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Developing Contextual Android-Based Thermodynamics Learning Media Integrating Local Coffee Drying Practices: An MDLC Approach

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ABSTRACT: This study aims to develop Android-based physics learning media on Thermodynamics material by raising the local context in the form of coffee drying process in Bondowoso Regency. The model used in the development of this media is Multimedia Development Life Cycle (MDLC) which consists of six stages, namely concept, design, material collecting, assembly, testing, and distribution. The media was designed using Android Studio, Articulate Storyline, Scratch, and Canva software, with the integration of visual, audio, animation, and interactive video elements to create interesting and contextualized learning. The design process is based on the results of field observations to obtain real data related to the stages of coffee processing, especially the drying process. The results of validation by expert validation and material validation showed an average media feasibility of 83.26%, which is included in the "very suitable" category. Thus, the learning media developed is declared suitable to be used as an alternative support for physics learning based on local wisdom, and has the potential to improve concept understanding in a more meaningful way.

Keywords: android, coffee drying, learning media, local wisdom, MDLC, thermodynamics.

ABSTRAK: *Penelitian ini bertujuan untuk mengembangkan media pembelajaran fisika berbasis Android pada materi Termodinamika dengan mengangkat konteks lokal berupa proses pengeringan kopi di Kabupaten Bondowoso. Model yang digunakan dalam pengembangan media ini adalah* Multimedia Development Life Cycle *(MDLC) yang terdiri dari enam tahap, yaitu konsep, desain, pengumpulan materi, perakitan, pengujian, dan distribusi. Media dirancang menggunakan perangkat lunak Android Studio, Articulate Storyline, Scratch, dan Canva, dengan integrasi elemen visual, audio, animasi, dan video interaktif untuk menciptakan pembelajaran yang menarik dan kontekstual. Proses desain didasarkan pada hasil observasi lapangan untuk memperoleh data nyata terkait tahapan pengolahan kopi, khususnya proses pengeringan. Hasil validasi oleh ahli media dan ahli materi menunjukkan rata-rata kelayakan media sebesar 83,26%, yang termasuk dalam kategori "sangat layak". Dengan demikian, media pembelajaran yang dikembangkan dinyatakan layak digunakan sebagai alternatif pendukung pembelajaran fisika berbasis kearifan lokal, serta berpotensi meningkatkan pemahaman konsep secara lebih bermakna.*

Kata kunci: *android, kearifan lokal, MDLC, media pembelajaran, pengeringan kopi, termodinamika.*

INTRODUCTION

The learning process in digital era demands the integration of technology and pedagogy in order to produce learning experiences that are quality, meaningful, and relevant to students' real lives. Technology has great potential in improving learning outcomes while creating space for teachers and students to innovate in managing the learning process (Rohmawati & Watini, 2022; Syafruddin, 2023). The presence of interactive and adaptive learning media to technological developments is one of the important factors that can help students understand abstract and complex subject matter. In addition, the use of media that is contextual to everyday life can facilitate As a learning medium, media serves to strengthen students' understanding and motivation by presenting theoretical concepts in realistic contextual simulations. This allows students to see the direct relevance of the subject matter, making learning easier and more meaningful (Dendodi et al., 2024).

Physics is one of the disciplines that has many concepts that are difficult for students to understand if only delivered through conventional methods such as lectures or reading textbooks. Concepts such as heat transfer, internal energy, heat engine efficiency, and changes in the form of substances are part of the Thermodynamics material that requires a visual and contextual approach to be fully understood. One strategy that can be done is to utilize technology-based learning media, such as Android applications, which have the advantage of presenting material interactively, flexibly, and can be accessed at any time. Android-based learning media allows the integration of multimedia elements such as animation, images, sound, video, and simulation, which can help students understand Physics concepts more concretely (Sidin, et al., 2022).

One of the topics in Thermodynamics that can be contextualized with phenomena around students is the coffee drying process. Coffee processing has a lot of educational content that can be carried out in physics learning. One of the physics content contained in the coffee processing process is thermodynamic material. Coffee processing must go through the right stages and conditions to produce good quality coffee. Coffee has different flavors by looking at the temperature used in the process, namely at the medium roast level with a temperature of 2040C (Arumsari et.al, 2021). This process is an important part of the post-harvest stage in the agricultural industry that directly involves the basic principles of Thermodynamics. In coffee drying, there is a transfer of heat energy from the environment or from the dryer to the coffee beans, with the aim of reducing the moisture content to a safe storage limit. This event can be analyzed through Law I of Thermodynamics, which states that energy cannot be created or destroyed, but only changes form. The heat energy transferred to the coffee beans causes an increase in internal energy and promotes the evaporation of water. If the drying process is carried out using a machine, then the efficiency of the drying machine and the direction of energy changes that occur are closely related to the Second Law of Thermodynamics, which explains the entropy and efficiency limits in the conversion of heat energy into work.

The use of real phenomena such as coffee drying in learning Thermodynamics not only enriches students' understanding of the material, but also forms a scientific mindset that is connected to the real world. Unfortunately, based on observations in the physics education study program at the University of

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Jember, it is known that lecturers have not optimally utilized technology-based learning media to deliver Physics material, especially Thermodynamics. The learning process is still dominated by the lecture method and the use of conventional textbooks, so students have difficulty in understanding concepts and do not get a fun and contextual learning experience. This condition shows the need for Android-based learning media development that is able to present Thermodynamics material visually, interactively, and contextually, by utilizing real examples such as the coffee drying process. The use of android media also supports mobile learning which is now widely applied to support learning anytime and anywhere (Abduljawad & Ahmad, 2023).

To answer these needs, researchers developed an Android-based Physics learning media using the Multimedia Development Life Cycle (MDLC) approach. This approach consists of six main stages, namely concept, design, material collecting, assembly, testing, and distribution (Melanda et al., 2023; Mustaghfaroh et al., 2021). The developed media contains Thermodynamics material with an emphasis on heat transfer, internal energy changes, dryer efficiency, and the laws of Thermodynamics associated with the coffee drying process as an applicative context.

The development of this media is motivated by two main problems, namely how the process of making Android-based learning media using the MDLC method on Thermodynamics material, and how the feasibility level of the media developed based on the results of expert validation and student responses. Some previous studies, such as those conducted by Anggelya et al., (2025), showed that Android-based learning media received very positive responses, with an average feasibility value of 92.80%. This is the basis and impetus for conducting similar development research on Physics material that is directly related to everyday life. However, this research is very important to be carried out because it lies in the integration of key elements that have not been synergistically raised in similar research, namely the real context of the coffee drying process as part of Indonesia's local agrarian wisdom which is clearly illustrated using interactive simulations built with Scratch to model the principles of Thermodynamics visually and dynamically, and final packaging in the form of a comprehensive Android application using the Multimedia Development Life Cycle (MDLC) method.

Thus, this research is entitled "Development of Physics Learning Media Applications on the Android-Based Coffee Drying Process Using the Multimedia Development Life Cycle (MDLC) Method". This study aims to describe the process of developing Android-based physics learning media that integrates coffee drying process simulation using Scratch within the framework of local wisdom through the Multimedia Development Life Cycle (MDLC) stages and analyze the level of feasibility of the media developed based on expert assessment in order to obtain learning media that is easier, more interesting, and more meaningful.

RESEARCH METHOD

The type of research used in this study is development research using the MDLC (Multimedia Development Life Cycle) method. Development research or

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also known as R&D (Research and Development) research is part of the methodology carried out to produce a product such as design, learning materials, learning media and so on (Kurniati et al., 2022). Research and Development (R&D) is a systematic methodology applied in academic and industrial fields to create applicable innovations, such as new products, systems, or models (Rahayu, 2025). This research procedure refers to the MDLC (Multimedia Development Life Cycle) method which will produce a media that can be used as an educational tool.

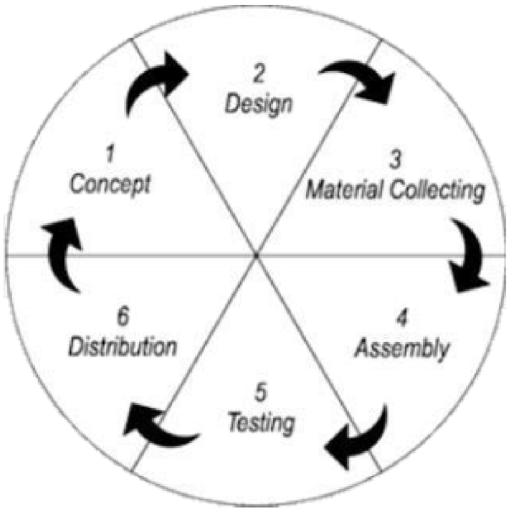

Figure 1. MDLC Method Cycle

The procedure for creating a media is as follows (Sumaryana & Hikmatyar, 2020): Concept stage, at this stage the researcher first creates or determines the concept of the media to be created so that later it can be easier because this concept will be a benchmark for making designs at a later stage, and can adjust the user and the purpose of this application. The design stage, at this stage the researcher will make a design according to the concept made earlier. This design will determine the specifications of the media starting from how the architecture, appearance and style and materials that may be suitable for use. At this stage, a design will be made from each scene to another scene depicted through a storyboard. The material collection stage, at this stage the researcher will collect materials or materials that are suitable and adapted to the design that has been made. Materials that generally exist in a media are text, images, video, audio and so on. This stage also requires basic competencies and indicators that will be a reference in incorporating material into the learning media to be designed. The assembly stage, until this stage means that all the materials that have been collected will then be assembled to later produce a media that is in accordance with what has been conceptualized and designed. This stage is done with various software that we want. Testing Stage, the finished media will then enter the trial stage. This stage is useful to determine the suitability of the concept and design of the media made, whether the media is suitable for distribution later. Distribution stage, this stage is the last stage. Media that is made and has passed the trial and revision stage will later be distributed and stored in storage media.

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The media validation process involved three expert validators to assess its feasibility prior to field testing. The first validator, a media/construct expert, evaluated the design, navigation, and technical aspects of the media. The second validator, a content expert, assessed the accuracy, completeness, and relevance of the learning material. The third validator, a language expert, reviewed grammar, spelling, and clarity of communication. These three specialists were selected to provide a comprehensive validation covering technical-constructive quality, academic content validity, and linguistic appropriateness. Their assessments were analyzed and used as the basis for revising the media.

The data analysis technique is done by taking data based on the results of the validation questionnaire. The data obtained from the validation results sheet is then used to determine the feasibility of the learning media used. The assessment of the validation results of media experts and material experts is determined using an achievement level scale because the assessment requires achievement standards and is adjusted to the predetermined categories. With a Likert scale using a scale of one to five. The following validation Likert scale guidelines can be seen in Table 1.

Table 1. Validation Likert Scale Guidelines (Sugiyono, 2019)

Skor	Description
5	Very Good
4	Good
3	Acceptable
2	Poor
1	Very Poor

This product trial was carried out by media experts and also material experts with data collection techniques carried out in this study are: (1) validation sheet, (2) interview, (3) documentation. The data analysis technique uses a feasibility percentage scale which will be processed with the following equation 1:

$$\boldsymbol{P} = \frac{\textbf{\textit{Total score obtained}}}{\textbf{\textit{Maximum or ideal number of scores}}} \boldsymbol{x}\ \mathbf{100}\% \quad (1)$$

Then the results of the data obtained will then be determined by looking at the percentage formula from Ridwan & Prasetyawan (Rozi and Kristari, 2020).

Table 2. Assessment Score Guidelines

Achievement Level (%)	Eligibility Criteria
81-100	Very Appropriate
61-80	Appropriate
41-60	Neutral
21-40	Inappropriate
0-20	Very Inappropriate

RESULT AND DISCUSSION

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Result

In this study, the validation of Android-based learning media was carried out by three subject matter experts with varying results. The first subject matter expert gave a percentage score of 92.67%, the second subject matter expert gave a score of 81.33%, and the third subject matter expert gave a score of 75.77%. When averaged, this media obtained a percentage score of 83.26% with a category of "Very Suitable". These results reinforce that the developed media has met the standards of content, language, and construction suitability for use in physics learning. The validation results can be seen in Table 3 below.

Table 3. Expert Validation Scores

Validator	Score (%)	Category
Expert 1	92.67	Very Suitable
Expert 2	81.33	Suitable
Expert 3	75.77	Suitable
Average	**83.26**	**Very Suitable**

This research was conducted using the Multimedia Development Life Cycle (MDLC) development model developed by Luther (1994). The MDLC model was chosen because it has a systematic flow and is suitable for multimedia-based media development. MDLC consists of six main stages, namely: concept, design, material collecting, assembly, testing, and distribution. This research was conducted in June-July 2025, with the research location in Bondowoso Regency, East Java, especially in coffee-producing areas as contextual objects.

Concept

At the concept stage the author also formulates several things in the development of physics learning media on the android-based coffee drying process using the MDLC method which are explained as follows: 1) define the app name; 2) define the genre of the App; 3) determine the software used, namely using Android Studio with the java programming language and using canva to design applications; 4) define in-app content.

Design

In this stage, researchers conducted direct observations in coffee farming areas in Bondowoso, East Java to obtain real data about the stages of coffee processing, especially the traditional and modern drying processes. This observation aims to obtain pictures, videos, and direct interviews that will be used as visual material and learning context in the media. Based on the results of concept analysis and field observations, the design of the Android-based interactive learning media flow was carried out. The design uses a use case diagram as shown in Figure 1 about the following Activity Diagram.

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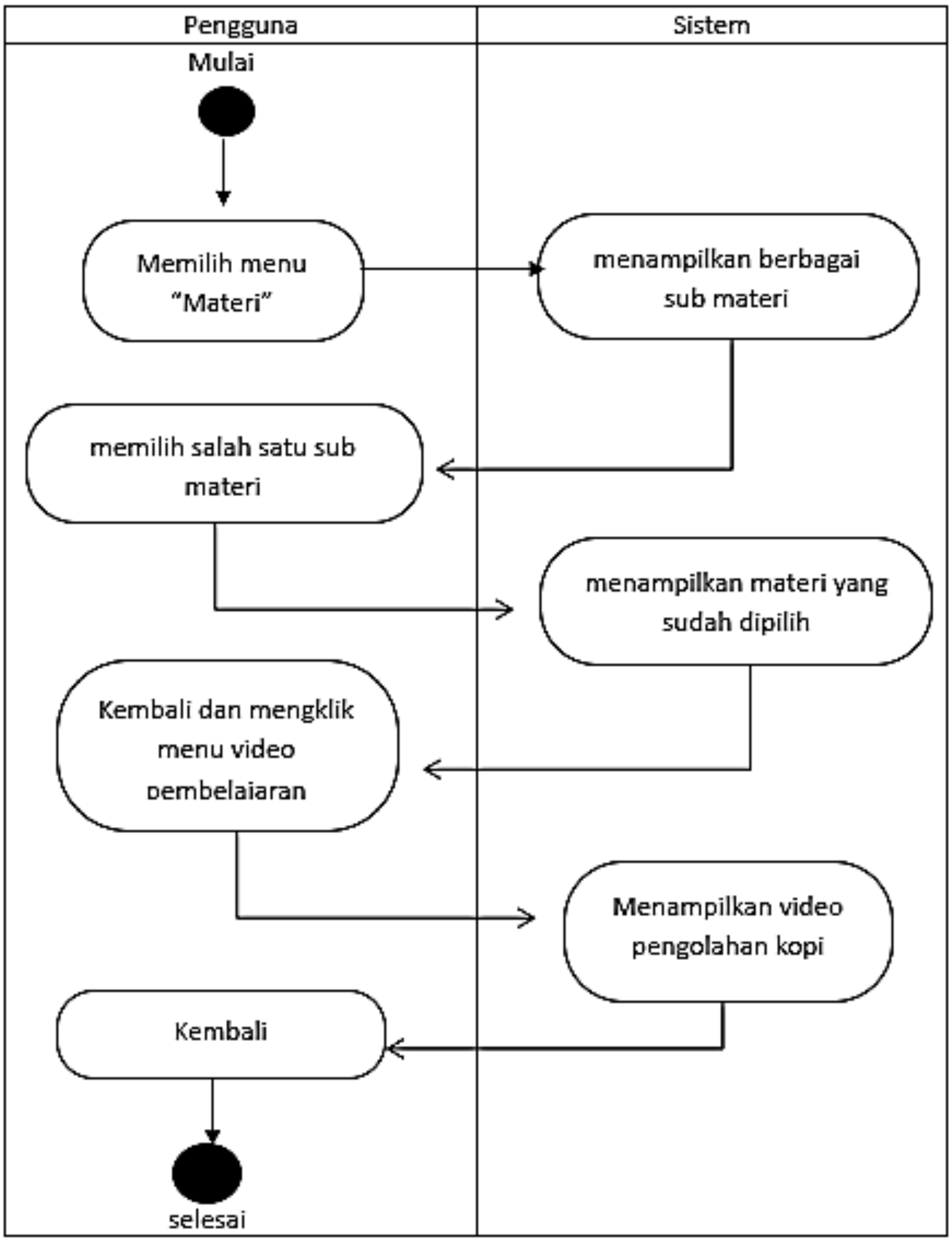

Figure 2. Activity Diagram

In Figure 2 the activity diagram explains the user interaction when selecting the "Start" menu in the application. Beginning with the user to start the application, after the system displays the main page which has several menus then the user selects the "Start" menu so that the system can display the next page which displays various menus, consisting of the introduction menu, material menu, and video menu contained in the material page on the coffee drying process. Then implement the design into the form of digital media using articulate storyline and scratch software.

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Material Collecting

In the collecting stage, the author collects materials, materials collected are materials, images, backgrounds, audio, digital photos, and other supporting materials. In practice, this stage can be done in parallel with the assembly stage.

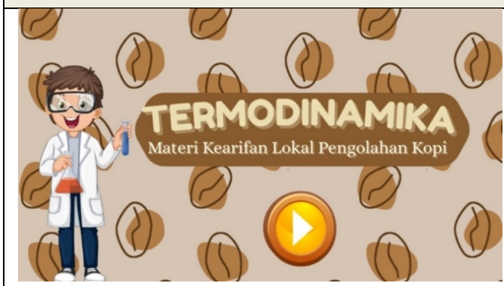
Some of the data and information collected to start making this media include:

a. The text data used is data about thermodynamic material in basic physics 1 courses.
b. The audio data used is media background music along with a video of the coffee drying process.
c. The image data used are background images and other images related to the coffee drying process media.

Assembly

The media is built by integrating animation, text, audio narration, and interactive video to visualize physics concepts in coffee processing. This stage is an important stage in the development of learning media because at this stage all the design elements that have been made previously-including layouts, illustrations, buttons, animations, and navigation-are assembled into a unified and functional display. In the context of Android-based learning media for coffee drying process, this stage produces a series of interfaces that bring together aesthetic elements, functionality, and local nuances to support a contextual and interesting learning process. Table 3 shows the display of android-based learning media on coffee drying process. The results of the android-based learning media display on the coffee drying process can be seen in Table 4.

Table 4. Android-based Learning Media Design Results on the Coffee Drying Process

View	Description
	This slide is a visual introduction to physics material, especially thermodynamics, with a local approach through a real example of coffee processing. There is a play button to enter the next scene. The aim is to attract learners' attention with a fun display that is close to everyday life.

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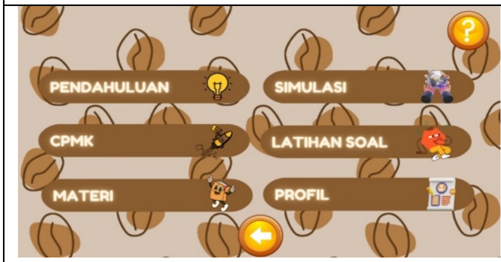
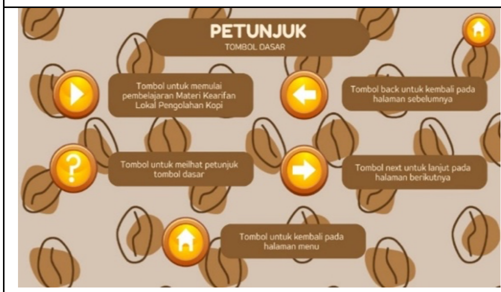
<table>
<tr><th>View</th><th>Description</th></tr>
<tr><td>
</td><td>This slide functions as a user data input page, which is usually used in applications or interactive media. There is a log in button to enter the main menu page.
The purpose of this page is to identify participants or students accessing the material and to give an interactive and personalized impression (welcoming users as if they were entering a physics learning application).</td></tr>
<tr><td>
</td><td>On this page there are several navigation buttons, namely Introduction, CPMK, Material, Simulation, Practice Questions, and Profile. In addition, there is also a Help button marked with a question mark icon in the upper right corner, as well as a Back button at the bottom center of the page.</td></tr>
<tr><td>
</td><td>This page is the display that appears when the user presses the Introduction button.
It contains a welcome from a mentor character named Koko, who introduces himself as a companion in learning Coffee Thermodynamics. In the opening message, Koko invites the user to uncover the scientific secrets behind the coffee-making process, as well as extending an invitation to explore the world of coffee together.</td></tr>
<tr><td>
</td><td>This page is the display that appears after pressing the question mark button (?) in the upper right corner of the main menu.
It contains instructions for using the basic buttons in the learning media. The title is "INSTRUCTIONS: BASIC BUTTONS". This page explains the function of each button icon that is often used during navigation.</td></tr>
<tr><td>
</td><td>This page is the display that appears when the user presses the CPMK button on the main menu.
It contains a list of Course Learning Outcomes (CPMK) which are the objectives of learning Thermodynamics based on local wisdom of coffee processing.</td></tr>
</table>

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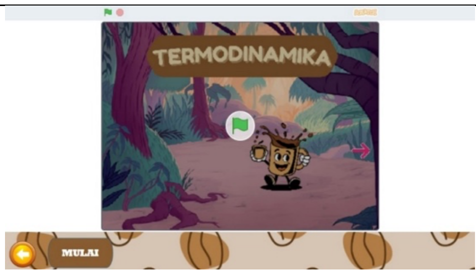
View	Description
	This page is the display that appears after the user presses the Material button on the main menu. The content of this page is a list of sub-materials that will be studied in the topic of Thermodynamics based on Local Wisdom of Coffee Processing.
	This image is a display of the page that appears after the user presses the Simulation button on the main menu. On this page there are two important buttons, namely: • Button "Mulai" in the bottom left corner used to start the interactive simulation on the theme of Thermodynamics • Button kembali (panah kuning) to the left of the “Start” button, which is used to return to the main menu page In the center of the screen is the interface of the Scratch platform, with an animated coffee cup character ready to invite the user to explore the simulation. There is also a green flag button in the center of the screen to run the simulation within the Scratch window.
	This image is a display of the page that appears after the user presses **button Latihan Soal** on the main menu. These two buttons direct users to do questions before and after learning the material. Pretest is used to determine students' initial understanding, while posttest is used to measure improvement after the learning process takes place. In the top right corner, there is a back button (yellow arrow icon) that serves to return to the main menu page.

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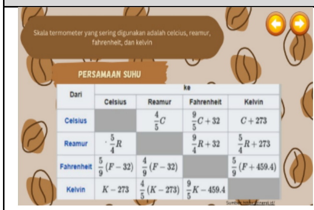
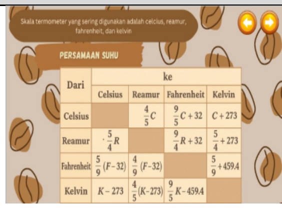
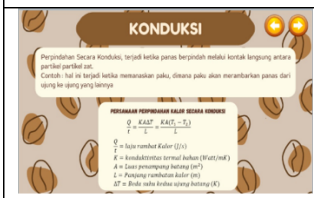
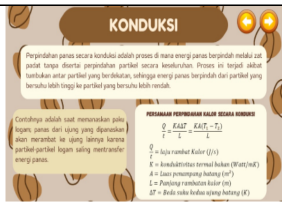
View	Description
	This image is a display of the page that appears after the user presses **button Profil** on the main menu. Contains the name and photo of the drafting team, both lecturers and students involved. In the upper right corner there are next and back buttons (yellow arrow icon) and a home button to return to the menu page.

Testing

This media is validated by material expert validators and media experts. The purpose of media validation is to determine the feasibility of android-based learning media designed by researchers.

Before	After	Description
		Correction of the temperature conversion table in the material content.
		Correction of equation and description of heat transfer by radiation.
		Correction of content material in accordance with the rules of proper and correct Indonesian language.
		Changing the home button on the material page to distinguish between home to the menu and home to the sub-material.

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Before	After	Description
		The addition of the titles conduction, convection, and radiation in coffee processing makes the image more rational.

The product validation data can be seen in Figure 3 as follows:

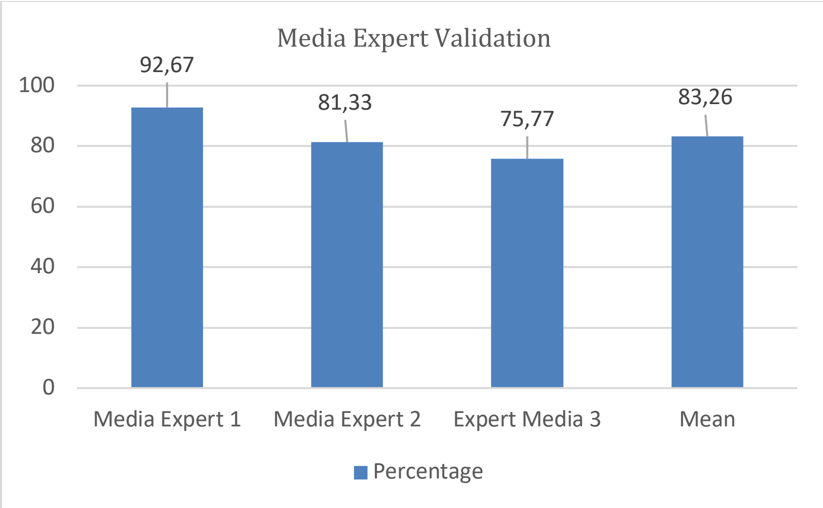

Figure 3. Media Expert Validation

The results of validation by subject matter expert one obtained a percentage score of 92.67%, subject matter expert two obtained 81.33%, and subject matter expert three obtained 75.77%. From these three percentages, the average score for the suitability of Android-based learning media was “Highly Suitable” with a percentage score of 83.26%. This study is in line with the results of research by Nurfadilla et al. (2023), which shows that the development of contextual and locally-based media can significantly improve students' understanding of science concepts. Additionally, the MDLC model has also been proven effective in the development of Android-based learning media, as demonstrated by Fajri & Sari (2021), who stated that the MDLC stages support the systematization of valid and engaging media design and development.

Distribution Stage

At the distribution stage, the Android-based physics learning media developed on the coffee drying process was distributed to the target users, teachers and students. Distribution was carried out after the media underwent expert validation and limited trials, so that its quality and suitability for use could be guaranteed. This media is distributed in the form of an application file with the .apk extension that can be installed directly on Android-based smartphone devices, making it easy for students and teachers to access it anytime and

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anywhere. Therefore, the distribution stage in this study confirms that Android-based learning media in the coffee drying process is ready to be used as an innovative medium in supporting basic physics learning.

The results of this study indicate that the development of physics learning media on the Android-based coffee drying process using the Multimedia Development Life Cycle (MDLC) method is in line with various previous studies that emphasize the effectiveness of interactive media in improving learning quality. Mustagfaroh *et al.* (2021) proved that interactive learning media on the subject of changes in the properties of objects received a very positive response, with an overall average response of 92.80%. This high percentage shows that media designs that prioritize interactivity can significantly increase student motivation and engagement in learning. In line with these findings, Widiastuti (2021) emphasized that Android-based physics learning media has high suitable with a validity of 85.25% and student response of 84%. This indicates that mobile learning can be a practical solution in enriching students' learning experiences, as well as an alternative medium that is adaptive to technological developments. Furthermore, Murtianingsih and Astono (2023) reinforce these results by showing that the integration of Smart Apps Creator-based media through the Problem-Based Learning (PBL) approach has been proven to improve students' critical thinking skills. This success was driven by investigative features that encouraged analysis, evaluation, and independence in learning. The consistency of the effectiveness of digital media was also demonstrated by research conducted by Koroh *et al.* (2024), who developed interactive learning applications on the subjects of Uniform Linear Motion (ULM) and Uniformly Accelerated Linear Motion (UALM). The media obtained a validity of 84.46% and was considered very suitable for use based on language, appearance, and feasibility aspects. The research by Putri *et al.* (2025) also supports this finding that Android-based media can improve students' science literacy, albeit at a moderate level. This shows that the effectiveness of media is not only limited to the aspect of motivation but also to the improvement of literacy skills relevant to the needs of the 21st century.

In addition to increasing motivation and literacy, other studies also highlight the contribution of interactive media to cognitive skills. Arrahmat et al. (2025) showed that TITANICS media on thermodynamics material successfully increased student understanding by 39% at the analysis level (C4). This significant increase is evidence that interactive media can encourage higher-order thinking skills. Praja et al. (2025) found similar results, discovering that Scratch-based media can strengthen collaboration among students, creating a more active and cooperative learning environment. Thus, the success of interactive media lies not only in individual aspects, but also in the social dimension of learning. Furthermore, Hermansyah et al. (2024) successfully developed 3D animation-based learning media with a feasibility rate of 96.9%. These results show that strong visualization contributes to students' attraction and understanding of abstract physics concepts. At the implementation stage, research by Kasri et al. (2021) and Musbar and Fitria (2023) emphasizes the importance of the dissemination process of learning media so that it can be widely used by teachers

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and students. The success of the media was also demonstrated by the validation conducted by Yusuf et al. (2024), which obtained an average score of 3.5 in the good category, indicating that the media and material aspects had met quality standards. In line with these findings, Solehatin et al. (2023) proved that the use of interactive multimedia media can increase student engagement, with an acceptance rate of 72.22%. These results confirm that the majority of students respond positively to interactive and visual media. Media validation in other studies also reinforces this argument. Bektiarso et al. (2023), for example, showed that digital modules based on local coffee and cocoa wisdom obtained a validity score of 88.32% in the excellent category. These findings are in line with the research by Nuraini et al. (2023), which produced an overall validity of 88.58% for digital modules based on local industrial agriculture wisdom.

This study's primary contribution extends beyond achieving high validation scores; it reveals *how* local contextualization functions as the key mechanism that translates media design (feasibility) into improved learning (effectiveness). The findings specify the process by which a concrete local context transforms abstract theoretical principles into measurable cognitive gains.

Discussion

In this study, the validation of Android-based learning media was carried out by three subject matter experts with varying results. The first subject matter expert gave a percentage score of 92.67%, the second subject matter expert gave a score of 81.33%, and the third subject matter expert gave a score of 75.77%. When averaged, this media obtained a percentage score of 83.26% with a category of "Very Suitable". These results reinforce that the developed media has met the standards of content, language, and construction suitability for use in physics learning. This study is in line with Nurfadilla *et al.* (2023), who found that contextual and locally-based media can significantly improve students' understanding of science concepts. Additionally, the MDLC model used in this study has also been proven effective, as stated by Fajri & Sari (2021), that the MDLC stages support the systematization of valid, practical, and attractive media design and development. The feasibility of interactive learning media is also demonstrated in the study by Maharani *et al.* (2024), where the use of Google Sites for momentum and impulse material obtained an N-gain score of 0.86 in the high category, as well as a positive student response of 88.59%. The research by Dewantara *et al.* (2025) and Wardi & Jauhariyah (2025) also reinforced this with high validity results in the development of scientific literacy-based assessment tools. These results show that both digital-based media and instruments are capable of meeting the needs for more accurate learning evaluation in line with curriculum requirements. The integration of local wisdom in the media also plays an important role, as demonstrated by Wulandari and Tanjung (2024) in the "Manghutti Tandok" activity and Taufiq *et al.* (2024) who combined RME with Luwu culture. Both studies emphasize that cultural context can strengthen the relevance of material and improve higher-order thinking skills (HOTS). In fact, Doloksaribu *et al.* (2025) prove that an ethnoscience approach with digital support

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effectively improves conceptual understanding, with an N-gain score of 0.692 in the moderate category.

Based on a synthesis of previous research findings and the validation results obtained in this study, it can be concluded that the development of Android-based physics learning media for the coffee drying process is highly relevant to current research trends. Interactive media has not only been proven to be valid, but also capable of increasing student motivation, science literacy, cognitive skills, and collaboration. In addition, the integration of local wisdom makes the learning media more contextual and meaningful. Therefore, the results of this study emphasize that the development of Android-based media using the MDLC method is a strategic innovation to address the challenges of physics learning in the digital era.

CONCLUSION

An Android-based physics learning medium that integrates a simulation of the coffee drying process using Scratch within a local wisdom framework has been successfully developed using a systematic MDLC approach. This learning medium integrates local content about the coffee drying process, equipped with interactive features such as simulations, videos, exercises, and intuitive navigation. The design of the learning media that has been developed supports contextual learning and makes it easier for students to understand thermodynamic concepts in a more interesting and applicable way. This learning media has an average feasibility score of 83.26% from three experts, which is categorized as “Very Suitable”. This study is limited to the development of learning media that has been validated by experts but has not been empirically tested with students to measure learning outcomes or engagement. The focus of this learning media is only on one topic of thermodynamics in a specific local context, which may limit its generalization. Further studies should test this learning media in real classrooms using experimental designs to measure its impact on learning outcomes and motivation. Expanding local content to other topics or contexts will also increase the effectiveness of applying learning media in the classroom.

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