

## Developing android-based physics student worksheets for improving high school students' critical thinking skills in thermodynamics

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**Abstract:** The purposes of this research are to develop a valid, practical, and effective android-based physics student worksheet. The research method used is Research & Development (R&D), with implementation stages modified from various existing development models. Data collection techniques include validation sheets, questionnaires, and critical thinking skills tests. The findings from the validation phase of the android-based physics student worksheets validity study indicated an overall Aikens V coefficient of 0.886. The top scores were in the media/display and presentation categories, with each receiving a score of 0.917. The materials or content section received a score of 0.875. The language component achieved a score of 0.833. The study discovered that 31 students, representing 86 percents in practical category. The N-Gain result showed as high improvement category with score is 0.71. The study showed that students' critical thinking skills got much better after students used worksheets based on android during their formative learning activities. Android-based physics student worksheets effectively satisfy students' needs and adhere to the criteria of validity, practicality, and effectiveness for learning.

**Keywords:** Android-based media, critical thinking skills, students worksheets

**Abstrak:** Tujuan penelitian ini adalah untuk mengembangkan lembar kerja fisika berbasis Android yang valid, praktis, dan efektif. Metode penelitian yang digunakan adalah *Research & Development (R&D)*, dengan tahapan implementasi yang dimodifikasi dari berbagai model pengembangan yang ada. Teknik pengumpulan data meliputi lembar validasi, kuesioner, dan tes kemampuan berpikir kritis. Temuan dari fase validasi studi validitas lembar kerja peserta didik fisika berbasis Android menunjukkan koefisien Aikens V keseluruhan sebesar 0,886. Skor tertinggi berada pada kategori media/tampilan dan presentasi, masing-masing menerima skor 0,917. Bagian materi atau konten menerima skor 0,875. Komponen bahasa mencapai skor 0,833. Temuan menunjukkan bahwa produk tersebut mencapai peringkat tinggi di setiap empat kategori yang dievaluasi. Studi ini menemukan bahwa 31 peserta didik, mewakili 86% berada pada kategori praktis. Hasil N-Gain menunjukkan bahwa berada pada kategori peningkatan tinggi dengan skor 0,71. Lembar kerja fisika berbasis Android secara efektif memenuhi kebutuhan peserta didik dan sesuai dengan kriteria validitas, kepraktisan, dan efektivitas pembelajaran.

**Kata kunci:** Media berbasis android, keterampilan berpikir kritis, lembar kerja peserta didik

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## INTRODUCTION

In the 20th century, education was often seen as a fixed system of analytical thinking. Contemporary views of teaching and learning suggest that education may help individuals to develop a richer understanding of ideas. Students need to be able to analyze evidence logically. Students also have to be able to handle context-dependent ideas. Critical thinking skills are learned skills, rooted in structured teaching and high senior school academic standards (Damopolii et al., 2021; Iftiah et al., 2023). Critical thinking skills help students to learn to question situations and to keep their arguments clear and logical (Fitriyanti et al., 2025; Hama & Amin, 2025; Suherni et al., 2026). These skills are especially important in

physics. Strong scientific thinking must be used by students to connect theory with real life situations natural phenomena (A'yun, et al., 2026; Harahap et al., 2025).

Critical thinking is very important, but teachers still face many challenges in the classroom every day. Physics is taught in senior high schools with a conventional teaching model. These approaches are teacher-centric. Numerous of practice problems are provided. This model of teaching often forgets the basic ideas behind the concepts (Harahap et al., 2025; Wedana et al., 2025). At SMA Negeri 1 Gowa in Grade XII 3, was found out that students had explain something that happened or see the relationship between different factors. Students had trouble checking their evaluating steps. Students didn't really try to understand the ideas from learning physics topics; students just put numbers into formulas to get answers without thinking about what the numbers or formulas meant. This means the students aren't understanding the ideas being taught. Under this conventional teaching model, students have a hard time improving their thinking skills (Burnama & Hariyono, 2024; Dayu et al., 2025).

The problem becomes especially serious in physics like thermodynamics. Thermodynamics deals with what happens at a scale, studies how things like energy, heat transfer, work and entropy are connected and influence one another. These concepts are difficult to grasp (Maisyaroh et al., 2025; Pangesti & Wasis, 2025). Conventional instruments such as printed worksheets do not help students understand these processes well (Maretha et al., 2025; Villayah & Suliyanah, 2025). Students often solve problems step by step, do not truly understand why the symbols and equations matter in real life. This leads to confusion about the core ideas such as thermodynamics (Maisyaroh et al., 2025).

Digital tools can make teaching and learning easier and more organized (Latjompoh et al., 2026; Mustofa et al., 2024). An android-based physics student worksheets can display simulations, demonstrations, virtual experiments and instant feedback all on one screen something printed worksheets cannot offer (A'yun, et al., 2026; Maretha et al., 2025). A big advantage in android tools that students can learn on their own. Students can watch events unfold over time, confirm whether their predictions are correct and view measurements of heat and energy changes directly (Burnama & Hariyono, 2024; Dayu et al., 2025; Salsabilla et al., 2024).

Android-based physics student worksheets features can be used to support the critical thinking skills that were examined in this study. Interactive simulations and real-world problem scenarios help students understand concepts more clearly. Giving students the opportunity to explore these ideas in depth (Maretha et al., 2025). When students adjust pressure, volume or temperature, students must think carefully about how each change might impact the system drawing on their knowledge. This kind of thinking strengthens their engagement. Students apply the ideal gas law to make sense of the changes students observe (Pangesti & Wasis, 2025).

Android-based physics student worksheets was chosen because students operate smoothly on the devices and easy to manage interactive content without needing complex setups (Ngurahrai et al., 2019; Wedana et al., 2025). Many studies that worksheets created using digital media to enhance student critical thinking skills (Maretha et al., 2025; Pangesti & Wasis, 2025; Salsabilla et al., 2024). Most digital apps require an internet connection. There are also a few simple android-based physics student worksheets that are made especially for teaching thermodynamics in senior high schools. Creating an android

worksheets should solve this issue and provide teachers and students with a user-friendly tool that functions effectively in classroom settings (Ngurahrai et al., 2019; Villayah & Suliyanah, 2025).

The study focuses on creating, testing and deploying an android-based physics student worksheets that is specially designed to help senior high school students learn thermodynamics. The primary objective is to developing an android-based physics student worksheets that assists students in improving their critical thinking skills. This research will also evaluate how effective android-based physics student worksheets are, in classrooms ensuring that both the content and the design fulfil educational standards. The study examines how the android-based physics student worksheets used in thermodynamics topic and how well the android-based physics student worksheets motivate senior high school students to think critically and solve problems.

## METHOD

The approach used the ADDIE model, which has five phases: Analysis, Design, Development, Implementation and Evaluation (Branch, 2009). The ADDIE model was chosen because it gives a structured framework for identifying educational needs, designing instructional plans, developing interactive multimedia materials, and conducting comprehensive evaluations to ensuring instructional quality and efficacy (Gustafson & Branch, 2002). This research used a modified version of the ADDIE process covering the stages of Analysis, Design, Development and formative Evaluation. The implementation phase was modified in real use, with 36 students in grade XII.3 at SMA Negeri 1 Gowa.

Analysis is the crucial first phase of this research. The analysis process includes examining the materials used in the learning process and how students learn in the classroom. The focus of the analyzed material is thermodynamics. The findings from the analysis phase serve as the basis for the design phase. This phase establishes learning objectives, defines tasks, and designs physics student worksheets. The learning activities are linked to parts of thinking. The design phase includes getting ideas from students as source datas. ADDIE method uses techniques that are already known to to enhance critical thinking skills, as conceptualized in Facione's framework (Facione, 2020).

During the development phase the first version of the android-based physics student worksheets was created and the needed research tools were put together. Before the android-based physics student worksheets could be used in the classroom experts looked over the product draft and the tools used to evaluate the android-based physics student worksheets. These experts made sure the content was appropriate. The experts checked if the teaching methods worked well, examined instructional clarity and pedagogical accessibility, also looked at whether the media used helped learning. The feedback from the experts and their suggestions helped improve the worksheets. This made the information simpler to grasp.

The final step of evaluation focuses on how the intervention works when evaluation actually used. It also checks if the results last over time. During learning from the android-based physics student worksheets, students use tools such as features, virtual simulations and problem-solving exercises. These are all part of the android-based worksheets, support active learning. Students also focus more on what each student needs. A test is given before learning begins. This test measures how well the students are thinking at the start. After the

learning session, another test is given. This second test measures how much the students' critical thinking skills had improved. Progress will be shown by using a method called Normalized Gain or N-Gain. Additionally, a practicality questionnaire is handed out. Questionnaire collect feedback from students. The results show that the android-based physics student worksheets are very useful. The android-based physics student worksheets easy to use. Android-based physics student worksheets help students get better at critical thinking skills.

This research was conducted at SMA Negeri 1 Gowa, located in the South Sulawesi Province of Indonesia with thirty-six students from grade XII.3 as the group of participants. In the ADDIE model for creating learning materials, thirty-six students participated in an evaluation phase. Their involvement was important because it helped find problems that appeared when watching students use the android-based physics student worksheets and checking if the android-based physics student worksheets worked well in a classroom. Pre-test and post-test were administered before and after the thermodynamics instruction all about thermodynamics. This setup had two purposes: it let the researcher collect views on how easy the tool was to use and it helped build information showing how effectively the android-based physics student worksheets improved students critical thinking skills. Other than students, three experts from the Physics Department at Universitas Negeri Makassar checked the learning materials the design of the resources and the research instruments before field testing with students.

This study used instruments in various parts to collect specific information: an interview guide, a form to get expert opinions, a questionnaire to gather student opinions, and the tests to look improvement students critical thinking skills. Classroom observations were conducted the interview guide to talk with physics teachers and learn about how teachers teach, conceptual errors made by students in the thermodynamics chapter, and what resources students use in their lessons. To better understand the learning environment, we conducted classroom observations. The qualitative data gathered from interviews and observations enabled the clear identification of baseline requirements the basic requirements for creating Android-based physics student worksheets. To ensure the material was accurate both in theory and, in use three expert reviewers were provided with validation forms.

After we finished these steps, we asked the students a survey to look how easy and comfortable students felt using the android-based physics student worksheets. Students were asked to share their opinions on five parts of usability using a five-point scale. The parts were: how the operation was clear, how the instructions were helpful, how the design was nice, how easy it was to use, and how good the overall experience was. To see how the learning from the android-based physics student worksheets worked we gave pre-tests and post-tests to measure thinking skills. This method looks at four parts of thinking: understanding, analyzing, making a conclusion and evaluating (Facione, 2020).

Students critical thinking skills show that ability of students to evaluate evidence, to understand connections between things, to make decisions, and to develop their thinking. In thermodynamics, the exam questions include topics like how pressure, volume and temperature are related, how heat, work and internal energy connected, different types of thermodynamic processes and cycles, practical applications of thermodynamic laws, and

problem-solving strategies for thermal systems problems with thermal systems. Data was collected step by step during the research.

The final product was tested with methods. Validity, practicality and effectiveness were the three core quality criteria: validity, practicality, and effectiveness in this study. Descriptive methods were used to collect and show opinions along, with student responses. The results from the tests given before and after the program were used to check how much the students' critical thinking skills had improved. The validity of the android-based physics student worksheets and research instruments was checked using the Aiken's V coefficient. Aiken's method is useful for showing how experts agree on test items, as established by Aiken (Aiken, 1980; Aiken, 1985).

Aiken's V coefficient was calculated using:

$$V = \frac{\sum s}{n(c-1)} \quad (1)$$

Description:

$V$  = Aiken's validity coefficient;

$\sum s$  = total adjusted rating score;

$s = r - I_0$

$r$  = score assigned by a validator;

$I_0$  = the lowest score on the rating scale;

$n$  = number of validators; and

$c$  = number of response categories.

The coefficient ranges from zero to one. When validity coefficients approach the upper limit, experts sometimes have different views depend on their opinions based all items in validation sheets (Aiken, 1985). The simplicity of using the android-based physics student worksheets was checked by looking at the students' answers in the questionnaires (Kania et al., 2024). The average score was calculated using:

$$\bar{X} = \frac{\sum X}{n} \quad (2)$$

Description:

$\bar{X}$  = mean response score;

$\sum X$  = total score obtained; and

$n$  = number of respondents.

Table 1. Students responses categories (Fikri & Madona, 2018)

| Mean Score | Practicality Category |
|------------|-----------------------|
| 4.60–5.00  | Very practical        |
| 4.00–4.59  | Practical             |
| 3.00–3.99  | Fairly practical      |
| 2.00–2.99  | Less practical        |
| 1.00–1.99  | Not practical         |

Table 1 presents the classification criteria for the resulting mean scores were classified using the criteria applied in this study. The product was considered usable when the average student score remained in a practical category, as long as the students' scores were good enough. The data collection process followed, ADDIE framework step by step, making sure there was a clear and organized way to go from finding out what was needed

and to checking how the results worked out (Branch, 2009). Content and media validity were systematically evaluated and media in android-based physics student worksheets, to check students were correct and suitable by using checklists before use in the lesson.

To look how the product worked, improvement of students critical thinking skills were measured using Normalized Gain (N-Gain) scores, in four areas of thinking: interpretation, analysis, inference and evaluation. The tests were checked carefully also how well the tests support learning were both thoroughly examined. The effectiveness of the product was evaluated by examining the improvement in students' critical thinking skills before and after using the android-based physics student worksheets. The analysis examined the scores of the same 36 students before and after taking the test. The calculation used was as follows:

$$N - \text{Gain } (G) = \frac{s_{\text{post}} - s_{\text{pre}}}{s_{\text{max}} - s_{\text{pre}}} \quad (3)$$

Description,

$G$  = normalized gain;

$s_{\text{post}}$  = posttest score;

$s_{\text{pre}}$  = pretest score; and

$s_{\text{max}}$  = maximum possible score.

The N-Gain scores for each student were calculated individually. These individual scores are summed to calculate the overall gain for the whole class. In physics education research, an applied approach looks at how much each student has learned by calculating their individual normalized gain, and then combines these gains to see how well the whole group understands the material (Nissen et al., 2018).

The android-based physics student worksheets was really helpful because the first and last tests showed that the measurable enhancements in students' critical thinking skills. The results from the N-Gain analysis were examined by grouping and sorting the data into categories, as presented in table 2.

Table 2. N-Gain score criterias (Hake, 1998)

| N-Gain Value  | Interpretation       |
|---------------|----------------------|
| $g \geq 0,70$ | High improvement     |
| 0,30 – 0,70   | Moderate improvement |
| 0,00 - 0.29   | Low improvement      |

## RESULTS AND DISCUSSION

Thermodynamics is a subject that studies how things like temperature, pressure, volume, heat, work, and internal energy are related and influence each other. Thermodynamics is not about memorizing formulas. Students must observe physical phenomena across various thermodynamic states, connect multiple representations of the same concept, also to explain the reason behind why something occurs in the way it does. So, students need to use evidence to provide their answers. Thermodynamics is a subject that usually presents significant conceptual and analytical challenges for students,

particularly regarding logical reasoning and abstract problem-solving. Especially true in the field of physics (Banda & Nzabahimana, 2021; Maisyaroh et al., 2025).

The results of the learning needs analysis show the importance of learning media that can connect students directly with real-life contexts and phenomena. To meet these needs, learning worksheets are designed based on four main ways of thinking: interpretation, problem-solving, making logical inferences, and evaluating information credibility and relevance. Moreover, thermodynamics deals with processes that are hard to see in everyday situations, so we need a method to show how these different elements are connected.

Studies indicate that using simulations, pictures, and online labs can help students see how different physical factors connect and improve their grasp of important ideas (Banda & Nzabahimana, 2021). Recent studies also show that digital instruments act as a full platform for looking at things, asking questions, joining in, and finding solutions, not just for storing information (A'yun, et al., 2026). From these results, four main needs were found: making sure the content matches what students are supposed to learn, adding organized problem-solving activities, using visual representations that help explain ideas, and giving students clear chances to work on critical thinking skills.

The development process starts by looking at what needs to be done. Next step is changed those needs. Turn the features into clear and detailed plans for the product. The design phase turns these requirements into a product and a clear way to learn. Using the ADDIE model, this stage organizes the learning material, decides the sequence of activities, uses different tools, and checks how effectively students are learning (Branch, 2009). Previous studies have found a common pattern in how digital worksheets and mobile learning are used in teaching physics (Ngurahrai et al., 2019; Salsabilla et al., 2024).

The physics student worksheets designed for android platform. The android-based android-based physics student worksheets serve as a hub for digital learning, offers learning instruments, step-by-step instructions, interactive multimedia elements, online learning options, practice problems, and activities to test what students have learned. Mobile learning lets student study anytime. Anywhere students choose. Mobile learning gives students access to learning resources. The android-based physics student worksheets use engaging instruments to keep students interested and active in lessons. Mobile learning helps everyone learn and keep up easily.

Learning activities are designed to help improve how students think. Students learn how to search for information consider reasons see how things change together make good decisions verify facts and generate new ideas to solve difficult problems. This structured approach aligns with established frameworks, demonstrating that critical thinking and problem-solving involve linked mental steps, which are essential for 21<sup>st</sup>-century education and go beyond just individual skills (Trilling & Fadel, 2009).

In design stage, instruments were also made to ensure the product functions as it was meant to. These tools were validation forms, student feedback surveys, and assessments to check critical thinking. All of these were made to collect information on whether the products work well, how simple the product is for students are to use, and student learning performance and critical thinking gains. The final outcome of the design phase was a group of directions and a functional model, which was the android-based physics student worksheets. The drawings that came with it showed how the prototype as the initial product was put together and how all its parts connected and worked together.

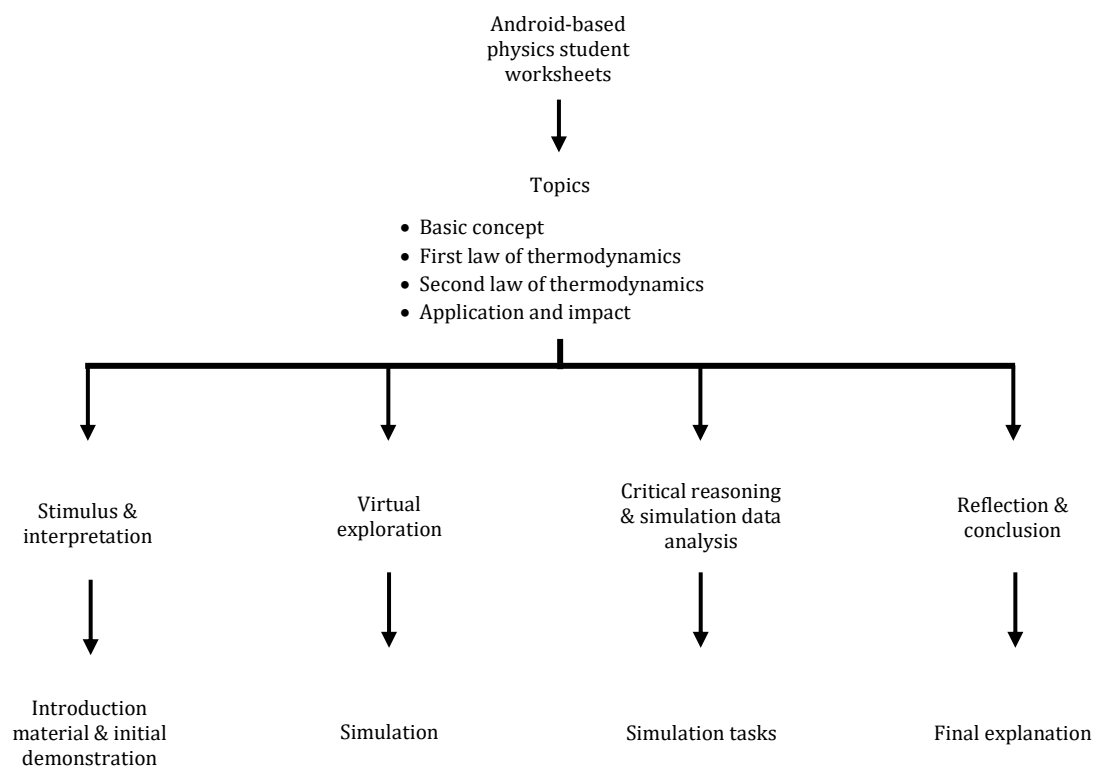
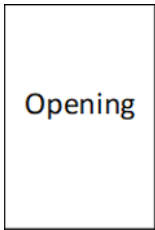
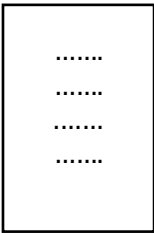
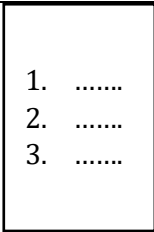


Fig 1. Prototype of android-based physics student worksheets

Figure 1 show that the prototype of android-based physics student worksheets. The material taken from physics teacher's references, such as module, books, and others. To visualized the prototype of android-based physics student worksheets, using Google Sites platform. Google Sites easy to use to make interactive worksheets from the storyboard of android-based physics student worksheets as shown in Table 3. The android-based physics student worksheets contain the interactive menu, the form of user identities, real-time URL to linked media which support the worksheets, etc. Coloring the worksheets, adding background, engaging sub-heading, and lot of other thinks to enhance the attractive of users.

Table 3. Storyboard of android-based physics student worksheets

| No. | Sketch                                                                              | Texts, Images, Videos, and Simulations | Information | Description                                                                                                                                                                                                                                                                      |
|-----|-------------------------------------------------------------------------------------|----------------------------------------|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.  |  | Texts                                  | Opening     | <ul style="list-style-type: none"> <li>The Opening is the first screen users look when open the android-based physics student worksheets, and users start using the android-based physics student worksheets. The design is interactive, easy to use, and procedural.</li> </ul> |

|    |                                                                                     |                               |              |                                                                                                                                                                                                                                                                                                                 |
|----|-------------------------------------------------------------------------------------|-------------------------------|--------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|    |                                                                                     |                               |              | <ul style="list-style-type: none"> <li>Users read the first command and completing personal details in Google Form.</li> </ul>                                                                                                                                                                                  |
| 2. |    | Texts                         | Sub Menu     | <ul style="list-style-type: none"> <li>Users directly enter from the first menu until the last menu.</li> </ul>                                                                                                                                                                                                 |
| 3. |    | Texts                         | Introduction | <ul style="list-style-type: none"> <li>Users read the objective of learning before start the learning.</li> <li>Users given the stimulation and interpretation to attractive the users to learn the topic</li> </ul>                                                                                            |
| 4. |   | Texts, Images, and Simulation | Contents     | <ul style="list-style-type: none"> <li>To approach the objective of learnings, users learn the topic and given simulation. The simulation contains of procedure, table of result, and questions about the simulation. Users start the simulation, the datas shown in table by users touching button.</li> </ul> |
| 5. |  | Texts                         | Quiz         | <ul style="list-style-type: none"> <li>Last chapter before close the android-based physics student worksheets, the users answer the questions about the topic.</li> </ul>                                                                                                                                       |

The expert validators provided valuable feedback on android-based physics student worksheets. The experts suggest several new looks, new instructions, and so on to enhance attention of users on the android-based physics student worksheets. The final product is illustrated in Figure 2. Navigation is set up so students can simply look at and open different sections of the worksheets in clear and straightforward manner. The content includes both words and images, help students not depend too much on words when they can't see the actual processes happening.



Fig 2. Final product of android-based physics student worksheets

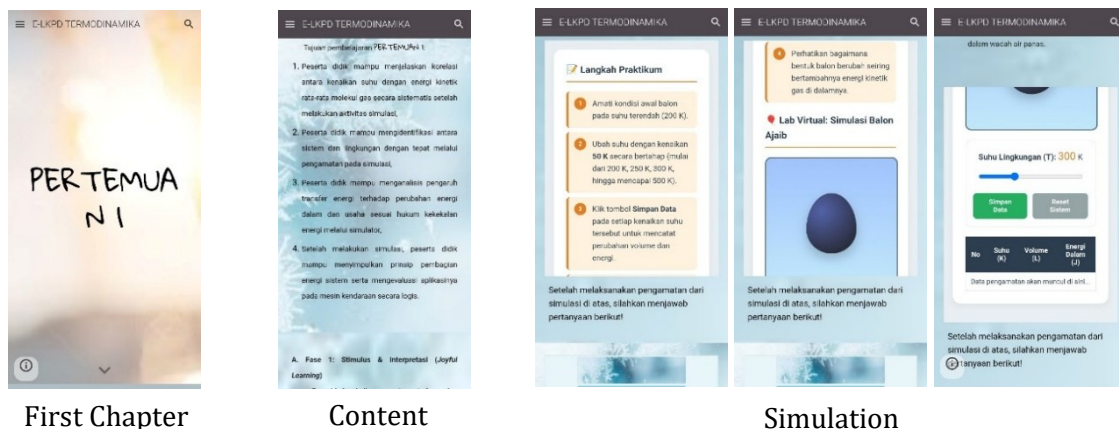


Fig 3. First meeting of android-based physics student worksheets



Fig 4. Other meetings of android-based physics student worksheet

The learning content has activities that ask students to use the information students learned from the material. One thing that really stands out is how the students reacted. This instructional approach is consistent with prior research regarding android-based physics student worksheets design about worksheets. For example, the electronic worksheets can be made to help students think clearly by including well-organized learning activities (Salsabilla et al., 2024), and the study made worksheets by using android platform, focused things available can help teach methods that improve thinking (Wedana et al., 2025).

The android-based physics student worksheets include sections that act like real-life situations and offer a way to learn through experiences. A dedicated feature named "Thermo-Dynamics Explorer" to help students understand these processes better. It

explains how different physical factors relate to the amount of work done. In "Thermodynamics Explorer", there are simulations help students see how the physical system changes and learn what happens when students change factors. These simulations are really helpful because sometimes the steps aren't easy to understand in classroom lessons.

Previous researchs before have found that using simulations provides significant pedagogical benefits. A study using simulations and discovered that students learn concepts more effectively when students can interact directly with models of real-world phenomena (Banda & Nzabahimana, 2021). One recent study has shown that using digital simulations during guided inquiry-based learning can help students think more critically about physics concepts (Dayu et al., 2025). The using of smartphone simulations in inquiry-based learning helps students develop better critical thinking skills, as shown by an N-Gain score of 0.675 (Lintangesukmanjaya et al., 2025).

In this study, simulations were used not just to show something visually, but also to give useful information that can help with future learning tasks. Students can use what they saw and the information students collected to support their answers, help them look how different things are connected, and build up their final thoughts. This integration helped the simulations become part of the learning process, instead of being seen as a separate technology feature. Before the product was used in the classroom, it was reviewed and approved by experts. This review looked at four areas, presented in Table 4.

Table 4. Expert validation results of the android-based physics student worksheets

| No. | Assessment Aspect | Aiken's V |
|-----|-------------------|-----------|
| 1.  | Content/material  | 0.875     |
| 2.  | Presentation      | 0.917     |
| 3.  | Language          | 0.833     |
| 4.  | Media/display     | 0.917     |
| 5.  | Overall mean      | 0.886     |

The Aiken's V overall coefficient was 0.886. The highest scores were in the presentation and media/display areas, with both scoring 0.917. The content or materials section got a score of 0.875. The language section received a score of 0.833. The results show that the product received good scores in all four areas that were reviewed. High scores for presentation and media are important because the product is designed to be used in environments where mobile devices are available. Android-based worksheets should have teaching content and be easy for students to use. Students should be able to locate resources, complete tasks, and seamlessly access required tools. The test results support what research has found about android-based worksheets design.

Expert review ensures that instructional materials are scientifically accurate and pedagogically suitable before classroom implementation (Salsabilla et al., 2024). The field testing phase involved evaluating the android-based worksheets involved testing the android-based physics student worksheets in a classroom. One group included 36 students from grade XII.3 at SMA Negeri 1 Gowa. The product was used once after completing all the steps, such as analyzing, designing, developing, getting feedback, and making any necessary changes. The test was carried out to check how useful the product is and how effectively it functions. Students took a test at the beginning of the lesson to see how well students could

think critically before starting the actual learning. They used an android-based physics student worksheets to learn about thermodynamics. Once the study was finished, the students took a test and filled out a questionnaire.

During the implementation of the android-based worksheet, students learned about thermodynamics, read the activity guidelines, used digital instruments and simulations, gathered information, and completed questions on worksheets. One thing that stood out was the difference in scores between pre-test and post-test. Using student answers and information about their learning progress is like earlier studies on creating mobile and digital media for teaching physics. The evaluating of android-based physics student worksheets using validation data, student responses, test results, and observations from the teaching process (Ngurahrai et al., 2019). The usability of the android-based physics student worksheets was checked by looking at the answers given by all 36 students who took part. The average score from all the responses was 114, and the highest score someone got was 150.

Table 5. Students' responses to the android-based physics student worksheets

| No.   | Response Category | Number of Students | Percentage |
|-------|-------------------|--------------------|------------|
| 1.    | Neutral           | 5                  | 14%        |
| 2.    | Practical         | 26                 | 72%        |
| 3.    | Very practical    | 5                  | 14%        |
| Total |                   | 36                 | 100%       |

We found that 26 students, which is 72 percent were considered practical. 5 students, which is 14 percent were considered neutral. Another five students, which is 14 percent were labeled very practical. Most students indicated that they enjoyed using the developed android-based physics student worksheets. The questionnaire asked about ways students use the product. These were aspects such as how the product looks on screen how easy it's to read how clear the instructions are, how well the product explains different steps what features allow interaction and whether the product works well for online activities. The way the students responded suggested that the students could possibly use the product while the students were studying.

These results corroborate previous studies with research that shows how using electronic devices can help students learn. Students liked using technology in physics lessons and 84 percent of the students gave feedback overall (Ngurahrai et al., 2019). Using instruments properly can really help students learn. These results show that android-based physics student worksheets work well when students are used along with an organized way of teaching. The results show how useful the worksheets are and this should be considered an indication of the worksheets value, in this study not as evidence that android platform alone makes learning more effective. The usefulness of the platform is based on how the digital instruments match the learning resources, directions and tasks that students follow. The android-based physics student worksheets were checked by looking at the students critical thinking skills scores and after the students used the worksheets in formative assessments.

Table 6. Pretest and posttest results of critical thinking skills

| No. | Statistic          | Pretest | Posttest |
|-----|--------------------|---------|----------|
| 1.  | Mean               | 10.08   | 23.72    |
| 2.  | Standard deviation | 3.16    | 2.64     |
| 3.  | Maximum score      | 17      | 28       |
| 4.  | Minimum score      | 5       | 18       |

On average the critical thinking skills scores went up from 10.08 before the test to 23.72 after students took the test. The top score rose from 17 to 28. The lowest score from 5 to 18. The standard deviation fell from 3.16 to 2.64 which means that after the intervention the scores were closely to the average than students were before. The increase in both the highest scores shows that improvement was happening not just for students who were already doing well at the start. The improvement was then measured using normalized gain. The concept of normalized gain was used (Oktavia et al., 2019). Normalized gain is defined as the ratio of actual gain to the maximum possible gain from the baseline score compared to the possible improvement, from the starting score.

Table 7. Overall improvement in critical thinking skills

| Pretest Mean | Posttest Mean | N-Gain | Category |
|--------------|---------------|--------|----------|
| 10.08        | 23.72         | 0.71   | High     |

The findings revealed an N-Gain of 0.71 was considered high, that students' skills to think critically improved significantly after students used android-based physics student worksheets during their formative learning activities. This improvement can be understood by looking at the sections of the learning activities that were done. Students received explanations of ideas, conceptual illustrations, hands-on tasks, and evaluative questions designed to promote analytical reasoning. These sections helped students understand information more clearly, look how different factors are connected, and come up with ways to solve physical problems.

These findings match earlier studies that show using interactive digital learning helps students develop better ideas and stronger thinking skills. Simulations aid students in comprehending physics concepts as students can engage with moving images that demonstrate how things function. Students who used guided inquiry-based learning along with digital simulations showed better improvement in their critical thinking skills compared to those who only used guided inquiry-based learning (Dayu et al., 2025). The group that utilized simulations obtained an N-Gain score of 0.68, showing a greater increase. When smartphone simulations were used together with inquiry-based learning, the N-Gain score was 0.675 (Lintangesukmanjaya et al., 2025).

These results also match what other studies have found about electronic worksheets. The electronic-based worksheets significantly improved the N-Gain scores by up to 0.68, which shows an enhancement in critical thinking abilities (Salsabilla et al., 2024). The employing of digital worksheets within context-relevant mobile learning can aid in enhancing students' critical thinking abilities (Villayah & Suliyanah, 2025). However, the N-Gain results from this study cannot be used to show that the Android platform alone was responsible for the improvements. Learning can be shaped by factors. What is being taught

matters. How the activities are organized also has an effect. How well students understand the material can really make a difference. Whether simulations are used affects learning too. How teachers help students affects how much students learn and grow. How involved students are during learning makes a difference. The analysis also looked at how six core critical thinking skills indicators. These six indicators were the main part of this study.

The data (Table 8) shows students demonstrated significant cognitive enhancement in critical thinking especially when it comes to solving problems and understanding how things change over time. The biggest improvement was in the part that measures how well students can create ideas for change and make simple designs for thermal systems with an N-Gain score of 0.73. The highest score was related to how well students understands operational efficiency and the basic ideas of Carnot engines and refrigeration systems with an N-Gain of 0.72. There was a way to create solutions, especially how the lessons were set up.

Table 8. Improvement in each critical thinking skills indicators

| No. | Critical Thinking Skills Indicators                                                           | Pretest | Posttest | N-Gain | Category |
|-----|-----------------------------------------------------------------------------------------------|---------|----------|--------|----------|
| 1   | Analyzing changes in pressure, volume, temperature, and simple Thermodynamics process graphs  | 71      | 154      | 0.70   | Moderate |
| 2   | Analyzing work, heat, and internal-energy changes based on the First Law of Thermodynamics    | 70      | 152      | 0.68   | Moderate |
| 3   | Evaluating the efficiency and operating principles of Carnot cycles and refrigeration systems | 48      | 150      | 0.72   | High     |
| 4   | Evaluating the validity statements concerning entropy and heat direction                      | 68      | 149      | 0.66   | Moderate |
| 5   | Predicting the effect of changing one parameter on the condition of a gas system              | 42      | 139      | 0.66   | Moderate |
| 6   | Creating modification ideas or simple solutions to optimize thermal-system design             | 54      | 153      | 0.73   | High     |

In contrast, the small gains in tasks that test how well students understand scientific concepts show that comprehending multi-faceted concepts requires complex cognitive processing. The smallest improvements were in entropy events. Specifically, topics related to entropy events and the prediction of gas system parameters both had N-Gain scores of 0.66. Even though these two areas had scores in the data students still show a clear improvement compared to what is normally seen in current research.

The particular signs encourage students to think and try to figure out what might happen next. They have to decide whether the usual things students observe follow the rules of physics or if students need to guess what would happen if something in a gas system is

changed. The tasks ask students to integrate information and consider the different situations that are presented. Becoming good at predicting what will happen usually needs a lot of time and involves real-life experiences along with practice. It's important to remember that the results show that how students' thinking evolves involves different ways of thinking, not just one type of problem-solving skills. This means that using worksheets can help they improve critical thinking skills.

The results from each step of the ADDIE process showed a connection between the part. During the development stage, the numerical assessment of content validity resulted in an Aiken's V score of 0.886. This strong evidence shows that the experts thought the information given, how the material was shown the words used and the way it looked were all very good and suitable for teaching physics in schools. Having content is important because digital learning instruments need to be easy to understand and have clear ideas but the android-based physics student worksheets should easy to use because that can make it harder to stay focused while learning. These results match with the study that electronic-based worksheets which are made with planning and reviewed by experts are effective for teaching in a classroom setting (Salsabilla et al., 2024; Wedana et al., 2025).

When students used the android-based physics student worksheets in the field, they found it simple to use. Most students thought the tool was helpful. A few students felt the tool was either really good or just average. The good reviews show that the android-based physics student worksheets are easy to use during learning, important that the software is simple to use because students can pay attention to learning the content rather than trying to figure out how to operate the program. Some neutral responses show that differences in smartphone features or how well students know how to use a device can affect students' experience. Digital learning platforms need to keep getting better, that can support students who have skills with technology and learn in different ways.

Digital learning instruments can help students learn effectively when interactive simulations, visual tools and problem-solving exercises are closely tied to the learning objectives (A'yun, et al., 2026; Fikri & Madona, 2018). Looking at the test results shows how much the thinking skills have improved. Significant progress was achieved in areas. This included understanding how various factors connect with each other applying the First Law of Thermodynamics looking at cycles spotting errors in statements about entropy predicting how gas properties could change and coming up with solutions for heat-related problems based on the situations provided. These big improvements show that using worksheets in the android-based physics student worksheets helps students learn science in ways instead of just repeating the same math problems over and over.

These results need to be looked at based on the situation and the background of the study. The experiment involved 36 students and utilized a single-group pretest and posttest design. N-Gain improved a lot after the intervention. Things like how many students got the material how much help the teacher gave how comfortable the students felt using the software and how often students took the same test might have helped make the scores better. Studies show that physics worksheets made for android platform are valid, user-friendly and help students learn well.

## CONCLUSION

The physics worksheets about thermodynamics were created using an android platform, following the five-step ADDIE method. This process involves using instruments, images, fun virtual activities and tough questions in physics based, all put together installed in a digital learning platform. The instruments combined three quality standards after being tested in situations. That shows the experts really like the content, how its structured the way the language is used and the pictures or visuals that are included. The android-based physics student worksheets work well, really helps students improve their critical thinking skills about how thermodynamics concepts work and make sense of the reasoning, behind them.

The main advantage of this product is that critical thinking skills turns materials into digital platform using mobile devices. Android-based physics student worksheets with thermodynamics materials and digital activities that students can interact with, which make it easier for students to learn about thermodynamics better. These results should be understood in the light of being applied to one group. Future studies should include a full group or other options, more participants and experiments that examine various learning environments. More studies could look into how long students retain their skills to think critically and check how well this android-based physics student worksheets work when teaching physics subjects.

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