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Development of a Learning Module on Linear Motion Material Using Robotics Based on Miniature Sahur Arakan Integrated with a STEM Approach

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Abstract: The integration of local wisdom in physics learning remains limited, and no module simultaneously combining the Arakan Sahur tradition, robotics technology, and the STEM approach has yet been developed. This study aimed to develop a straight-motion learning module using robotics based on Arakan Sahur miniatures integrated with STEM and to analyze its feasibility in terms of content quality, presentation, usability, and implementation in learning activities. The study employed the Research and Development (R&D) method using the Borg and Gall model limited to five stages. Data were collected through material expert validation questionnaires, media expert validation questionnaires, teacher perception questionnaires, student response questionnaires, and interviews. The feasibility indicators included material relevance, language clarity, content presentation, STEM integration, self-instructional characteristics, stand-alone usability, and user-friendliness of the module. The results showed that material expert validation achieved an average score of 3.47 (very good), while media expert validation reached 3.50 (very good) after two rounds of revision. Teacher perceptions obtained an average score of 3.44 (very good), and responses from 22 students reached 3.55 (very good). The module also demonstrated explicit implementation of the four STEM components through robotics programming, motion analysis, engineering design, and mathematical calculations. In addition, 95.5% of students showed high interest in learning physics using robotics-based activities. In conclusion, the developed module is considered valid and practical for use in high school physics learning and contributes as an innovative teaching material integrating physics concepts, local culture, robotics, and STEM learning.

Keywords: Module; Robotics; Straight Motion; Sahur Parade Miniature; STEM.

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Introduction

Physics learning is expected to help students understand natural phenomena through concepts closely related to everyday life, such as motion, force, and energy (Hardiansyah & Wahyu, 2021; Lestari et al., 2022). One local cultural activity relevant to linear motion concepts is the Arakan Sahur tradition in West Tanjung Jabung, where participants move collectively along certain routes during Ramadan. The movement patterns in this tradition can be associated with physics concepts such as distance, displacement, velocity, and acceleration in uniform linear motion (GLB) and uniformly accelerated motion (GLBB). Therefore, integrating local cultural contexts into physics learning can support contextual understanding and make abstract concepts easier for students to comprehend.

A preliminary study conducted at SMA Negeri 3 Tanjung Jabung Barat identified a gap between physics learning and the utilization of local culture in classroom instruction. Interview results with physics teachers

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showed that learning activities had never integrated the Arakan Sahur tradition with robotics or STEM-based learning. In addition, questionnaire results indicated that 21 out of 22 students (95.5%) expressed interest in learning physics using robotics-based media, while 18 students (81.8%) had prior experience participating in or observing the Arakan Sahur tradition. However, existing learning resources had not utilized this local context as part of physics instruction. As a result, students tended to perceive physics as abstract and less connected to real-life experiences. These findings indicate the need for innovative teaching materials that integrate local wisdom, robotics technology, and STEM approaches in physics learning.

The research gap lies in the limited availability of physics learning modules that simultaneously integrate local cultural contexts, robotics technology, and STEM approaches in linear motion learning. Previous research by Almuharomah et al. (2019) developed a STEM-based physics module integrated with local wisdom to improve students' creative thinking skills. The study showed positive feasibility and effectiveness results; however, it was limited to sound-wave material and did not incorporate robotics technology or motion programming activities. Therefore, the development of a robotics-assisted STEM module based on the Arakan Sahur tradition becomes relevant to support contextual and technology-integrated physics learning.

The STEM (Science, Technology, Engineering, and Mathematics) approach emphasizes the integration of interdisciplinary knowledge in solving real-world problems (Muttaqiin, 2023). In this study, the science aspect is represented through the understanding of linear motion concepts, the technology aspect through the use of the mBlock programming application, the engineering aspect through the design of miniature robotics, and the mathematics aspect through motion calculations involving distance, time, and velocity. Through robotics-assisted activities, students are expected not only to understand theoretical concepts but also to apply them in project-based learning experiences.

This study aims to develop and analyze the feasibility of a robotics-based linear motion learning module using Arakan Sahur miniatures integrated with a STEM approach. The development process includes needs analysis, product design, expert validation, and limited field testing. The resulting module is expected to support contextual physics learning while strengthening the integration of local wisdom and educational technology in classroom practice.

Method

Research Design

This study employed the Research and Development (R&D) method using the Borg and Gall model, aimed at developing and validating a physics learning module. The Borg and Gall model was chosen for its comprehensive and systematic characteristics, where each development stage undergoes a cycle of testing and revision based on empirical data (Husnayayin et al., 2024). This study limited implementation to the Preliminary Field Testing stage due to time, cost, and scope constraints. The product developed is a physics learning module on linear motion utilizing robotics technology based on the Arakan Sahur miniature, integrating a STEM approach and local Jambi cultural values.

Development Procedure

This study adopted the development procedure from the Borg and Gall model, summarized into five main stages. These five stages include: (1) research and information gathering, (2) planning, (3) development of the initial product form, (4) initial field trials, and (5) revision and final product. This procedure was chosen based on its systematic characteristics and the possibility of empirical data-based revisions at each stage (Husnayayin et al., 2024).

The first stage, research and information gathering, aimed to gather baseline data needed for module development. During this stage, researchers analyzed the Merdeka curriculum related to learning outcomes for linear motion kinematics, analyzed physics material to be integrated with robotics and Arakan Sahur culture, analyzed student characteristics (cultural background, academic ability, and learning styles), and analyzed teacher and student needs for innovative and contextual teaching materials.

The second stage, planning, aimed to draft the module before entering the development phase. Activities included determining the development team (researchers, supervising lecturers, material and media expert validators, and physics teachers), determining resources (laptops, Canva, mBlock, and scientific references), developing a development schedule, determining the product scope, creating a storyboard, determining product specifications, and constructing a module prototype. The module prototype included a cover, foreword, table of contents, concept map, description of linear motion material, robotics project activities, integration of Arakan Sahur cultural values, project-based evaluation, and a bibliography.

The third stage, developing the initial product, is the realization of the design into a test-ready product, which is then validated by experts. Product validation is conducted by subject matter and media experts through a questionnaire containing statements to assess the module's suitability to learning objectives and the media's effectiveness in supporting learning. The results of this validation serve as the basis for conceptual and practical improvements to the product before entering the pilot testing phase.

The fourth stage, the initial field trial, is conducted on a small scale to identify the product's strengths and weaknesses. Individual trials involving six students assess the module's readability, while small group trials involving 22 students assess its practicality. Data collection is conducted through user response questionnaires and observation sheets focused on student responses to STEM-based activities, interactions with robotics technology, and understanding the concept of linear motion through Jambi's local culture.

Figure 1. Development Procedure

The fifth stage, revision and final product, is the final refinement stage based on all the collected input. Revisions are based on suggestions from expert validators (materials and media), findings from individual and small group trials, and analysis of user response questionnaires. After going through all stages of revision, the final product was produced in the form of a learning module on straight motion material using robotics based on Arakan Sahur miniatures integrated with the STEM approach, which has been tested for its feasibility.

Population and Sample

The trial subjects in this study were 11th-grade students (Phase F) and one physics teacher at SMA Negeri 3 Tanjung Jabung Barat. Subjects were selected using a purposive sampling technique (Sugiyono, 2015) with specific criteria: students who had studied linear motion and physics teachers who taught the subject. The individual trial involved 6 students, while the small group trial involved 22 students. The sample selection was based on the research need to obtain direct user feedback on the developed module (Maharani & Bernard, 2018).

Data Collection Techniques

To ensure the quality and consistency of the research instruments, reliability testing was conducted before the implementation of the limited field trial. The reliability of the questionnaires was analyzed using Cronbach's Alpha coefficient to determine the internal consistency of each instrument. According to Tai (2020) and Putri (2020), an instrument is considered reliable if the Cronbach's Alpha coefficient is greater than 0.70. The reliability analysis covered the teacher perception questionnaire and student response questionnaire, which were developed using a 4-point Likert scale. The results of the reliability test showed that all instruments met the acceptable reliability criteria, indicating that the questionnaires were sufficiently consistent and appropriate for data collection in this study. In addition, content validity had previously been examined through expert judgment involving material experts and media experts to ensure the relevance and suitability of the instrument indicators with the objectives of the study.

Table 1. Blueprint of Expert Material Validation Questionnaire

Assessed Aspect	Indicator	Item Number
Material Feasibility	Relevance of content to learning outcomes and physics learning objectives	1, 2
	Coverage of physics concepts	3
	Suitability of content with local culture	4
	Accuracy of illustrations and images	5
	Suitability to teachers' needs	6
Module Item Relevance	Representation of educational robotics	7
	Coverage of physics concepts in STEM approach	8
	Ease of understanding concepts	9
Language Feasibility	Effectiveness of sentence usage	10, 11
	Clarity of language use	12, 13

Content Presentation & Layout	Organization of book layout	14
	Coherence between chapters and subchapters	15

Source: Adapted from Tai (2020)

Table 2. Blueprint of Expert Media Validation Questionnaire

Assessed Aspect	Indicator	Item Number
Self-Instructional	Module provides clear independent learning instructions	1
	Learning objectives are clearly stated at the beginning	2
	Module facilitates independent practice exercises	3, 4
Self-Contained	Core material is presented completely in one unit	5, 6
	There is a connection between material, exercises, and evaluation	7
	Project-based and robotics-integrated presentation in the module	8
Stand Alone	Module can be used without additional media	9, 10
	Procedures for using miniature media are clearly explained	11
User Friendly	Consistency of appearance (font, color, spacing) supports comfort	12, 13
	Module is easy to navigate and understand	14, 15, 16
	Module is visually attractive	17, 18
	Language is appropriate to students' developmental level	19, 20

Source: Adapted from Putri (2020)

Table 3. Blueprint of Teacher Perception Questionnaire

Assessed Aspect	Indicator	Item Number
Self-Instructional	I can teach straight motion material independently using this module	1, 2
	The module motivates me to develop creative teaching strategies	3
Self-Contained	All straight motion materials (theory, examples, exercises) are complete	4, 5
	The module clearly integrates theory, robotics practice, and local culture	6
	Instructions for miniature-based practicum (Arakan Sahur) are easy to implement	7
Stand Alone	Module can be used without additional tools/software beyond those recommended	8
	Module explains robotics usage steps and troubleshooting in detail	9, 10
User Friendly	Module design (layout, color, font) is professional and comfortable to read	11, 12
	Material systematics (chapter order, numbering) ease teaching delivery	13
	Physics technical language is clearly explained	14
	Illustrations/diagrams help visualize straight motion concepts	15
	Robotics and STEM activities increase student engagement	16

Source: Adapted from Putri (2020)

Table 4. Blueprint of Student Response Questionnaire

Assessed Aspect	Indicator	Item Number
Self-Instructional	I can learn independently using this module	1, 2
	The module provides easy-to-follow learning instructions	3
	The module motivates me to learn independently	4
Self-Contained	All materials in one topic are available in the module	5, 6
	The module integrates material, examples, and exercises	7
	Integration between theory and practice	8
Stand Alone	Module can be used without other supporting media	9
	Module explains how to use robotics miniatures	10, 11
User Friendly	Module appearance is attractive and easy to read	12, 13
	Layout helps me understand the content	14
	Module is easy to navigate and not confusing	15
	Language is easy to understand	16, 17
	Illustrations/images help understanding	18

	Module provides an enjoyable learning experience	19, 20

Source: Adapted from Putri (2020)

Table 5. Interview Guideline Blueprint

Aspect	Indicator	Question Number
Interest	Response to appearance, willingness to try, curiosity	1, 2, 3, 4
Material	Ease of understanding uniform and accelerated motion (GLB/GLBB), relation between theory and practice	5, 6, 7, 8
STEM Experience	Perception of technology (robotics), engineering (design/build), and mathematics (calculation)	9, 10, 11, 12
Strengths	Perceived added value compared to conventional media	13, 14, 15
Weaknesses	Identification of technical obstacles (robot errors), unclear instructions, or excessive time	16, 17, 18

Data Analysis Techniques

Data analysis in this study was conducted quantitatively using descriptive statistics and qualitatively using the Miles and Huberman model. Qualitative data analysis encompasses three main activities: data reduction (distilling validator suggestions into essential points), data presentation (organizing results in tabular and systematic narrative form), and drawing conclusions (summarizing points for improvement or retention in the module) (Sugiyono, 2020). Quantitative data analysis was conducted by calculating the average score for each assessment indicator using a 4-point Likert scale. Assessment findings categorized as poor and very poor served as the primary reference in the revision and refinement process for the final product.

Table 6. Likert Scale Scoring

Description	Perception	Score
The product is highly inappropriate, thus becoming the top priority for revision.	Very Poor / Strongly Disagree	1
The product tends to be inappropriate, thus serving as a basis for significant revision to achieve minimum feasibility.	Poor / Disagree	2
The product is good, not a priority for revision, but can be optimized if minor weaknesses are found.	Good / Agree	3
The product is highly appropriate, thus no revision is needed.	Very Good / Strongly Agree	4

Source: Khoiriah (2017)

Table 7. Likert Scale Score Classification

Score Range	Criteria
1.00 – 1.75	Very Poor / Strongly Disagree
1.76 – 2.50	Poor / Disagree
2.51 – 3.25	Good / Agree
3.26 – 4.00	Very Good / Strongly Agree

Source: Nahal et al. (2019)

Result and Discussion

Results of the Research and Information Collection Stage

The research and information collection stage revealed that most students have high experience and interest in integrating local culture and robotic technology into physics learning.

Table 8. Students' Experience in Participating in Arakan Sahur

No	Category	Description	F	%
1	Experienced	Students have had direct experience participating in or observing the Arakan Sahur activity as part of local cultural traditions.	18	81.8%
2	Not Experienced	Students have not had direct experience with Arakan Sahur, so their understanding is limited to secondary information.	4	18.2%
Total			**22**	**100%**

Table 9. Students' Interest in Learning Using Robotics

No	Category	Description	F	%
1	Interested	Students show positive attitudes and high enthusiasm toward the integration of robotic technology in physics learning.	21	95.5%
2	Not Interested	Students show low interest or tend to resist the use of robotics as a learning medium in physics.	1	4.5%
Total			**22**	**100%**

Based on the results of the research and information gathering phase, it was found that the majority of students had experience and interest in integrating local culture and robotics technology into physics learning. Table 8 shows that 18 students (81.8%) stated that they had participated in or witnessed the Arakan Sahur tradition, indicating that this local cultural activity remains familiar to most students. Only 4 students (18.2%) reported having no direct experience with the tradition. Meanwhile, Table 9 shows that 21 students (95.5%) expressed interest in learning physics using robotics, while only 1 student (4.5%) expressed no interest. These findings indicate that students are generally familiar with the local cultural context and show positive responses toward the use of robotics in physics learning. Therefore, the integration of Arakan Sahur culture and robotics technology has the potential to support the development of more contextual and engaging physics learning materials.

Interviews with physics teachers also revealed that there is no learning module that simultaneously integrates Arakan Sahur local culture, robotics technology, and STEM approaches. The research and information gathering phase successfully identified a learning gap, namely the lack of a module that integrates Arakan Sahur local culture with robotics technology and STEM approaches. This finding aligns with research by Almuharomah et al. (2019) who also began developing a STEM module integrated with local wisdom through an in-depth needs analysis. However, this study went further by integrating all three elements simultaneously (local culture, robotics, and STEM), while Almuharomah's research focused solely on the drumbeat culture without involving robotics technology.

Material Expert Validation Results

The results of the first stage of material expert validation were analyzed descriptively to determine the scores achieved for each assessment aspect. Data obtained from the validators indicated that there was variation in achievement across aspects, with content presentation and layout achieving the lowest average scores. To facilitate interpretation of the validation results, the average scores for each aspect are presented graphically in Figure 1 below.

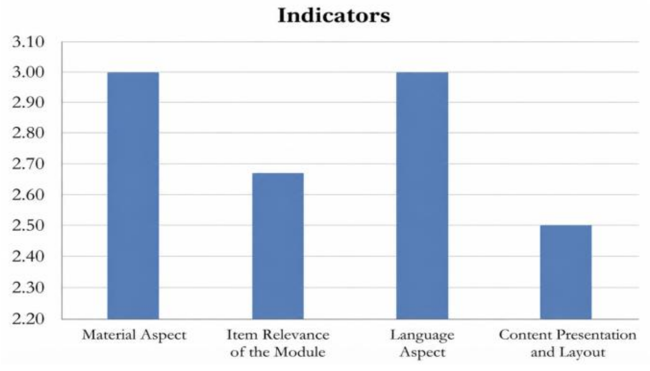


Figure 2. Graph of indicators for Phase 1 Material Validation Results
Source: Data Processing in Microsoft Excel

Based on the results of the first phase of validation, in addition to quantitative data, the validator also provided a number of qualitative comments and suggestions for improvement. In general, these suggestions are as follows:

Table 10. Validator Comments and Suggestions

No	General Comments / Suggestions
1	In the introductory section regarding the contents of the module, it is best to represent it using number symbols, not dots (not scientific).
2	Ideally, instructions for using the module should be provided.
3	On pages 2 and 3 and related pages (image explanations, for example Image 1) are placed below the image.
4	On page 6 (the dot symbol is replaced by a letter symbol, for example a.) regarding the local economic impact section.
5	On pages 11 and 12 (the dot symbol is replaced by a letter symbol, e.g. a.).
6	Ideally, it is represented and explained regarding the physical variables related to straight motion.
7	Correct the formulas on pages 44 and 45 (mistake between formula and description).
8	On page 47, the symbol for ΔV is an overline because it indicates a vector.

9	There must be consistency between speed and velocity (as in the formula on page 68).
10	There is an inconsistency in writing the formula (speed vs velocity are swapped).
11	The core balance of matter is not yet optimal; ideally it should be explained in sequence, especially regarding GLB and GLBB (what is the difference, what are the physical variables, when does GLB occur and when does GLBB occur).
12	Tidy up the writing, avoid the word "while" at the beginning of the sentence.

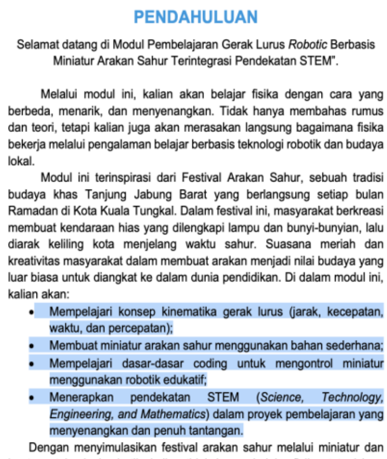
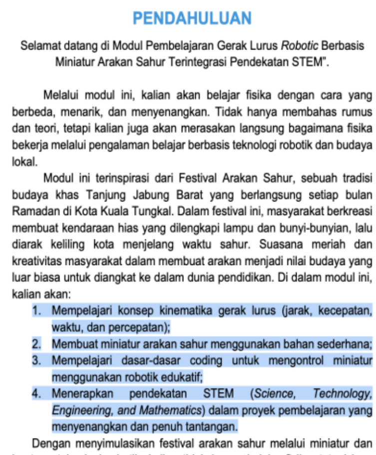
The results of the first-stage material expert validation showed variations across assessment aspects, particularly in the content presentation and layout aspect, which obtained the lowest average score. This finding indicates that the initial version of the module still required improvements in the organization of material presentation, consistency of scientific writing, and clarity of visual components. Several weaknesses identified by validators included inconsistencies in the use of physics terminology, inaccuracies in formula descriptions, inconsistent notation between speed and velocity, and the absence of structured explanations regarding the differences between GLB and GLBB concepts. These findings suggest that although the module content was generally relevant to learning objectives, the conceptual coherence and scientific accuracy of the material still needed refinement to support effective student understanding.

In addition, validators emphasized the importance of improving the pedagogical structure of the module. For example, the recommendation to add module usage instructions reflects the need to strengthen the self-instructional characteristic of the module, allowing students to use it more independently. Suggestions regarding the placement of image captions, numbering systems, and consistency of writing formats also indicate that visual organization and readability are important aspects influencing learning effectiveness. From the conceptual perspective, validators highlighted that explanations of physical variables in linear motion should be presented more systematically to avoid misconceptions among students. This is particularly important because the module integrates robotics activities and STEM learning, which require students to connect theoretical understanding with practical implementation.

Furthermore, the validators' comments demonstrated that the integration of local culture and robotics in the module had been considered relevant, but the scientific presentation still required adjustment to achieve better conceptual balance. Revisions such as correcting vector notation, improving formula explanations, and reorganizing the sequence of GLB and GLBB material were intended not only to improve technical accuracy but also to strengthen the module's ability to guide students in understanding physics concepts contextually. Therefore, the revision process focused not merely on improving visual appearance but also on enhancing conceptual clarity, scientific consistency, and the pedagogical quality of the learning content.

Based on all these suggestions, the researchers systematically revised the module. The results of the revisions are shown in the following table:

Table 11. Revision Results Before and After Material Validation

<table>
<tr><th>No</th><th>Before</th><th>After</th></tr>
<tr><td>1.</td><td>
PENDAHULUAN
Selamat datang di Modul Pembelajaran Gerak Lurus *Robotic* Berbasis Miniatur Arakan Sahur Terintegrasi Pendekatan STEM".
Melalui modul ini, kalian akan belajar fisika dengan cara yang berbeda, menarik, dan menyenangkan. Tidak hanya membahas rumus dan teori, tetapi kalian juga akan merasakan langsung bagaimana fisika bekerja melalui pengalaman belajar berbasis teknologi robotik dan budaya lokal.
Modul ini terinspirasi dari Festival Arakan Sahur, sebuah tradisi budaya khas Tanjung Jabung Barat yang berlangsung setiap bulan Ramadan di Kota Kuala Tungkal. Dalam festival ini, masyarakat berkreasi membuat kendaraan hias yang dilengkapi lampu dan bunyi-bunyian, lalu diarak keliling kota menjelang waktu sahur. Suasana meriah dan kreativitas masyarakat dalam membuat arakan menjadi nilai budaya yang luar biasa untuk diangkat ke dalam dunia pendidikan. Di dalam modul ini, kalian akan:
• Mempelajari konsep kinematika gerak lurus (jarak, kecepatan, waktu, dan percepatan);
• Membuat miniatur arakan sahur menggunakan bahan sederhana;
• Mempelajari dasar-dasar coding untuk mengontrol miniatur menggunakan robotik edukatif;
• Menerapkan pendekatan STEM (*Science, Technology, Engineering, and Mathematics*) dalam proyek pembelajaran yang menyenangkan dan penuh tantangan.
Dengan menyimulasikan festival arakan sahur melalui miniatur dan</td><td>
PENDAHULUAN
Selamat datang di Modul Pembelajaran Gerak Lurus *Robotic* Berbasis Miniatur Arakan Sahur Terintegrasi Pendekatan STEM".
Melalui modul ini, kalian akan belajar fisika dengan cara yang berbeda, menarik, dan menyenangkan. Tidak hanya membahas rumus dan teori, tetapi kalian juga akan merasakan langsung bagaimana fisika bekerja melalui pengalaman belajar berbasis teknologi robotik dan budaya lokal.
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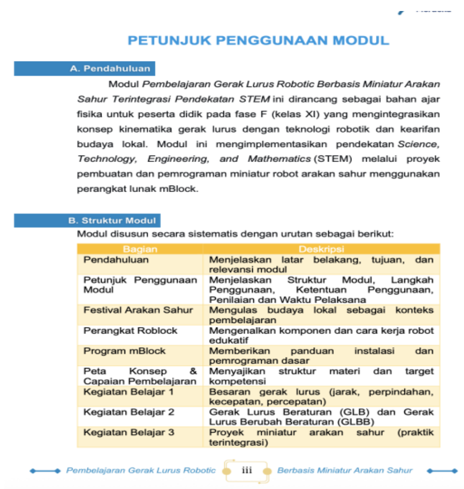
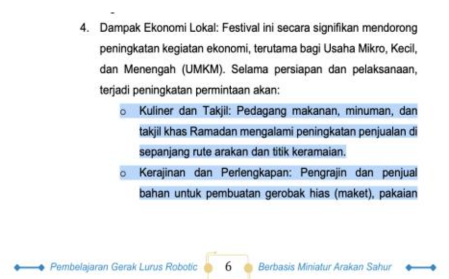
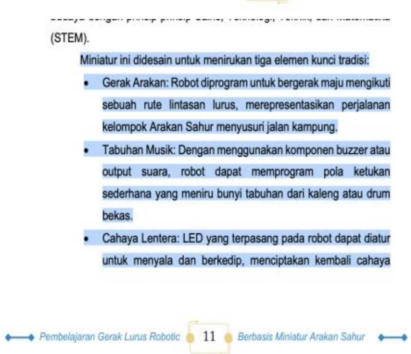
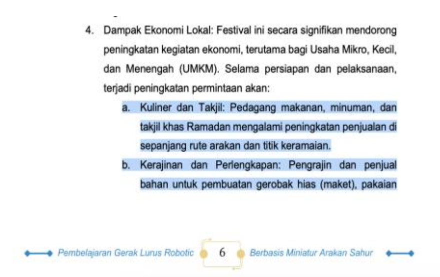
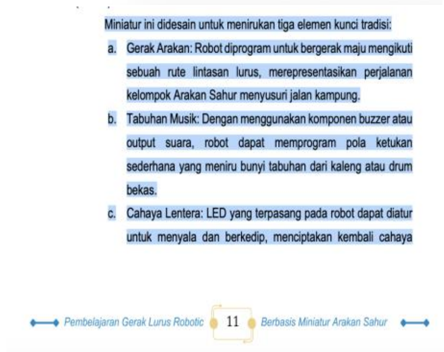
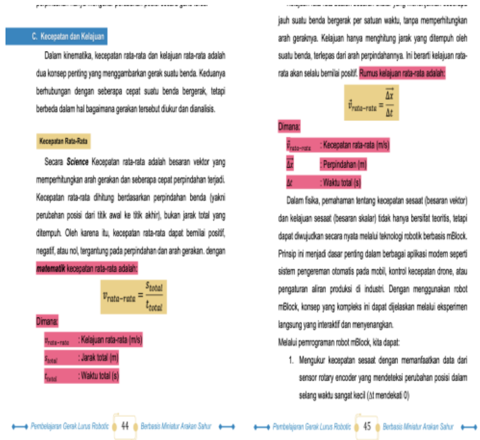
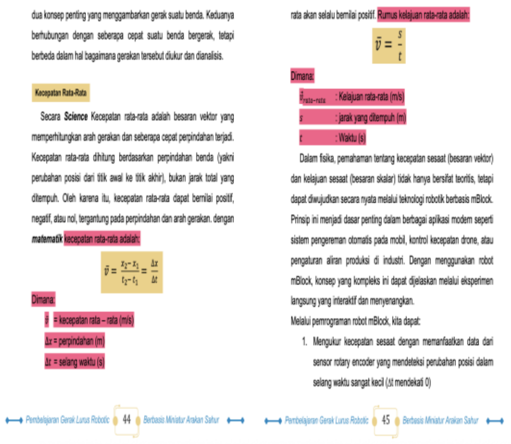
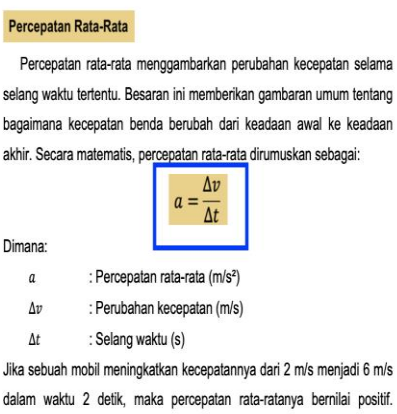
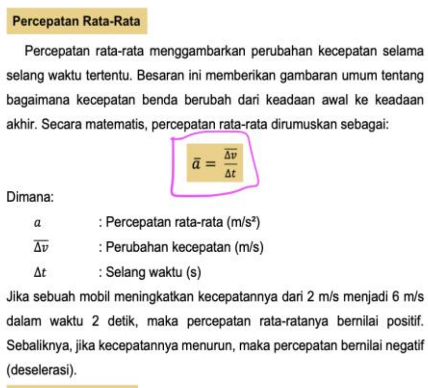
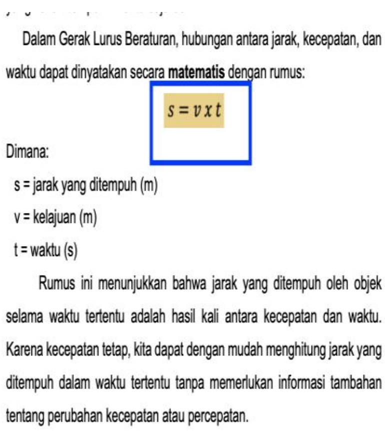
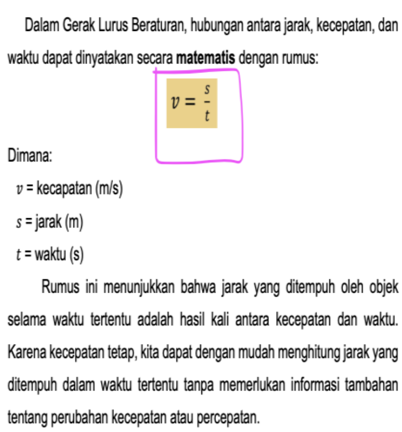
1. Mempelajari konsep kinematika gerak lurus (jarak, kecepatan, waktu, dan percepatan);
2. Membuat miniatur arakan sahur menggunakan bahan sederhana;
3. Mempelajari dasar-dasar coding untuk mengontrol miniatur menggunakan robotik edukatif;
4. Menerapkan pendekatan STEM (*Science, Technology, Engineering, and Mathematics*) dalam proyek pembelajaran yang menyenangkan dan penuh tantangan.
Dengan menyimulasikan festival arakan sahur melalui miniatur dan
Changes to the numbering, this applies throughout the module.</td></tr>
</table>

<table>
<tr><th>No</th><th>Before</th><th>After</th></tr>
<tr><td>2.</td><td>Instructions for using the module are missing.</td><td>
PETUNJUK PENGGUNAAN MODUL
A. Pendahuluan
Modul *Pembelajaran Gerak Lurus Robotic Berbasis Miniatur Arakan Sahur Terintegrasi Pendekatan STEM* ini dirancang sebagai bahan ajar fisika untuk peserta didik pada fase F (kelas XI) yang mengintegrasikan konsep kinematika gerak lurus dengan teknologi robotik dan kearifan budaya lokal. Modul ini mengimplementasikan pendekatan *Science, Technology, Engineering, and Mathematics* (STEM) melalui proyek pembuatan dan pemrograman miniatur robot arakan sahur menggunakan perangkat lunak mBlock.
B. Struktur Modul
Modul disusun secara sistematis dengan urutan sebagai berikut:
Bagian | Deskripsi
Pendahuluan | Menjelaskan latar belakang, tujuan, dan relevansi modul
Petunjuk Penggunaan Modul | Menjelaskan Struktur Modul, Langkah Penggunaan, Ketentuan Penggunaan, Penilaian dan Waktu Pelaksana
Festival Arakan Sahur | Mengulas budaya lokal sebagai konteks pembelajaran
Perangkat Roblock | Mengenalkan komponen dan cara kerja robot edukatif
Program mBlock | Memberikan panduan instalasi dan pemrograman dasar
Peta Konsep & Capaian Pembelajaran | Menyajikan struktur materi dan target kompetensi
Kegiatan Belajar 1 | Besaran gerak lurus (jarak, perpindahan, kecepatan, percepatan)
Kegiatan Belajar 2 | Gerak Lurus Beraturan (GLB) dan Gerak Lurus Berubah Beraturan (GLBB)
Kegiatan Belajar 3 | Proyek miniatur arakan sahur (praktik terintegrasi)
Pembelajaran Gerak Lurus Robotic iii Berbasis Miniatur Arakan Sahur

Added instructions for using the module</td></tr>
<tr><td>3.</td><td></td><td>
Changes to the position of the image caption to the bottom and numbering.</td></tr>
<tr><td>4.</td><td>
4. Dampak Ekonomi Lokal: Festival ini secara signifikan mendorong peningkatan kegiatan ekonomi, terutama bagi Usaha Mikro, Kecil, dan Menengah (UMKM). Selama persiapan dan pelaksanaan, terjadi peningkatan permintaan akan:
o Kuliner dan Takjil: Pedagang makanan, minuman, dan takjil khas Ramadan mengalami peningkatan penjualan di sepanjang rute arakan dan titik keramaian.
o Kerajinan dan Perlengkapan: Pengrajin dan penjual bahan untuk pembuatan gerobak hias (maket), pakaian
Pembelajaran Gerak Lurus Robotic 6 Berbasis Miniatur Arakan Sahur

(STEM).
Miniatur ini didesain untuk menirukan tiga elemen kunci tradisi:
• Gerak Arakan: Robot diprogram untuk bergerak maju mengikuti sebuah rute lintasan lurus, merepresentasikan perjalanan kelompok Arakan Sahur menyusuri jalan kampung.
• Tabuhan Musik: Dengan menggunakan komponen buzzer atau output suara, robot dapat memprogram pola ketukan sederhana yang meniru bunyi tabuhan dari kaleng atau drum bekas.
• Cahaya Lentera: LED yang terpasang pada robot dapat diatur untuk menyala dan berkedip, menciptakan kembali cahaya
Pembelajaran Gerak Lurus Robotic 11 Berbasis Miniatur Arakan Sahur</td><td>
4. Dampak Ekonomi Lokal: Festival ini secara signifikan mendorong peningkatan kegiatan ekonomi, terutama bagi Usaha Mikro, Kecil, dan Menengah (UMKM). Selama persiapan dan pelaksanaan, terjadi peningkatan permintaan akan:
a. Kuliner dan Takjil: Pedagang makanan, minuman, dan takjil khas Ramadan mengalami peningkatan penjualan di sepanjang rute arakan dan titik keramaian.
b. Kerajinan dan Perlengkapan: Pengrajin dan penjual bahan untuk pembuatan gerobak hias (maket), pakaian
Pembelajaran Gerak Lurus Robotic 6 Berbasis Miniatur Arakan Sahur

Miniatur ini didesain untuk menirukan tiga elemen kunci tradisi:
a. Gerak Arakan: Robot diprogram untuk bergerak maju mengikuti sebuah rute lintasan lurus, merepresentasikan perjalanan kelompok Arakan Sahur menyusuri jalan kampung.
b. Tabuhan Musik: Dengan menggunakan komponen buzzer atau output suara, robot dapat memprogram pola ketukan sederhana yang meniru bunyi tabuhan dari kaleng atau drum bekas.
c. Cahaya Lentera: LED yang terpasang pada robot dapat diatur untuk menyala dan berkedip, menciptakan kembali cahaya
Pembelajaran Gerak Lurus Robotic 11 Berbasis Miniatur Arakan Sahur</td></tr>
</table>

<table>
<tr><th>No</th><th>Before</th><th>After</th></tr>
<tr><td></td><td></td><td>The change in the dot symbol to the letter a. This applies throughout the module.</td></tr>
<tr><td>5.</td><td>
C. Kecepatan dan Kelajuan
Dalam kinematika, kecepatan rata-rata dan kelajuan rata-rata adalah dua konsep penting yang menggambarkan gerak suatu benda. Keduanya berhubungan dengan seberapa cepat suatu benda bergerak, tetapi berbeda dalam hal bagaimana gerakan tersebut diukur dan dianalisis.
Kecepatan Rata-Rata
Secara Science Kecepatan rata-rata adalah besaran vektor yang memperhitungkan arah gerakan dan seberapa cepat perpindahan terjadi. Kecepatan rata-rata dihitung berdasarkan perpindahan benda (yakni perubahan posisi dari titik awal ke titik akhir), bukan jarak total yang ditempuh. Oleh karena itu, kecepatan rata-rata dapat bernilai positif, negatif, atau nol, tergantung pada perpindahan dan arah gerakan. dengan matematik kecepatan rata-rata adalah:
$v_{rata-rata} = \frac{s_{total}}{t_{total}}$
Dimana:
$v_{rata-rata}$: Kelajuan rata-rata (m/s)
s_{total} : Jarak total (m)
t_{total} : Waktu total (s)
Pembelajaran Gerak Lurus Robotic 44 Berbasis Miniatur Arakan Sahur
jauh suatu benda bergerak per satuan waktu, tanpa memperhitungkan arah geraknya. Kelajuan hanya menghitung jarak yang ditempuh oleh suatu benda, terlepas dari arah perpindahannya. Ini berarti kelajuan rata-rata akan selalu bernilai positif. Rumus kelajuan rata-rata adalah:
$\vec{v}_{rata-rata} = \frac{\overrightarrow{\Delta x}}{\Delta t}$
Dimana:
$\vec{v}_{rata-rata}$: Kecepatan rata-rata (m/s)
$\overrightarrow{\Delta x}$: Perpindahan (m)
Δt : Waktu total (s)
Dalam fisika, pemahaman tentang kecepatan sesaat (besaran vektor) dan kelajuan sesaat (besaran skalar) tidak hanya bersifat teoritis, tetapi dapat diwujudkan secara nyata melalui teknologi robotik berbasis mBlock. Prinsip ini menjadi dasar penting dalam berbagai aplikasi modern seperti sistem pengereman otomatis pada mobil, kontrol kecepatan drone, atau pengaturan aliran produksi di industri. Dengan menggunakan robot mBlock, konsep yang kompleks ini dapat dijelaskan melalui eksperimen langsung yang interaktif dan menyenangkan.
Melalui pemrograman robot mBlock, kita dapat:
1. Mengukur kecepatan sesaat dengan memanfaatkan data dari sensor rotary encoder yang mendeteksi perubahan posisi dalam selang waktu sangat kecil (Δt mendekati 0)
Pembelajaran Gerak Lurus Robotic 45 Berbasis Miniatur Arakan Sahur</td><td>
dua konsep penting yang menggambarkan gerak suatu benda. Keduanya berhubungan dengan seberapa cepat suatu benda bergerak, tetapi berbeda dalam hal bagaimana gerakan tersebut diukur dan dianalisis.
Kecepatan Rata-Rata
Secara Science Kecepatan rata-rata adalah besaran vektor yang memperhitungkan arah gerakan dan seberapa cepat perpindahan terjadi. Kecepatan rata-rata dihitung berdasarkan perpindahan benda (yakni perubahan posisi dari titik awal ke titik akhir), bukan jarak total yang ditempuh. Oleh karena itu, kecepatan rata-rata dapat bernilai positif, negatif, atau nol, tergantung pada perpindahan dan arah gerakan. dengan matematik kecepatan rata-rata adalah:
$\bar{v} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{\Delta x}{\Delta t}$
Dimana:
$\bar{v}$ = kecepatan rata – rata (m/s)
Δx = perpindahan (m)
Δt = selang waktu (s)
Pembelajaran Gerak Lurus Robotic 44 Berbasis Miniatur Arakan Sahur
rata akan selalu bernilai positif. Rumus kelajuan rata-rata adalah:
$\bar{v} = \frac{s}{t}$
Dimana:
$\bar{v}_{rata-rata}$: Kelajuan rata-rata (m/s)
s : jarak yang ditempuh (m)
t : Waktu (s)
Dalam fisika, pemahaman tentang kecepatan sesaat (besaran vektor) dan kelajuan sesaat (besaran skalar) tidak hanya bersifat teoritis, tetapi dapat diwujudkan secara nyata melalui teknologi robotik berbasis mBlock. Prinsip ini menjadi dasar penting dalam berbagai aplikasi modern seperti sistem pengereman otomatis pada mobil, kontrol kecepatan drone, atau pengaturan aliran produksi di industri. Dengan menggunakan robot mBlock, konsep yang kompleks ini dapat dijelaskan melalui eksperimen langsung yang interaktif dan menyenangkan.
Melalui pemrograman robot mBlock, kita dapat:
1. Mengukur kecepatan sesaat dengan memanfaatkan data dari sensor rotary encoder yang mendeteksi perubahan posisi dalam selang waktu sangat kecil (Δt mendekati 0)
Pembelajaran Gerak Lurus Robotic 45 Berbasis Miniatur Arakan Sahur</td></tr>
<tr><td>6.</td><td>
Percepatan Rata-Rata
Percepatan rata-rata menggambarkan perubahan kecepatan selama selang waktu tertentu. Besaran ini memberikan gambaran umum tentang bagaimana kecepatan benda berubah dari keadaan awal ke keadaan akhir. Secara matematis, percepatan rata-rata dirumuskan sebagai:
$a = \frac{\Delta v}{\Delta t}$
Dimana:
a : Percepatan rata-rata (m/s²)
Δv : Perubahan kecepatan (m/s)
Δt : Selang waktu (s)
Jika sebuah mobil meningkatkan kecepatannya dari 2 m/s menjadi 6 m/s dalam waktu 2 detik, maka percepatan rata-ratanya bernilai positif.</td><td>
Percepatan Rata-Rata
Percepatan rata-rata menggambarkan perubahan kecepatan selama selang waktu tertentu. Besaran ini memberikan gambaran umum tentang bagaimana kecepatan benda berubah dari keadaan awal ke keadaan akhir. Secara matematis, percepatan rata-rata dirumuskan sebagai:
$\bar{a} = \frac{\overline{\Delta v}}{\Delta t}$
Dimana:
a : Percepatan rata-rata (m/s²)
$\overline{\Delta v}$: Perubahan kecepatan (m/s)
Δt : Selang waktu (s)
Jika sebuah mobil meningkatkan kecepatannya dari 2 m/s menjadi 6 m/s dalam waktu 2 detik, maka percepatan rata-ratanya bernilai positif. Sebaliknya, jika kecepatannya menurun, maka percepatan bernilai negatif (deselerasi).

Improvements to the formula</td></tr>
<tr><td>7.</td><td>
Dalam Gerak Lurus Beraturan, hubungan antara jarak, kecepatan, dan waktu dapat dinyatakan secara matematis dengan rumus:
$s = v\,x\,t$
Dimana:
s = jarak yang ditempuh (m)
v = kelajuan (m)
t = waktu (s)
Rumus ini menunjukkan bahwa jarak yang ditempuh oleh objek selama waktu tertentu adalah hasil kali antara kecepatan dan waktu. Karena kecepatan tetap, kita dapat dengan mudah menghitung jarak yang ditempuh dalam waktu tertentu tanpa memerlukan informasi tambahan tentang perubahan kecepatan atau percepatan.</td><td>
Dalam Gerak Lurus Beraturan, hubungan antara jarak, kecepatan, dan waktu dapat dinyatakan secara matematis dengan rumus:
$v = \frac{s}{t}$
Dimana:
v = kecapatan (m/s)
s = jarak (m)
t = waktu (s)
Rumus ini menunjukkan bahwa jarak yang ditempuh oleh objek selama waktu tertentu adalah hasil kali antara kecepatan dan waktu. Karena kecepatan tetap, kita dapat dengan mudah menghitung jarak yang ditempuh dalam waktu tertentu tanpa memerlukan informasi tambahan tentang perubahan kecepatan atau percepatan.

Improvements to the formula</td></tr>
</table>

After revisions were made based on comments from subject matter expert validators, the learning module entered the second validation phase. The results are as follows:

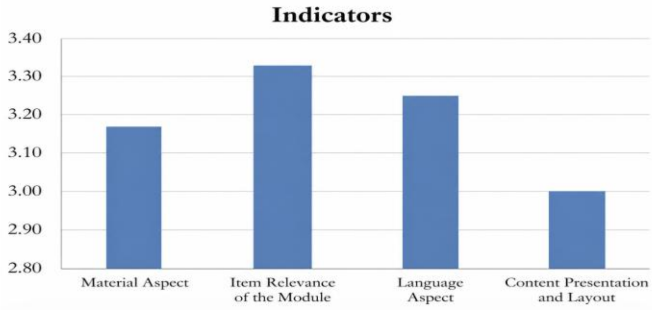


Figure 3. Stage 2 Material Validation Indicator Chart
Source: Data Processing inMicrosoft Excel

The first stage of material expert validation obtained a total average of 3.13 (Good category), which increased to 3.47 (Very Good category) after revision. In the first stage of validation, the content presentation and layout aspects obtained the lowest average (2.50) with a Not Good category, mainly due to inconsistencies in formula writing and the use of unscientific dot symbols (Table 4). After revisions based on 12 validator suggestions (Table 5), the second stage of validation showed improvements in all aspects, with the module item relevance aspect reaching an average of 3.33 (Very Good) and the material aspect reaching 3.17 (Very Good) (Figure 1). Thus, the module was declared suitable from a material aspect for use in the next stage.

The results of the validation by material experts in stage 2 showed a significant improvement from stage 1, especially in the relevance aspect of module items that include the representation of physics concepts in the STEM approach (increased from a score of 2 to 4). This improvement proves that the researcher has succeeded in explicitly representing the four pillars of STEM (Science, Technology, Engineering, Mathematics) in the module, as the main highlight of the validator in the first stage.

This finding is in line with Muttaqiin's (2023) research which emphasized that the STEM approach is not just an acronym but a framework of thinking that demands explicit connections between disciplines. In this module, the Science aspect is represented by the understanding of the concepts of GLB and GLBB, the Technology aspect by the use of the mBlock application, the Engineering aspect by the design and assembly of the Arakan Sahur miniature robot, and the Mathematics aspect by the calculation of distance, time, and speed.

Media Expert Validation Results

The results of the first stage of media expert validation were analyzed based on four main aspects that reflect the characteristics of a good learning module. Of these four aspects, self-instructional and user-friendliness were the primary concerns, as they scored below the ideal feasibility threshold. Figure 4. presents a graphical indicator of the first stage of media validation results to facilitate the identification of any items requiring revision.

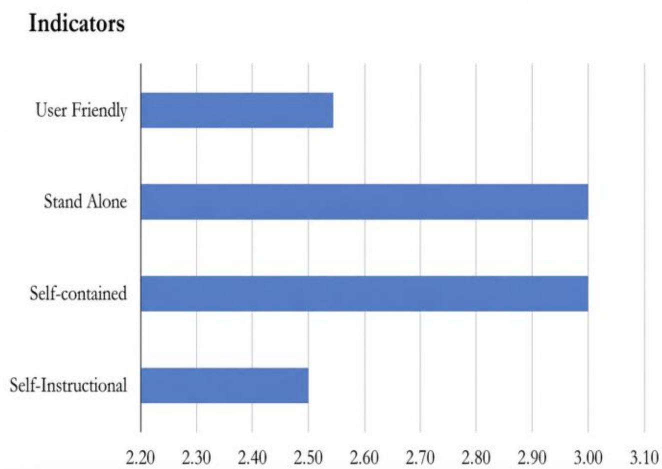


Figure 4. Indicator graph of Stage 1 Media Validation Results
Source: Data Processing inMicrosoft Excel

Based on the results of the first phase of validation, in addition to quantitative data, the validator also provided a number of qualitative comments and suggestions for improvement. In general, these suggestions are as follows:

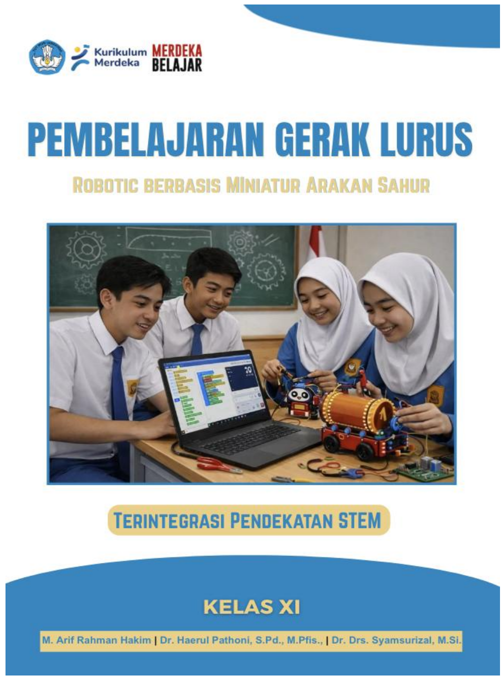
Table 12. Validator Comments and Suggestions

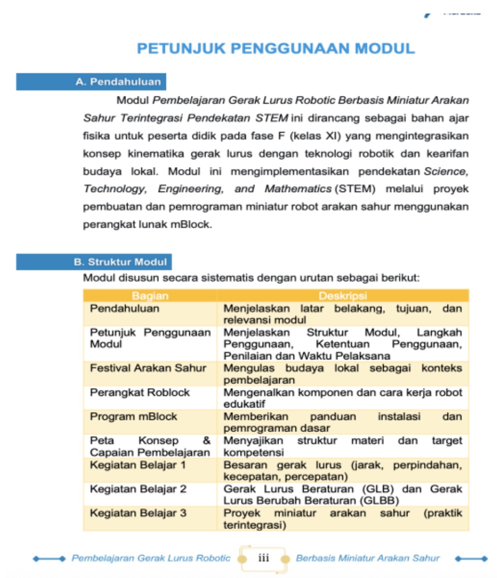
No	General Comments / Suggestions
1	Improve the image captions, create sequential numbers so that readers can understand clearly and easily.
2	The cover color should be white
3	Add module usage instructions.

Based on all these suggestions, the researchers systematically revised the module. The results of the revisions are shown in the following table:

Table 13. Revision Results Before and After Media Validation Stage 1

<table>
<tr><th>No</th><th>Before</th><th>After</th></tr>
<tr><td>1.</td><td>


</td><td>


Changes to cover color
</td></tr>
<tr><td>2.</td><td>Instructions for using the module are missing.</td><td>

PETUNJUK PENGGUNAAN MODUL
A. Pendahuluan
Modul *Pembelajaran Gerak Lurus Robotic Berbasis Miniatur Arakan Sahur Terintegrasi Pendekatan STEM* ini dirancang sebagai bahan ajar fisika untuk peserta didik pada fase F (kelas XI) yang mengintegrasikan konsep kinematika gerak lurus dengan teknologi robotik dan kearifan budaya lokal. Modul ini mengimplementasikan pendekatan *Science, Technology, Engineering, and Mathematics* (STEM) melalui proyek pembuatan dan pemrograman miniatur robot arakan sahur menggunakan perangkat lunak mBlock.
B. Struktur Modul
Modul disusun secara sistematis dengan urutan sebagai berikut:
<table>
<tr><th>Bagian</th><th>Deskripsi</th></tr>
<tr><td>Pendahuluan</td><td>Menjelaskan latar belakang, tujuan, dan relevansi modul</td></tr>
<tr><td>Petunjuk Penggunaan Modul</td><td>Menjelaskan Struktur Modul, Langkah Penggunaan, Ketentuan Penggunaan, Penilaian dan Waktu Pelaksana</td></tr>
<tr><td>Festival Arakan Sahur</td><td>Mengulas budaya lokal sebagai konteks pembelajaran</td></tr>
<tr><td>Perangkat Roblock</td><td>Mengenalkan komponen dan cara kerja robot edukatif</td></tr>
<tr><td>Program mBlock</td><td>Memberikan panduan instalasi dan pemrograman dasar</td></tr>
<tr><td>Peta Konsep & Capaian Pembelajaran</td><td>Menyajikan struktur materi dan target kompetensi</td></tr>
<tr><td>Kegiatan Belajar 1</td><td>Besaran gerak lurus (jarak, perpindahan, kecepatan, percepatan)</td></tr>
<tr><td>Kegiatan Belajar 2</td><td>Gerak Lurus Beraturan (GLB) dan Gerak Lurus Berubah Beraturan (GLBB)</td></tr>
<tr><td>Kegiatan Belajar 3</td><td>Proyek miniatur arakan sahur (praktik terintegrasi)</td></tr>
</table>
Pembelajaran Gerak Lurus Robotic iii *Berbasis Miniatur Arakan Sahur*
Added instructions for using the module
</td></tr>
<tr><td>3.</td><td></td><td></td></tr>
</table>

No	Before	After
		 Changes to the position of the image caption to the bottom and numbering.

After revisions were made based oncomments from subject matter expert validators, the learning module entered the second validation phase. The results are as follows:

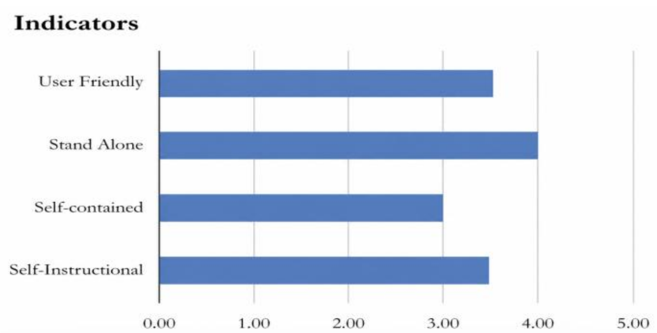


Figure 5. Graph of indicators of student perception results
Source: Data Processing in*Microsoft Excel*

The responses of 22 students to the learning module obtained a total average of 3.55 (Very Good category) on a maximum scale of 4. Based on the response questionnaire consisting of 20 statements, the user-friendly aspect obtained the highest average (3.58), followed by the stand-alone aspect (3.53), self-contained (3.42), and self-instructional (3.35) (Figure 3). This achievement indicates that students are very satisfied with the module's appearance, ease of use, and completeness of the material. Items such as an attractive appearance, easy-to-read fonts, images and illustrations that aid understanding, and a sense of enjoyment of learning all received high scores. The self-instructional aspect, which was the lowest aspect (3.35), remained in the Very Good category, but indicated that a small number of students still needed teacher guidance in independent learning. Overall, the module was considered very practical by students. Student responses to the module were also very positive, with the user-friendliness aspect achieving the highest average score (3.58). Students stated that the module's display was attractive, the font was easy to read, the images and illustrations aided comprehension, and they enjoyed learning using the module. Individual interviews revealed that all respondents (100%) showed high interest in the module, primarily due to the concrete visualization of the robot and their curiosity in modifying the Arakan Sahur miniature. This finding supports the theory of Hardiansyah & Wahyu (2021) which states that understanding physics through a local cultural context helps students connect theory with real-life experiences. In this study, 81.8% of students who had participated in Arakan Sahur felt a direct connection between the movements of the miniature robot and the movements of the Arakan Sahur participants, thus making learning more meaningful.

The self-instructional aspect obtained the lowest average score in student responses (3.35), although it remained in the “Very Good” category. This indicates that while most students were able to learn independently using the module, some still required teacher guidance during project implementation. This finding aligns with Rahmawati & Kurniawan (2022), who reported that STEM-based modules integrated with PhET simulations also showed lower self-instructional scores because students still needed initial orientation to understand project-based learning activities. Theoretically, these findings support Thuneberg et al. (2018), who stated that a good learning module should facilitate independent learning without entirely replacing the teacher’s role as a facilitator.

The implementation of the STEM approach in this module was reflected concretely through several learning activities integrated into the robotics project. In the Science aspect, students analyzed the concepts of distance, displacement, speed, and acceleration through observations of the miniature robot movement. In the Technology aspect, students used the mBlock programming application to control robot motion and adjust movement commands. In the Engineering aspect, students designed and assembled the Arakan Sahur miniature robot and evaluated its movement performance during trials. Meanwhile, the Mathematics aspect was implemented through calculations of travel time, velocity, and acceleration based on experimental data collected during robot testing. These activities demonstrate that STEM integration in the module was not limited to theoretical explanations but was directly applied through contextual and project-based learning experiences.

With a total average score of 3.44 from teachers and 3.55 from students, the module was considered procedurally feasible for implementation in physics learning. The positive responses also indicate that the integration of robotics, STEM activities, and local cultural contexts was able to support more interactive and meaningful learning experiences for students.

Revised Results and Final Product

The revision phase resulted in a final product of a valid, practical, and usable learning module after going through a series of iterative improvements based on input from validators, teachers, and students. Revisions based on validation by material experts in stage 1 corrected inconsistencies in formula writing, physics concept descriptions, and the provision of vector symbols. Revisions based on validation by media experts in stage 1 added instructions for module use, image numbering, cover color changes, and standardization of fonts and spacing. Revisions based on teacher perceptions added a more detailed assessment rubric and guidance.*troubleshooting*. Revisions based on student trials added visual icons (reading, practice, experiment, conclusion icons) and enriched the variety of example questions. The final module product has the following characteristics: (1) instructions for use with visual icons, (2) coherent GLB and GLBB material, (3) explicit STEM integration, (4) robotics practicum steps, (5) neat layout with structured image numbering, (6) communicative language, and (7) assessment rubrics and guidelines.

Development Limitations

Based on the results of the research and development of a linear motion learning module using robotics based on Arakan Sahur miniatures integrated with the STEM approach, there are several limitations that need to be acknowledged. First, this research is limited to the experimental stage.*preliminary field testing*(limited trial) involving 22 students in one school, so it has not yet measured the effectiveness of the module broadly in improving learning outcomes or critical thinking skills through*main field testing*.Second, the development of this module relies on the availability of robotics hardware (Roblock miniatures) and the mBlock programming application, which require significant costs as well as access to electricity and computers, so it has not been tested in areas with limited technological infrastructure. Third, this module was designed specifically for the cultural context of Arakan Sahur (West Tanjung Jabung, Jambi), so its transferability to areas with different local wisdom requires re-adaptation of the content. Fourth, the limited time for the trial meant that some students did not have the opportunity to complete the module exploration independently, so that the learning aspect*self-instructional*Although in the very good category, it still indicates the need for teacher mentoring. Fifth, this study did not include instrument reliability analysis and inferential statistical tests to measure the questionnaire's internal consistency. Therefore, the generalizability of these findings is limited, and further research is needed to test the module's effectiveness on a broader scale using a quasi-experimental design.

Conclusion

Based on the results of the research and development that has been carried out, it can be concluded that the learning module for straight motion material using robotics based on Arakan Sahur miniatures integrated with the STEM approach was successfully developed through the Borg and Gall model which is limited to five main stages. This module was declared conceptually feasible based on validation by material experts which reached an average of 3.47 (very good category) after two revisions, as well as validation by media experts which reached an average of 3.50 (very good category). The module was also declared procedurally feasible based on teacher perceptions which reached an average of 3.44 (very good category) and responses from 22 students which reached an average of 3.55 (very good category). The success of this module lies in the explicit integration of the four pillars of STEM (Science, Technology, Engineering, Mathematics) and its ability to connect the abstract concept of straight motion with concrete experiences through robotics and the local cultural context of Arakan Sahur, which has been proven to increase students' interest in learning by up to 95.5%. For future researchers, it is recommended to continue the research to the next stage.main field testingand effectiveness testing using a quasi-experimental design to quantitatively measure the increase in students' understanding of concepts, critical thinking skills, or problem-solving abilities after using this module compared to conventional learning.

Acknowledgements

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