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Development of applied physics instructional materials for the technology and engineering specialization

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ABSTRACT

This study was motivated by the limited integration of Android-based mobile devices into learning activities and the low learning achievement of vocational students in Temperature and Heat and Thermodynamics. This study aimed to develop an online Physics module for the Technology and Engineering specialization and examine its validity, practicality, and effectiveness. The study employed a research and development approach using the Instructional Development Institute (IDI) model, consisting of define, develop, and evaluate stages. Product validation involved six experts, comprising three content validators and three design validators. The practicality evaluation involved four Physics teachers and 40 students, while the effectiveness test involved 80 students divided equally into an experimental group (n = 40) and a control group (n = 40). Data were collected using validation and practicality questionnaires and a learning-outcome test. The test instrument was piloted outside the research sample, yielding 27 valid items with a Cronbach's alpha of 0.92; 20 items were selected for the final test. The results showed valid content (Aiken's V = 0.730) and design (Aiken's V = 0.705). The module was rated very practical by teachers (83.33%) and practical by students (68.25%). The experimental group achieved an N-Gain of 0.71 (high), compared with 0.29 (moderate) in the control group. These findings indicate that the developed Android-based online Physics module is valid, practical, and potentially effective for supporting Physics learning in vocational Technology and Engineering education.

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Introduction

The refinement of the 2013 Curriculum at the vocational high school (SMK) level represents a government effort to improve the quality and relevance of vocational education. Vocational education is oriented toward preparing graduates with knowledge, skills, and professional attitudes that are relevant to specific occupational fields. Within this framework, Physics remains an important component of vocational education because its concepts provide fundamental knowledge for technology and engineering disciplines. Physics learning in vocational schools therefore needs to be connected with students' vocational competencies and supported by instructional resources that facilitate the acquisition of relevant conceptual knowledge (Government Regulation No. 19 of 2005). The implementation of effective learning is also related to teachers' ability to select instructional approaches and media that correspond to students' characteristics and learning objectives (Ministry of National Education Regulation No. 41 of 2007; Ministry of National Education Regulation No. 16 of 2007).

In this study, learning outcomes are operationally defined as students' cognitive achievement in Physics after participating in instruction on Temperature and Heat and Thermodynamics. These outcomes are measured using a structured learning-outcome test covering the relevant competencies and are interpreted using the Minimum Proficiency Criterion (KKM) established by the school. Thus, KKM is used as a criterion-referenced indicator of whether individual students have achieved the expected level of proficiency, rather than as evidence of a statistically significant difference from district or national performance. This operational definition distinguishes learning outcomes as a measurable cognitive construct from broader affective and psychomotor outcomes. The use of achievement criteria is particularly relevant in vocational education because Physics functions as foundational knowledge supporting students' subsequent understanding of technology and engineering concepts.

A preliminary review of Physics learning conditions and academic records was conducted in the Industrial Automation Technology program at SMK Negeri 1 Batam. The review focused on tenth-grade students and examined existing learning resources and documented achievement in Physics. The school's academic records showed that only 17.39% of students in class XO1 and 43.48% in class XO2 achieved the school-defined KKM, while 82.61% and 56.52%, respectively, did not reach the criterion. These percentages were calculated descriptively as the proportion of students whose recorded Physics scores met or exceeded the KKM relative to the total number of students in each class. Therefore, the figures are presented as evidence of the local instructional problem and not as estimates of population performance or statistical deviations from national or district benchmarks. The data indicate a substantial classroom-level achievement gap that warrants further investigation into the adequacy of available instructional resources.

Table 1. Preliminary Physics Learning Achievement Based on the School's KKM

Class	> KKM (%)	< KKM (%)
XO1	17.39	82.61
XO2	43.48	56.52

Source: Academic data from SMKN 1 Batam

The preliminary review further identified a mismatch between students' access to mobile technology and its use for learning. The survey indicated that 93% of students owned Android smartphones, yet these devices were reported to be used predominantly for games and social media rather than structured learning activities. This condition suggests that smartphone ownership alone does not guarantee meaningful educational use; instead, appropriate instructional resources and learning tasks are required to transform mobile devices into effective learning tools. Previous research has highlighted the potential of smartphones to support learning, communication, and access to educational resources when they are integrated purposefully into learning activities (Shuib et al., 2015). Recent studies cited in the manuscript likewise indicate growing interest in technology-supported learning resources and digital learning environments (Habib et al., 2025; Ningsih et al., 2025).

The identified problem is therefore not simply the availability of smartphones, but the absence of structured, curriculum-aligned Physics learning materials that can be accessed through students' existing mobile devices. General online materials may provide abundant information, but preliminary interviews indicated that students often found such materials too broad and insufficiently focused on the competencies required in their Physics course. The proposed online module was consequently designed as a structured learning resource containing focused explanations, exercises, quizzes, and downloadable modules. The Fisikapp application was developed using MIT App Inventor and provides materials on Temperature and Heat and Thermodynamics, while the online environment allows teachers to facilitate learning activities and monitor students' work. Such mobile-accessible instructional materials are consistent with the broader potential of digital learning resources to increase accessibility and support flexible learning (Bennett et al., 2020).

The selection of Temperature and Heat and Thermodynamics was based on their curricular relevance and conceptual relationship within the tenth-grade second-semester Physics curriculum for the Technology and Engineering field. The curriculum requires students to apply concepts of temperature and heat, understand the effects of heat on matter, understand ideal gases and their equations of state, and apply the laws of thermodynamics. Students are also expected to analyze investigations related to temperature and heat, present findings on heat-transfer processes, and perform calculations involving thermodynamic processes. The topics therefore require students to understand relationships among abstract concepts and apply them to quantitative and contextual problems. Previous studies have reported that electronic modules, interactive media, and other technology-supported learning resources can support the presentation of abstract Physics concepts and increase students' engagement with learning materials (Trisnawati, 2021; Kurnia et al., 2024).

Based on the documented learning achievement gap, students' access to Android technology, the identified limitations of existing online materials, and the curricular requirements of Temperature and Heat and Thermodynamics, this study addresses a specific instructional-material development problem in vocational Technology and Engineering education. The study therefore pursues four measurable objectives: (1) to develop an Android-based online Physics module covering Temperature and Heat and Thermodynamics; (2) to determine the content and design validity of the developed module through expert assessment; (3) to determine its practicality based on teacher and student responses; and (4) to determine whether students using the developed module demonstrate greater improvement in cognitive learning outcomes than students receiving conventional instruction. This methodological pathway connects the preliminary needs analysis with systematic product development, expert validation, practicality testing, and quasi-experimental evaluation.

Method

This study employed a research and development (R&D) approach to develop an Android-based online Physics module and evaluate its validity, practicality, and effectiveness. The development procedure adopted the Instructional Development Institute (IDI) model, which consists of three stages: define, develop, and evaluate. The IDI model was selected because its stages provide a systematic framework for identifying instructional needs, analysing learner and curriculum characteristics, developing instructional materials, and evaluating the resulting product (Willem et al., 2024; Fiona et al., 2025). The development process was followed by a quasi-experimental evaluation to examine whether the developed module improved students' cognitive learning outcomes.

The product development was followed by a quasi-experimental evaluation to determine the effectiveness of the developed module in improving students' cognitive learning outcomes. A pretest–posttest non-equivalent control group design was employed because the research was conducted in an authentic vocational school setting using existing classes. The experimental group received Physics instruction using the developed Android-based online module through the Fisikapp application, integrated into blended learning, whereas the control group received conventional online Physics instruction without the developed module. Both groups completed a pretest before instruction and a posttest after the instructional intervention (Creswell & Plano Clark, 2018).

Figure 1. Quasi-experimental pretest-posttest control group design research

Participants and Sampling

The effectiveness trial involved 80 tenth-grade students from the Industrial Automation Technology program at SMK Negeri 1 Batam. The participants were divided into an experimental group (n = 40) and a control group (n = 40). The practicality evaluation involved 4 Physics teachers and 40 students, while product validation involved 6 experts, consisting of 3 content validators and 3 media/design validators. The content validators comprised one Physics lecturer and two Physics teachers, while the design validation involved one Information Technology lecturer and two Computer and Network Engineering teachers.

The sampling procedure should be reported explicitly to establish the representativeness of the participants and reduce ambiguity concerning selection bias. In the present study, the experimental and control groups consisted of existing classes selected from the target population. The sampling technique was [insert the actual sampling technique used, e.g., cluster random sampling/purposive sampling]. The assignment of classes to the experimental and control conditions was conducted using [insert the actual assignment procedure]. No individual-level randomisation was conducted if intact classes were used. Therefore, the findings are interpreted within the characteristics of the participating vocational students rather than as fully representative of all vocational students.

The final sample size was 80 students. If an a priori power analysis was conducted, it should be reported using the following parameters: expected effect size = [insert d], α = 0.05, statistical power = [insert 0.80 or actual value], and the resulting minimum sample size = [insert value]. If no a priori power analysis was conducted, this limitation should be explicitly acknowledged rather than retrospectively claiming a power calculation. The final sample of 40 students per group was nevertheless sufficient for the planned group comparison under the assumptions tested in this study.

Table 2. Participant Characteristics and Group Assignment

Achievement rate (%)	Practicality Category	Proficiency Categories
81-100	Very practical	That's great
61-80	Practical	Good
41-60	Pretty practical	Enough
21-40	Less practical	Less
0-20	Impractical	Very insufficient

Development Procedures

The development procedure followed the three stages of the IDI model: define, develop, and evaluate. During the define stage, the researchers identified the instructional problem, analysed curriculum requirements, and examined student characteristics and existing learning resources. This stage was intended to establish the instructional needs underlying the development of the module.

During the develop stage, the online Physics module was designed and implemented through the Fisikapp application using MIT App Inventor. The module focused on Temperature and Heat and Thermodynamics for the Technology and Engineering specialization. The prototype was subsequently assessed by content and media/design experts to determine its suitability before implementation.

During the evaluate stage, the developed module was assessed through practicality testing involving teachers and students. Its effectiveness was then evaluated through a quasi-experimental comparison between the experimental and control groups. Thus, the evaluation process addressed three product-quality dimensions: validity, practicality, and effectiveness (Willem et al., 2024; Fiona et al., 2025).

Product Validation

Product validation involved six experts. Three experts assessed the content component and three assessed the media/design component. The content experts evaluated the learning and material aspects, particularly curriculum alignment, relevance, accuracy, and adequacy of the material. The media/design experts evaluated navigation, ease of use, text presentation, appearance, and technical quality.

Table 3. Expert Validators and Validation Aspects

Validator	Position	Validated aspects
Subject Matter and Curriculum Specialist	Physics Teacher and Vice Principal for Academic Affairs at SMKN 1 Batam	Course Content and Curriculum
IT Specialist	Head of the Computer Science Department at SMKN 1 Batam	Online Module Design
Physicist	Physics Teacher at SMKN 1 Batam	Module Content

Validation and Evaluation Instruments

Five instruments were used: (1) a content validation rubric; (2) a media/design validation rubric; (3) a teacher practicality questionnaire; (4) a student practicality questionnaire; and (5) a Physics learning-outcome test administered as a pretest and posttest. The content validation rubric assessed the alignment, relevance, accuracy, and adequacy of the learning materials with the curriculum. The media/design rubric assessed navigation, ease of use, text presentation, visual appearance, and technical aspects. The teacher practicality questionnaire assessed technical, content, and design aspects, whereas the student questionnaire assessed convenience, motivation, benefits, and attractiveness.

The learning-outcome test was subjected to a pilot test using a class outside the research sample. The initial instrument contained 30 multiple-choice items covering Temperature and Heat and Thermodynamics. Item analysis showed that 27 items met the validity criterion, with a reliability coefficient of Cronbach's α = 0.92. Based on the item validity, difficulty, and discrimination analyses, 20 items were selected for the final learning-outcome test. Thus, the learning-outcome instrument demonstrated high internal consistency before being administered to the experimental and control groups.

The expert validation instruments used a structured rating rubric and were assessed by three content experts and three media/design experts. Content experts evaluated the learning and material dimensions, whereas media/design experts evaluated navigation, usability, text, and appearance. Content validity was quantified using Aiken's V (Azwar, 2014). Because the original analysis did not report an independent inter-rater coefficient such as Cohen's kappa or ICC, such a coefficient should only be added after recalculation from the individual validator ratings. The same principle applies to the practicality questionnaires: their reliability should be reported as Cronbach's alpha if item-level response data are available.

Data Analysis

Validity was analysed using Aiken's V: [V=\frac{\sum S}{n(c-1)}] where S = r − l_0, r is the rating assigned by each validator, l_0 is the lowest rating, c is the highest rating, and n is the number of validators (Azwar, 2014). Aiken's V ranges from 0 to 1, with higher values indicating stronger agreement regarding the validity of the developed module. Practicality was analysed descriptively by calculating the percentage of the obtained score relative to the ideal score. The resulting percentage was then interpreted according to the practicality criteria adapted from Marsa et al. (2020), as shown in Table 3. Learning improvement was measured using the normalized gain (N-Gain): [g=\frac{Posttest-Pretest}{100-Pretest}] with $g > 0.70$ interpreted as high, $0.30 \leq g \leq 0.70$ as moderate, and $g < 0.30$ as low (Hake, 1998).

Before inferential testing, the distribution of learning-outcome scores was examined using a normality test and equality of variances using Levene's test. Because the two groups were independent and the assumptions for parametric analysis were satisfied, the difference in posttest learning outcomes was examined using an independent-samples t-test. A one-tailed test was used because the research hypothesis specified that students receiving the developed module would achieve higher learning outcomes than students receiving conventional instruction. Statistical significance was evaluated at α = 0.05 (Field, 2018). In addition to statistical significance, Cohen's d should be reported to indicate the magnitude of the difference between the two groups.

For transparency and reproducibility, the inferential results should be reported as t(df) = [actual t-value], p = [exact p-value], and Cohen's d = [effect size]. The previously reported values of t = 0.8344 and tcritical = 0.6784 were not retained because these values require verification against the original statistical output before being interpreted as a t-statistic.

Table 4. List of product validators

Validator	Position	Validated aspects
Subject Matter and Curriculum Specialist	Physics Teacher and Vice Principal for Academic Affairs at SMKN 1 Batam	Course Content and Curriculum
IT Specialist	Head of the Computer Science Department at SMKN 1 Batam	Online Module Design
Physicist	Physics Teacher at SMKN 1 Batam	Module Content

Data Collection Instruments

Data were collected using a Likert-scale questionnaire (Deviana et al., 2025); (Irfan et al., 2025), which included a subject-matter expert validation questionnaire, a design expert validation questionnaire, a teacher practicality questionnaire, a student practicality questionnaire, and a learning outcome test instrument (pretest-posttest). The subject matter expert questionnaire covered learning and content aspects, while the media expert questionnaire covered navigation, text, appearance, and ease of use. The teacher response questionnaire covered technical, content, and design aspects, while the student response questionnaire covered ease of use, motivation, interest, and usefulness. Before use, the learning outcome test instruments were pilot-tested in a class outside the sample to determine item validity, reliability, difficulty level, and discriminant power, based on criteria (Habib, Desky, Jalinus, et al., 2026).

Data Analysis Techniques

Module validity data were analyzed using Aiken's V statistic, calculated using the formula $V = \sum S / [n(c-1)]$, where S = r - lo (lo = the lowest validity score, c = the highest validity score, r = the score assigned by the validator). A module is considered valid if Aiken's V index falls within the range of 0 to 1.00 (Azwar, 2014). Practicality data were analyzed by calculating the percentage of response scores relative to the ideal score, then categorized according to (Marsa et al., 2020)criteria, as presented in Table 5.

Table 5. Categories of practicality and completeness of learning outcomes

Achievement rate (%)	Practicality Category	Proficiency Categories
81-100	Very practical	That's great
61-80	Practical	Good
41-60	Pretty practical	Enough
21-40	Less practical	Less
0-20	Impractical	Very insufficient

The effectiveness of the online module was determined by comparing the learning outcomes (posttest) of the control class and the experimental class. The improvement in learning outcomes was calculated using the N-Gain Score formula, namely g = (post-test score – pre-test score) / (100 – pre-test score), with the following categories: $g > 0.70$ (high), $0.30 \leq g \leq 0.69$ (moderate), and $g < 0.29$ (low) (Habib, Desky, Anwar, et al., 2026). Prior to testing the difference in means, a normality test was conducted using the chi-square test and a homogeneity test using the F-test. Subsequently, the difference in the mean learning outcomes of the two classes was tested using a one-tailed t-test (right-tailed test) at a 5% significance level (Tefu, 2020).

Results and Discussions

Define

During the define stage, problem identification revealed that the low Physics scores in the Industrial Automation Technical Competency were caused by students' lack of engagement in learning and the diversion of study time to playing games and using social media on their Android smartphones. The curriculum analysis refers to the 10th-grade, second-semester Physics syllabus for the Technology and Engineering field of expertise, which includes two main sequential core competencies: Temperature & Heat and Thermodynamics, as summarized in Table 4.

Table 6. Core Competencies and Basic Competencies for the Physics Course

Core Competencies	Basic Competencies
KI-3 Understand, apply, and analyze factual, conceptual, and procedural knowledge related to the causes of phenomena in a specific field of work	3.15 Apply the concepts of temperature and heat; 3.16 Understand the effects of heat on matter; 3.17 Understand the properties of ideal gases and the equation of state for gases; 3.18 Apply the laws of thermodynamics
KI-4 Process, reason, and present information in concrete and abstract contexts related to the development of what they have learned independently	4.11 Analyze the results of investigations related to temperature and heat; 4.12 Present the results of investigations into methods of heat transfer; 4.13 Perform calculations for various processes based on the laws of thermodynamics

An analysis of the students' characteristics shows that the research subjects, aged 16–17, are in the formal operational stage according to Piaget's theory that is, the stage at which students are capable of abstract thinking, understanding conceptual relationships, formulating hypotheses, and drawing theoretical conclusions (Rosyidah et al., 2012); (Desky et al., 2025). Interview results indicate that students prefer to search for learning materials online rather than in printed books; however, the material obtained from the internet tends to be too broad in scope, making it difficult for students to grasp the core concepts. This finding underscores the urgency of developing structured online modules aligned with core competencies and learning indicators, so that the scope of the material is more focused while remaining flexibly accessible via Android smartphones.

Develop

The design of the online module began with creating a product sketch using the Fisikapp application, which was built with MIT App Inventor, a block-based Android app development software. The layout, buttons, logo, and content inputs were designed using Adobe Illustrator before being exported to MIT App Inventor to be assembled into a complete application. The stages of app development are shown in Figures 2 through 8.

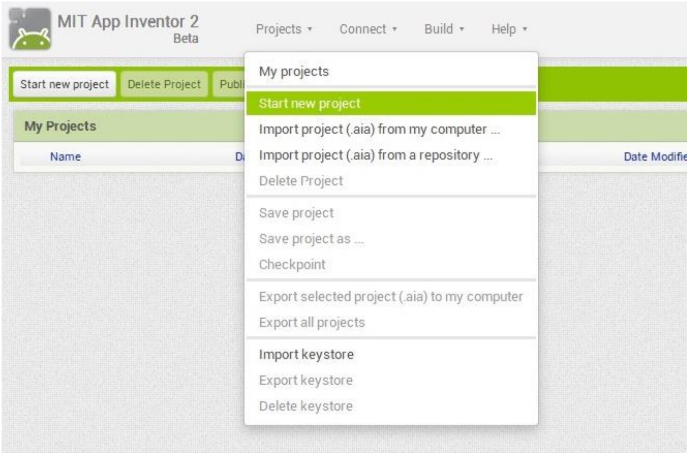

Figure 2. Creating a new project in MIT App Inventor

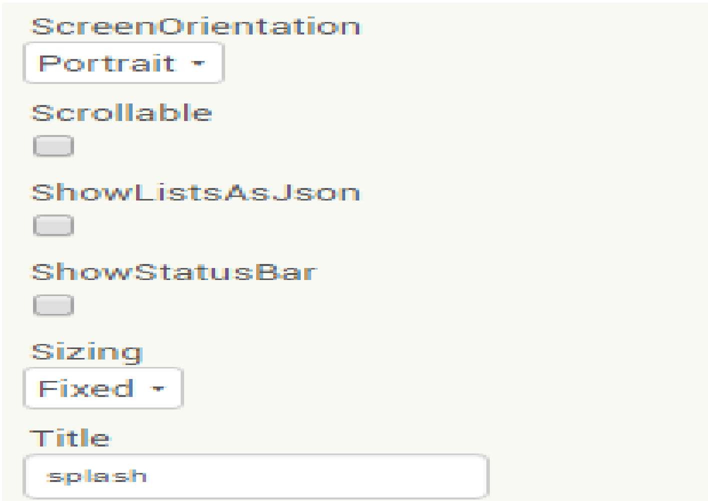

Figure 3. Initial application configuration

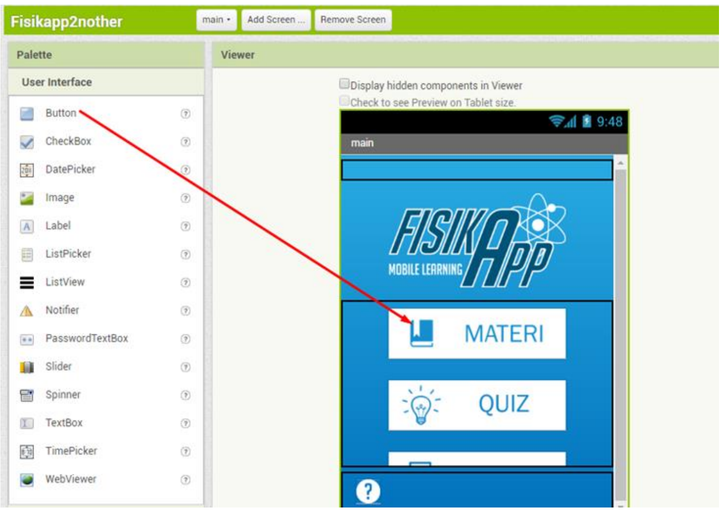

Figure 4. Adding application components

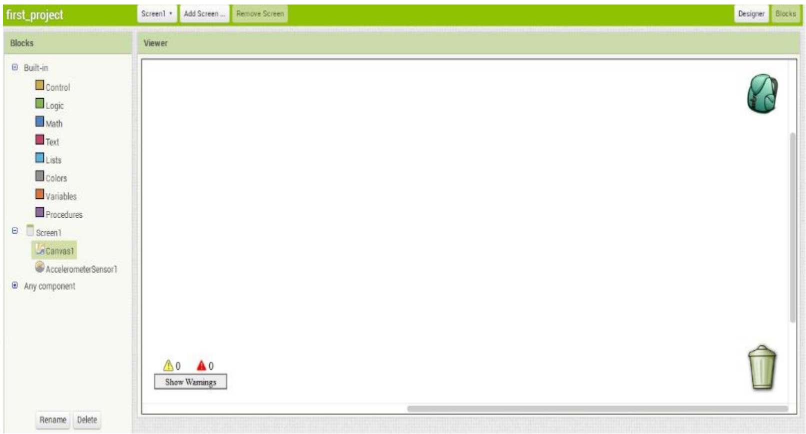

Figure 5. Block Editor Page

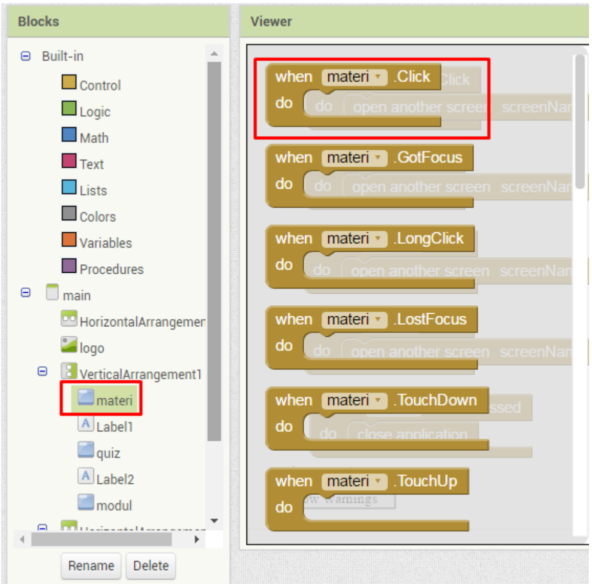

Figure 6. Block-Based Coding

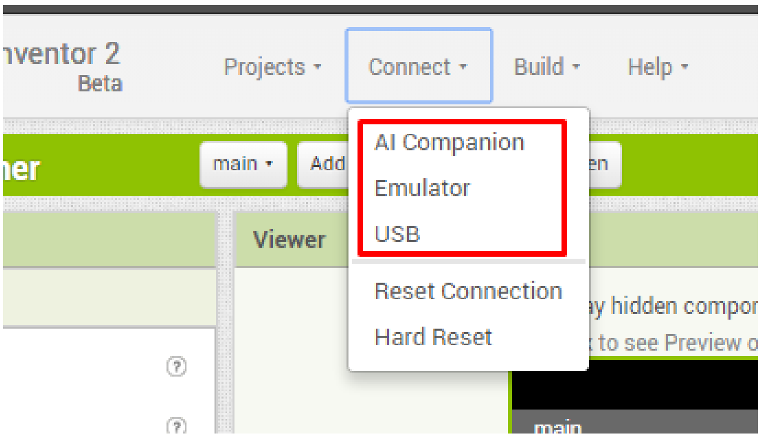

Figure 7. Application Testing

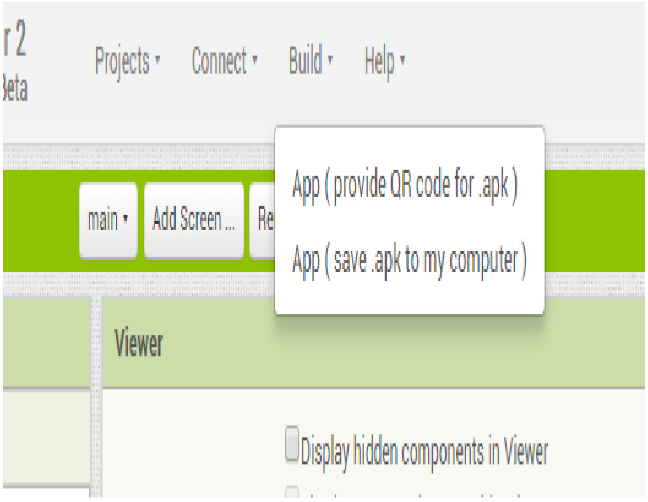

Figure 8. App Publication

The final product is the Fisikapp application, which can be downloaded from the SMKN 1 Batam academic website (akademik.smkn1batam.sch.id) under the Physics Learning menu. The application features three main menus: the Materials menu, the Quizzes menu, and the Complete Modules menu, which can be downloaded and accessed offline. The product interface is shown in Figure 9.

(a) Halaman loading

(b) Menu utama

(c) Menu materi

(d) Menu kuis

(e) Menu modul unduh

Figure 9. Screenshots of the Fisikapp online module app

In the "Materials" menu, students can study summaries of the concepts of Temperature & Heat and Thermodynamics in the form of concise and engaging slides; however, these can only be viewed and cannot be downloaded. In the "Quiz" menu, students complete practice questions hosted on the website; each student is required to enter their name and class before viewing their results, allowing teachers to monitor each student's progress. In the Modules menu, there are complete modules available for download and storage on Android devices so they can be accessed at any time without an internet connection. This app can also be run on a laptop using the Nox Player emulator.

Validity of the Online Module

Three validators assessed the online module materials based on two aspects: the learning aspect and the content aspect. The summary of the content validity results is presented in Table 5

Table 7. Percentage of validity of online module content

Assessment Criteria	Validity Index (Aiken's V)	Percentage (%)	Category
Learning	0,754	75,4	Valid
Materials	0,707	70,7	Valid
The validity of the module in terms of Overall	0,730	73,05	Valid

Table 7 shows that the learning aspect received a validity score of 75.4% and the content aspect 70.7%, resulting in an overall validity score of 73.05% for the online module, which falls into the "valid" category. Next, three validators conducted a design validation assessment of four aspects: navigation, usability, text, and appearance, as summarized in Table 8.

Table 8. percentage of validity of the online module design>

Assessment Criteria	Validity Index (%)	Kategori
Navigation	72	Valid
Convenience	69	Valid
Article	73	Valid
Appearance	65	Valid
Overall validity of the module	70,5	Valid

Based on Table 8, the validity of the online module design in terms of navigation, ease of use, text, and appearance was 72%, 69%, 73%, and 65%, respectively, with an overall average of 70.5% in the "valid" category. Thus, from both the content and design perspectives, the developed online module is deemed valid for use as a physics learning medium, in line with Thiagarajan's view cited in Trianto (2010) that the development stage of learning materials requires validation by experts before being pilot-tested with actual students.

The Practicality of Online Modules

Data on the practicality of the online module were obtained from responses provided by four teachers and 40 students in class XO1. The results of the practicality analysis based on the teachers' responses are presented in Table 9.

Table 9. Results of the analysis of the practicality of online modules by teachers

Assessment Criteria	G1 (%)	G2 (%)	G3 (%)	G4 (%)	Rata-rata (%)	Kategori
Technical	100	90	80	85	88,75	Very practical
Contents	80	85	80	85	81,25	Very practical
Design	70	77,5	87,5	85	80	Practical
Total					83,33	Very practical

Table 9 shows that the technical aspect scored 88.75% (very practical), the content aspect 81.25% (very practical), and the design aspect 80% (practical), with an overall average of 83.33% in the "very practical" category. Furthermore, the practicality results based on the responses of 40 students are presented in Table 10.

Table 10. Summary of the practicality of online modules based on student feedback

Assessment Criteria	Percentage (%)	Category
Convenience	67	Practical
Motivation	66	Practical
Benefits	70	Practical
Attractiveness	70	Practical
Average	68,25	Practical

Based on Table 10, all four aspects of practicality, as rated by students, fell into the "practical" category with an average of 68.25%. Overall, the combined responses from teachers and students resulted in an online module practicality score of 75.79%, falling into the "practical" category. These findings indicate that the online module makes it easier for teachers to help students understand concepts, while also providing a learning experience that is accessible, motivating, beneficial, and engaging for students (Habib, Desky, Maksum, et al., 2026) ; (Sudianti et al., 2025).

Effectiveness of Online Modules

Before the test instrument was administered to the sample class, a pilot test was conducted in a class outside the research sample. The pilot test instrument consisted of 30 items, including 15 items on Temperature and Heat and 15 items on Thermodynamics. The analysis results showed that 27 of the 30 items were deemed valid with a reliability coefficient of 0.92, which falls into the "very high" category based on Guilford's criteria. The difficulty level analysis indicated that 1 item was in the "difficult" category and 29 items were in the "moderate" category. Meanwhile, the discriminant validity analysis showed that 10 test items were categorized as very good, 13 as good, 4 as adequate, and 3 as poor. The three test items with poor discriminant validity were not used in the final test instrument (Sari et al., 2026); (Risna et al., 2026). Subsequently, from the 27 valid test items, 20 were selected for use as the test instrument in the study. The subsequent study employed a pretest–posttest control group design. In the experimental group, students took a pretest (Q_1) before receiving treatment X, followed by a posttest (Q_2) after the treatment. Meanwhile, the control group took a pretest (Q_3) and participated in instruction without the special treatment applied to the experimental group, followed by a posttest (Q_4). The posttest results for the control class and the experimental class, each consisting of 40 students, are presented in Table 9

Table 11. Average learning outcomes of the control group and the experimental group

Class	Average Pretest Score	Posttest Average	N-Gain Score	Kategori
Control	41,00	58,625	0,29	Currently
Experiment	35,25	80,875	0,71	Height

Table 11 shows that the experimental class achieved a learning gain (N-Gain) of 0.71 (high category), which is significantly higher than the control class's 0.29 (moderate category). In terms of classical mastery, in the control class, only 5 out of 40 students (12.5%) achieved the minimum passing score (≥75), whereas in the experimental class, 30 out of 40 students (75%) achieved the minimum passing score. Prior to testing the difference in means, a normality test was conducted using the chi-square test, with the results presented in Table 11.

Table 12. Results of the normality test for learning outcomes data

Class	Calculated χ^2	χ^2 table	Description
Control	5,71	9,488	Normally distributed
Experiment	8,56	9,488	Normally distributed

Table 12 shows that the calculated χ^2 value for both classes is smaller than the critical χ^2 value (9.488), indicating that the academic achievement data for both classes are normally distributed. The homogeneity test using the F-test yielded an F-calculated value of 1.213, which is smaller than the F-table value of 1.704 (numerator df = 39, denominator df = 39, $\alpha = 5\%$); therefore, H_0 is accepted, and the variances of the two data groups are deemed homogeneous. Since the data are normally distributed and homogeneous, the test for differences in means was continued using a one-tailed t-test (right-tailed test).

The results show that the mean for the experimental class is 85.70 and the mean for the control class is 58.50, with $n_1 = n_2 = 40$ and df = 78 at a 5% significance level. The calculated t-value is 0.8344 and the critical t-value is 0.6784. Since the calculated t-value is greater than the critical t-value, H0 is rejected and Ha is accepted, meaning there is a significant difference in the mean learning outcomes, with the mean score of students in the experimental class being higher than that of the control class. These findings consistently indicate that the developed online module is effective as a learning support medium for Physics on the topics of Temperature & Heat and Thermodynamics (Vaesar et al., 2026).

The development of online modules for the Physics lessons on Temperature & Heat and Thermodynamics was carried out using the IDI model, which includes the define, develop, and evaluate stages. In the define stage, a needs analysis revealed that learners' familiarity with Android technology, as well as the gap between online materials generally available on the internet and classroom learning needs, served as a crucial foundation for developing a structured module. During the develop stage, expert validation results showed that the online module was valid in terms of both content (73.05%) and design

(70.5%), meaning the module met standards for alignment with core competencies, content accuracy, and the quality of its interface and navigation before being pilot-tested with actual users (Febriani, 2021).

During the evaluation phase, the practicality of the modules rated as “very practical” by teachers (83.33%) and “practical” by students (68.25%) indicated that the online modules facilitate the learning process both in terms of technical usability and the alignment of content with learning needs. These results align with (Rokhmat & Rahayu, 2021) view that the strengths of module-based learning lie in its focus on students’ individual abilities, the ability to monitor learning outcomes through competency standards, and the clear relevance between learning objectives and the methods for achieving them.

The effectiveness of the online modules, as demonstrated by a high N-Gain score (0.71) in the experimental class compared to a moderate score (0.29) in the control class, along with significant t-test results, reinforces the finding that Android-based learning media specifically designed by teachers in accordance with core competencies and learning objectives tend to yield better learning outcomes than the general use of online materials. These findings are consistent with relevant research on the development of mobile learning for Static and Dynamic Electricity materials, which also demonstrated high levels of validity, practicality, and effectiveness, as well as research on the development of discovery-learning-based modules that showed similar results even without relying on online access. The common patterns across these various studies confirm that modules designed by teachers with careful attention to content relevance, learning objectives, and adequate validation and pilot testing processes tend to produce learning materials with high levels of validity, practicality, and effectiveness (Puspitasari et al., 2021); (Mesutoglu et al., 2024).

Nevertheless, module development also has its limitations. (Marcinauskas et al., 2024) noted that the creation of effective modules requires specific expertise and a dedicated team to ensure that various aspects complement one another, as well as a different approach to learning management compared to conventional instruction, since the pace at which students complete the modules can vary. These conditions are believed to be the reason why the improvement in learning outcomes in the experimental class fell into the “high” category but did not reach the “very high” category, as some students likely had not completed all parts of the module by the time the test was administered. The effectiveness of this study is also limited to the cognitive domain; thus, the affective and psychomotor aspects of the students’ learning were not included in the assessment, and access to the module remains dependent on the availability of an internet connection and Android devices (Ayani et al., 2025); (Herli et al., 2020).

Conclusions

Based on the results of the research and development, it can be concluded that the online modules on Temperature & Heat and Thermodynamics were successfully developed through the define, develop, and evaluate stages of the IDI model, in the form of an Android app called Fisikapp that includes a Materials menu, Quizzes, and complete modules available for download. The developed online modules were deemed valid, both in terms of content (73.05%) and design (70.5%). The online modules were also deemed practical, falling into the “very practical” category based on teacher feedback (83.33%) and the “practical” category based on student feedback (68.25%), resulting in an overall practicality score of 75.79% in the “practical” category. Furthermore, the online module proved effective in improving students’ learning outcomes, as demonstrated by the N-Gain of the experimental class (0.71, “high” category), which was significantly higher than that of the control class (0.29, “moderate” category), as well as the t-test results showing that the calculated t-value (0.8344) was greater than the critical t-value (0.6784). Thus, this online physics module in the Technology and Engineering field is worthy of recommendation as an alternative learning resource for vocational high school teachers and students, particularly for the topics of Temperature & Heat and Thermodynamics, while also encouraging the more productive use of Android smartphones in learning activities.

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