are only oriented to cognitive aspects.

This research suggested that further development should be needed by adding information on the 4C indicator in each problem presented in the teaching material. Adding experimental content using a virtual lab adds to students' learning experience independently, especially when using a distance learning system.

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