

## **Development of Integrated Augmented Reality Multimedia in Thermodynamics Material For Physics Learning in Grade XI**

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**Abstract:** The sophistication of information technology is still not widely utilized and integrated into the learning process in the world of education, even though technology can be one of the driving factors in improving educational progress. This research and development aims to develop mobile learning multimedia integrated with augmented reality on thermodynamic material and determine the level of validity and reliability of the multimedia that will be used to help increase student motivation and concept understanding. AR multimedia was developed using the ADDIE model stages (analysis, design, development, implementation, and evaluation), then validated by experts, namely one media expert lecturer and two teachers who have approximately 10 years of experience in the field of education. Furthermore, a limited trial was conducted on 25 11th grade students of SMA 11 Negeri Pekanbaru. Data were collected using a validation instrument sheet and a response questionnaire sheet. The collected data was analyzed using the Aiken V formula and Pearson product moment correlation. Therefore, if students have difficulty understanding learning concepts, this augmented reality integrated multimedia is highly recommended for use in the learning process.

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Development, Multimedia,  
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## **Introduction**

Technological progress was so rapid felt in the era of the 2000s until now, especially in the development of information and telecommunications technology. Seeing the increasing needs of consumers, changes in tools that are adjusted and can facilitate all human activities are needed. The process of developing information technology, also called digital technology, started with the transformation of world society, which began to switch to utilizing digital technology in every personal and social activity. According to Danuri, digital technology is information technology in the form of the automatic operation of a computerized system or computer-readable format that aims to facilitate all human activities quickly and accurately (Danuri, 2021).

The development of technology can be felt in all aspects of life, one of which is the field of education. In the field of education, technology is used as a media tool in teaching natural symptoms and natural facts and their application; thus, if so far the learning process has been abstract or theoretical only, with the help of technology, the learning concept is

more accurate and directed (Rahadian, 2017). With the increase in technology creation, all parties need to balance their capabilities with these technological advances. This can be done with the support of an internet network that is starting to be evenly distributed in almost all regions of Indonesia (Selatan et al., 2021). Given the development of technology using the internet network as a medium of liaison and outreach between users, Therefore, the world of education needs to improve innovation and infrastructure that allow it to follow the developments and innovations that have been made (Azka et al., 2019).

One of the innovations carried out in the world of education is the innovation of learning media, where learning media acts as a tool for teachers to interpret and explain learning appropriately. One of the innovations in learning media is the use of multimedia content as digital teaching materials, in which there are images, audio texts, and even animations that are associated with the intended learning content (Lanzilotti et al., 2006). Multimedia can be concluded as an interactive learning process tool that is arranged to include students and teachers, teaching materials, whiteboards, stationery, and learning tools and facilities in the form of rooms and audio-visual classes (Yusuf, 2018). According to (Suryandaru, 2020), teachers must be creative and innovative because they are responsible for designing learning activities and implementing technological developments into them so that the learning process is no longer teacher-centered or relies on conventional learning.

The use of technology in learning continues to grow; computers are no longer the only technology medium used but also mobile devices, commonly called mobile learning, which refers to the use of information technology devices in the form of mobile phones, commonly known as smartphones, laptops, or even tablet PCs (Anwar et al., 2020). Mobile devices used in multimedia development this time are Android-based smartphones or tablet PCs, because these devices are most commonly used by students in Indonesia, and also because the purchase price of these devices is relatively cheap and affordable. Learning using mobile is proven to make the learning atmosphere more fun, interactive, and independent; this is evident from the research that has been carried out by Hanafi (Hanafi, 2012).

Many things can be developed in multimedia mobile learning, in addition to being able to display images, audio, video, and other interactive displays. We can develop multimedia mobile learning using advanced artificial intelligence, such as 3D visualization (three-dimensional) in multimedia mobile learning. With the help of 3D simulation, the learning concept will be more directed, and students will no longer misunderstand and mistake information. One of the developments in 3D visualization is called augmented reality. According to (Kang et al., 2013) their research revealed that augmented reality is a technology that combines virtual objects that appear when the existing barcode is captured by the camera, and the results are displayed in the form of 3D visuals.

Indonesia is ranked fourth with the largest population in the world, has a rich cultural heritage, and is ethnically and linguistically diverse. The education landscape in the country is characterized by significant achievements but also faces various challenges, including gaps in educational opportunities and learning facilities in various regions (Fadli et al., 2019). The development of multimedia learning is still not widely developed using the latest technology. This is because there are still many teachers who stutter about technology or have not received much information related to the use of technology in developing learning media. Therefore, it is necessary to design multimedia based on mobile learning so that it can be a new breakthrough and new knowledge for teachers in Indonesia, especially in developing technology-assisted learning media, in order to create a better and more accurate learning process.

Based on the explanation above, the purpose of this study is to answer several questions, as follows:

1. How to develop multimedia mobile learning integrated with augmented reality in class XI high school thermodynamics material in Indonesia?
2. What is the level of validity of multimedia mobile learning integrated with augmented reality in class XI high school thermodynamics material in Indonesia?
3. How is the reliability level of mobile learning multimedia integrated with augmented reality in class XI high school thermodynamics material in Indonesia

### **Research Method**

The research method used is the research and development method (R & D). R & D is a method to develop a product, and the results can be tested for feasibility (Sugiyono, 2013). Researchers will develop learning media in the form of multimedia mobile learning integrated with augmented reality in thermodynamic material class XI high school. The development model used is the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation), consisting of five stages of development (R. M, 2009). The following development procedure is shown in Figure 1.

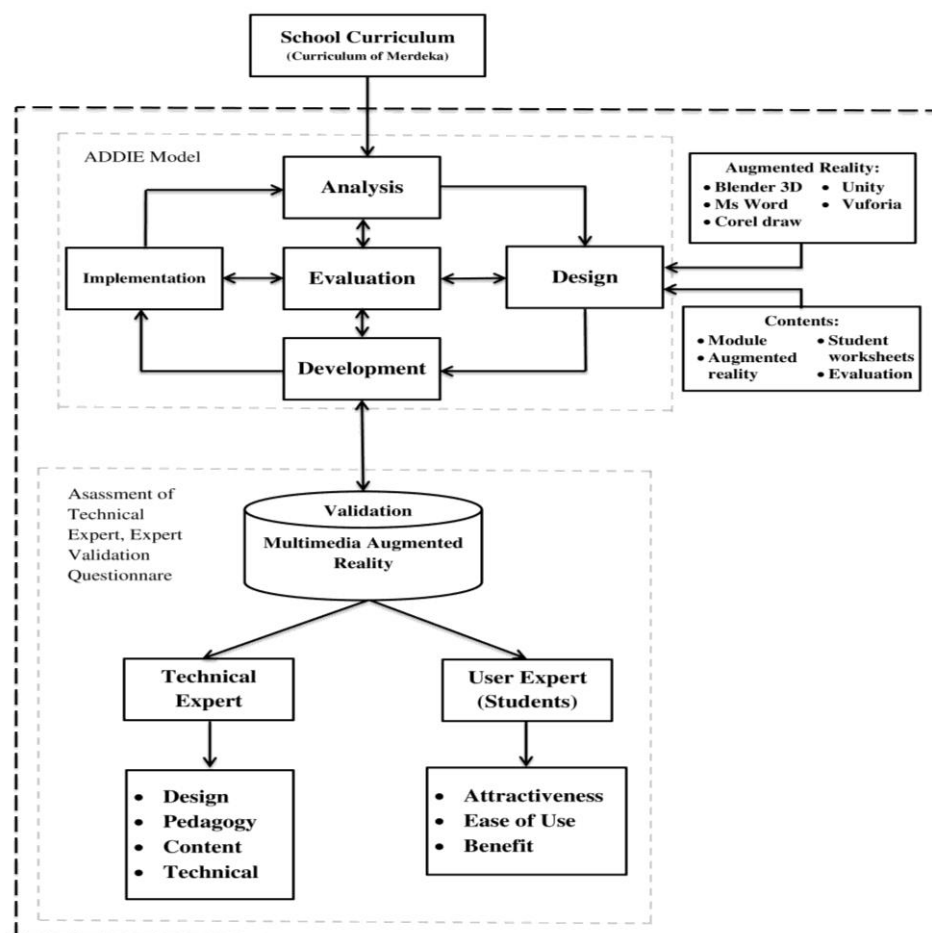


Figure 1 Development Procedure. Adapted from (Nasir & Fakhrudin, 2023)

Based on Figure 1, we can see several stages of integrated multimedia development of augmented reality, where there are 2 phases, namely the phase of developing multimedia using the ADDIE model and both phases of media validation carried out by experts and users.

### ***Augmented Reality (AR) Integrated Multimedia Development Procedure***

#### **1. Analysis**

The first stage that needs to be done is to analyze and identify problems and devices needed in the development of multimedia-augmented reality. This stage consists of several steps:

##### **1.1 Needs analysis**

This stage is carried out to identify the things needed in the multimedia development process, more specifically the students' own needs for the multimedia to be created. Information can be gained from interviews with teachers and students.

##### **1.2 Analysis of student characteristics**

This stage is carried out to find out the characteristics of students, because the multimedia to be developed is intended for them. Of course, the media made must be in accordance with the characteristics of students so that multimedia can be accepted and in accordance with the character and wishes of students.

### 1.3 Material Analysis

Given that there are quite a lot of learning materials, it is necessary to analyze what material will be developed. This is done so that the material discussed is more focused on one subject only, so that the content of the media does not float.

### 1.4 Media Program Analysis

The next stage is to identify what devices will be used in the process of developing multimedia integrated augmented reality.

## 2. Design

At this stage, researchers design all multimedia development processes. The design that has been made becomes a reference in the development of AR multimedia.

## 3. Development

This stage begins the realization activities of the multimedia development design. It is at this stage that we will produce multimedia integrated with augmented reality.

## 4. Implementation

The next stage is to implement AR multimedia in students, as media users later.

## 5. Evaluation

Once multimedia AR is implemented, there is a response and a user response. So it is necessary to evaluate in order to produce better multimedia (Arofah & Cahyadi, 2019).

### **Validation**

#### 1. Technical Expert

The next step is the validation of AR multimedia by experts in the field of multimedia and physics pedagogy, where the validators are lecturers and teachers who have teaching experience for approximately 10 years. Validation tests are carried out to determine the feasibility of the multimedia developed; if it has been tested as valid, several revisions are then carried out, and multimedia can be limited.

#### 2. User Expert

Limited trials are carried out on the intended user, namely students. Given the limited time in this research process, a limited trial was carried out, namely in a group of tenth grade high school students with members of around 20–25 students. This user trial was conducted to determine the reliability and response of students to the multimedia developed.

### **Instrument Sheet**

The instruments used to collect data are validation sheets for validators and response questionnaire sheets for students. The validation sheet can be seen here: <https://s.id/1Z8c2>. The student response questionnaire sheet can be seen here: <https://s.id/1Z8ce>.

### **Data Analysis Techniques**

Analysis of the results of expert validation aims to make the resulting product known whether it is valid so that it is feasible to be tested on students (Kartika et al., 2019). In the analysis of the results of instrument validity in this study using Aiken's V formula (Azwar, 2012), the formula is:

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

V = Assessor Conformity Index

s = Average score - the lowest score in that category

c = Number of Categories

n = Number of Appraisers

The results of the data obtained are then categorized based on the criteria in Table 1.

Table 1. The Value of the Aiken Coefficient and Category (Creswell, 2021)

| Value V Aiken      | Category           |
|--------------------|--------------------|
| $0,80 < \leq 1,00$ | valid (very high)  |
| $0,60 < \leq 0,80$ | valid (high)       |
| $0,40 < \leq 0,60$ | Valid (sufficient) |
| $0,20 < \leq 0,40$ | unauthorized (low) |
| $0,00 < \leq 0,20$ | invalid (very low) |

Multimedia is declared valid if the Aiken v value is greater than 0.4. (Anggraini et al., 2020). User trial analysis carried out two measurements, first measuring Pearson's product moment correlation and how to calculate it using the following formula:

$$r_{xy} = \frac{N \sum xy - (\sum x)(\sum y)}{\sqrt{[n \sum x^2 - (\sum x)^2][n \sum y^2 - (\sum y)^2]}} \quad (2)$$

$r_{xy}$  = Coefficient between variable X and variable Y

N = Number of students

$\sum X$  = Number of item scores of variable test respondents X

$\sum Y$  = Number of item scores of test respondents variable Y (Suherman, 2003)

The following are the validity categories used (Suherman, 2003):

Table 2. Pearson Product Moment Correlation Rating Category

| Correlation Coefficient   | Category  |
|---------------------------|-----------|
| $0,80 < r_{xy} \leq 1,00$ | Very High |
| $0,60 < r_{xy} \leq 0,80$ | Tinggi    |
| $0,40 < r_{xy} \leq 0,60$ | Keep      |
| $0,20 < r_{xy} \leq 0,40$ | Low       |
| $0,00 < r_{xy} \leq 0,20$ | Very Low  |

The response questionnaire is said to be valid when the correlation coefficient value is large ( $> 0.40$ ) or in the medium category.

The measurement used is a reliability test using the Cronbach Alpha formula. Based on the expression (Arikunto, 2010), the alpha formula is used to find the reliability of instruments whose scores are not 1 or 0. The formula is as follows:

$$r_{11} = \left( \frac{k}{n-1} \right) \left( 1 - \frac{\sum s_b^2}{s_t^2} \right) \quad (3)$$

$r_{11}$  = Instrument Reliability

k = Number of poll items

$\sum s_b^2$  = Number of grain variances

$s_t^2$  = Total variance (Asrul, 2015)

The use of this formula is because the score of the instrument is continuous. Whether or not an instrument is reliable is seen from its value. A test is said to be reliable if the coefficient is greater than 0.60 (Ghozali, 2006).

## Result and Discussion

### Analisis

Interviews have been conducted with one of the physics teachers and several grade 11 high school students at ICBS Payakumbuh. Based on the information obtained, it can be concluded that in the learning process, students need interactive learning media that are easily

accessible and in line with advances in telecommunication technology that are familiar to them, namely the use of smartphones and gadgets in the learning process. Students hope that there is a learning medium that can make them motivated and excited about the learning process. This is evident from the results of research conducted by Fuad, namely that the innovation of learning media has proven its benefits in increasing student learning motivation, strengthening understanding of concepts, and increasing active participation in learning. Students can experience learning that is more fun, immersive, and suits their individual learning style (Utomo, 2023). The subject matter used is thermodynamics material, because according to the teacher, thermodynamics is one of the lessons that is difficult for students to understand because it is difficult to visualize thermodynamic processes. Therefore, thermodynamics is very suitable if developed into integrated multimedia augmented reality.

### Design

The following is a design for developing AR-integrated multimedia, as seen in Figure 2.

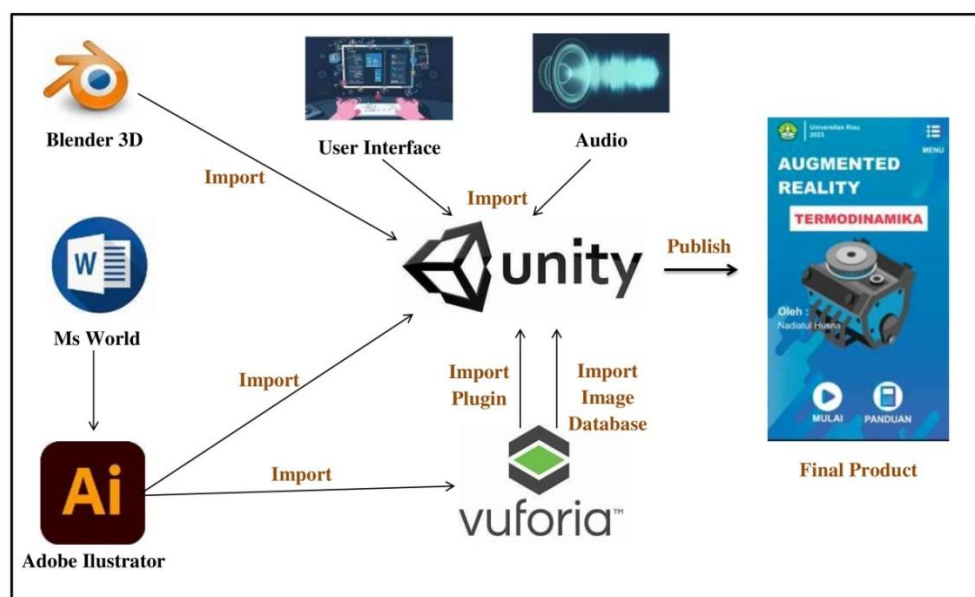


Figure 2 Procedure for Developing Multimedia Augmented Reality  
 The application flowchart design of AR multimedia can be seen in Figure 3

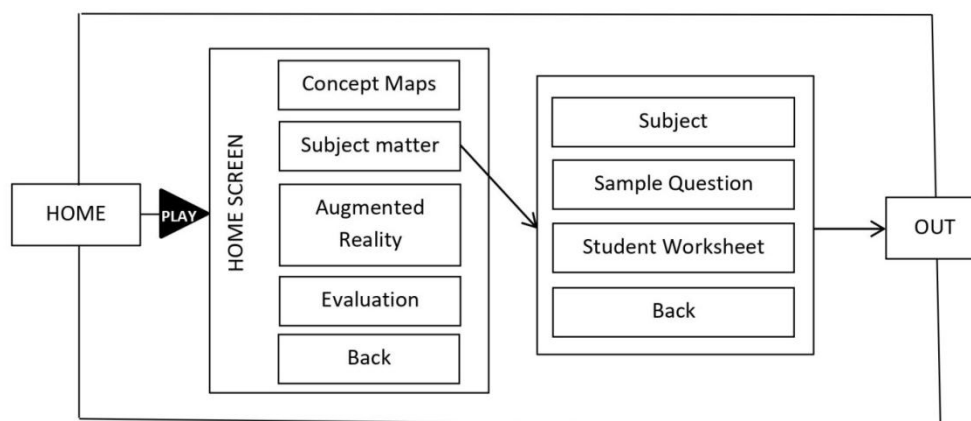


Figure 3 AR Multimedia Application Flowchart

## Development

The results and development process of Multimedia Integrated Augmented Reality can be seen in Figure 4-11.

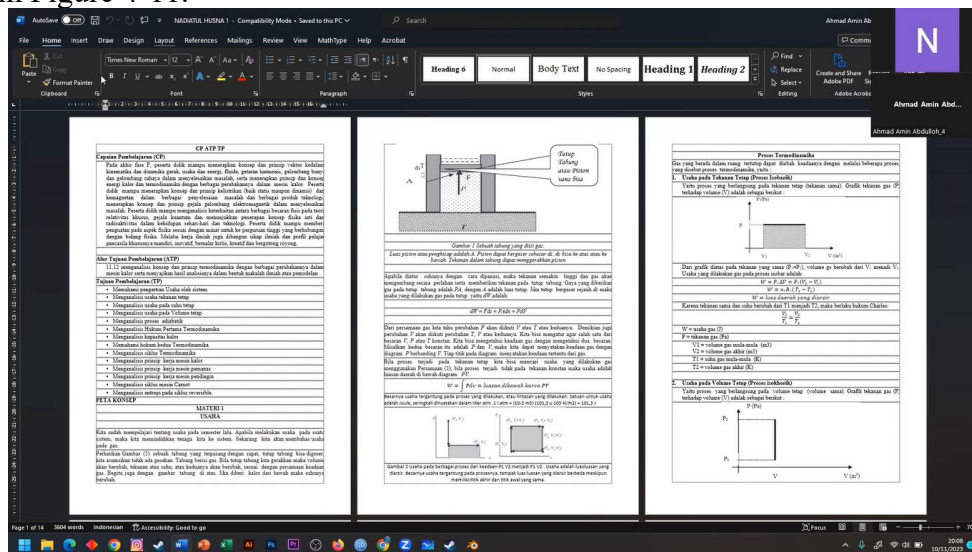


Figure 4 Creating Content on Ms Word

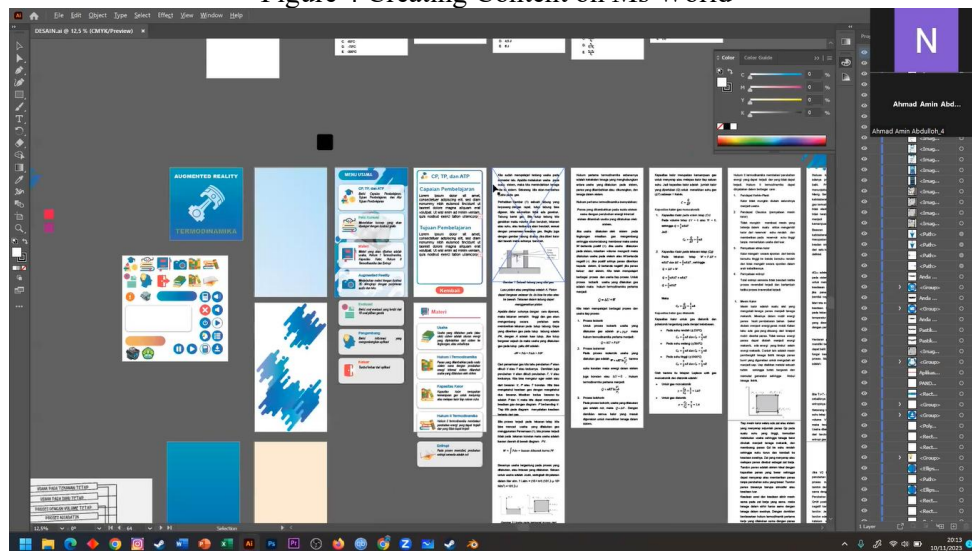


Figure 5 Exporting and Collecting Content in Adobe Illustrator

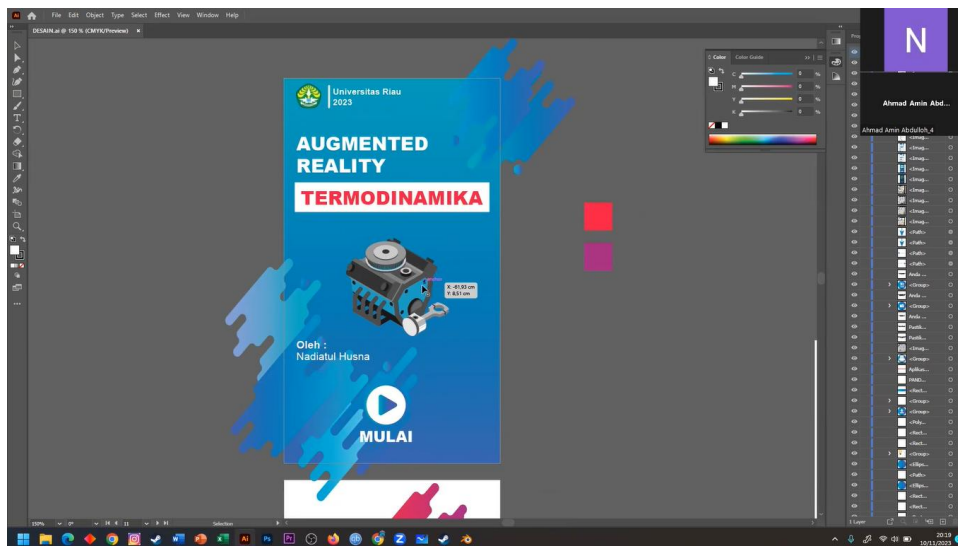


Figure 6 Designing the User Interface

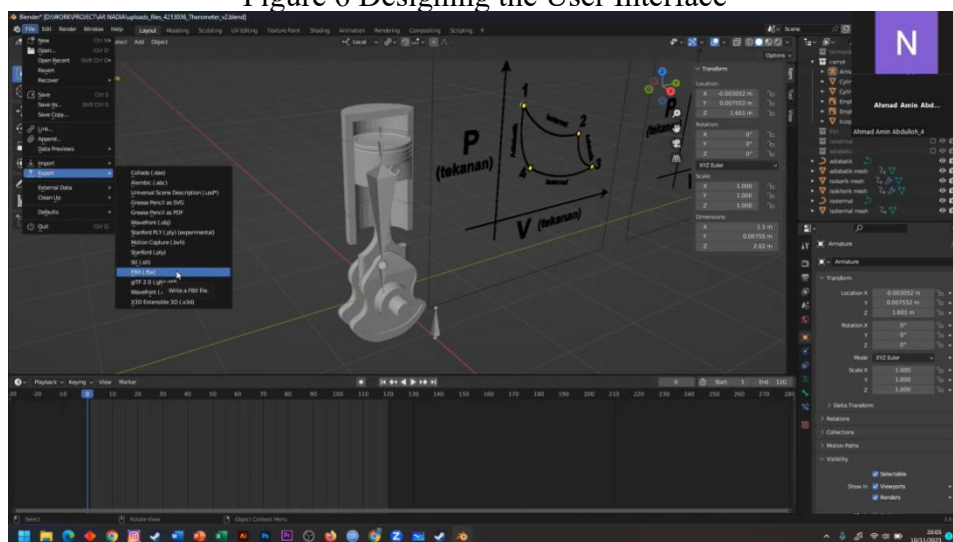


Figure 7 Creating 3D using a Blender 3D

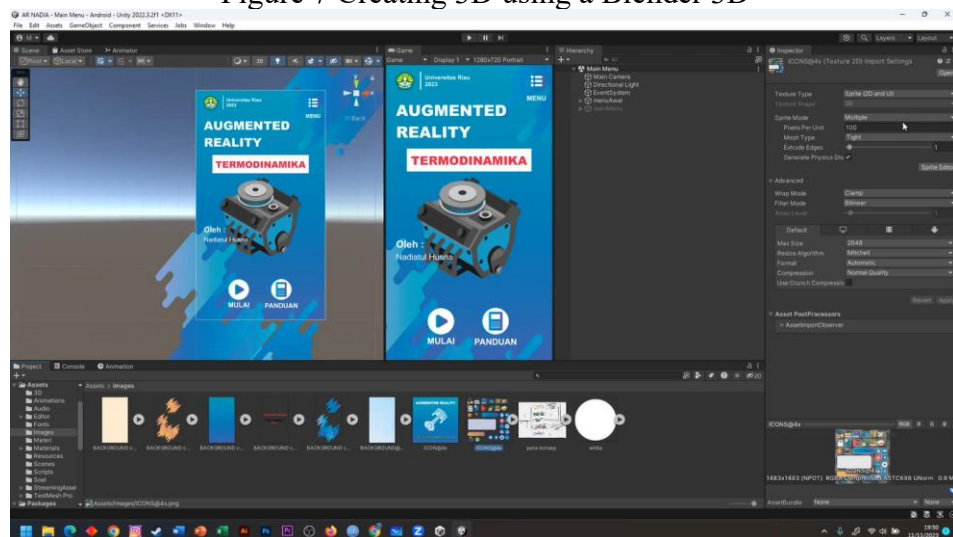


Figure 8 Inputting All Content in Unity

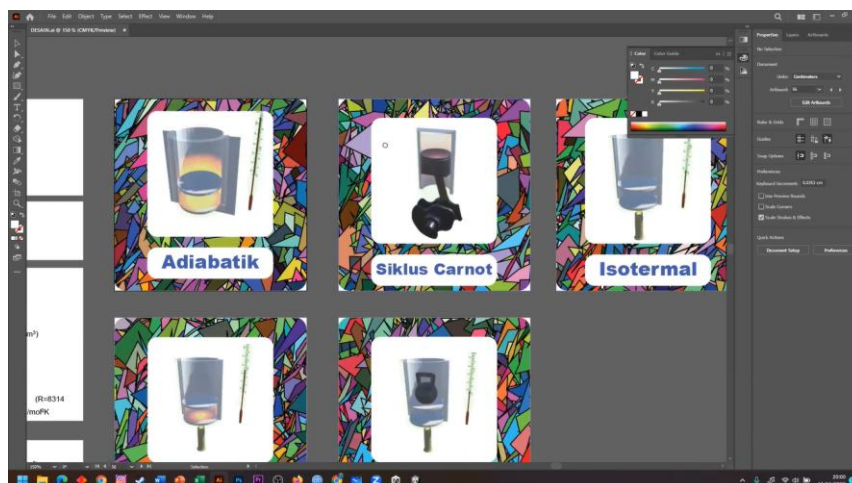


Figure 9 Making Markers

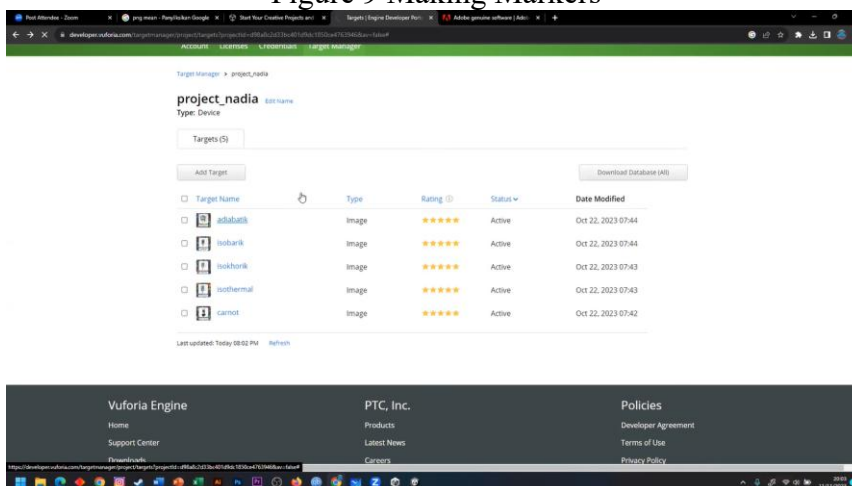


Figure 10 Uploading Markers to Vuforia

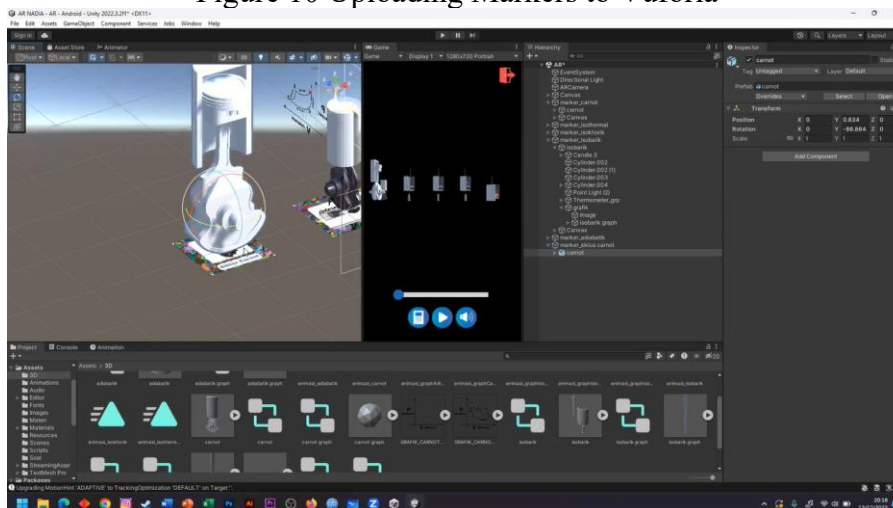
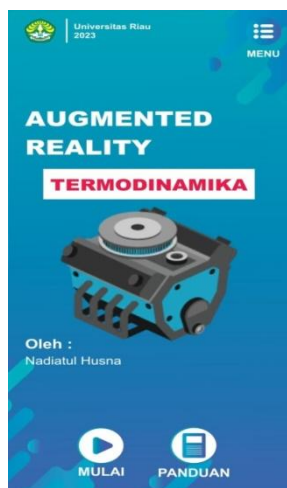


Figure 11 Combining 3D with Markers in Unity

The following results of the integrated multimedia display of augmented reality on thermodynamics material and multimedia in the form of applications installed on smartphones can be seen in Figures 12.



a) Early Display of AR Multimedia on Mobile Phone



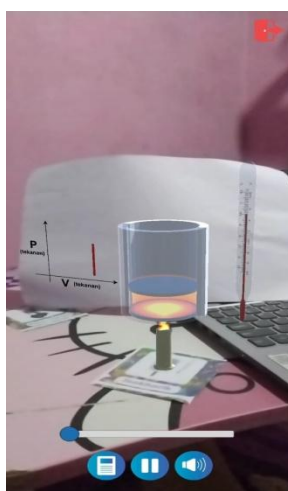
b) Main Menu Display



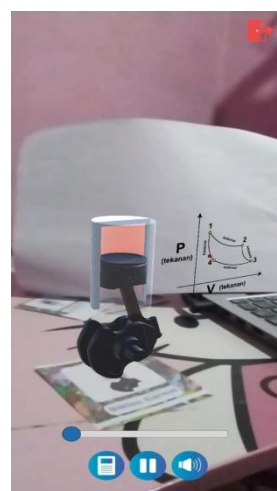
c) Display of Material Content



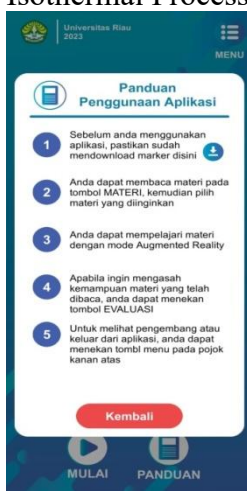
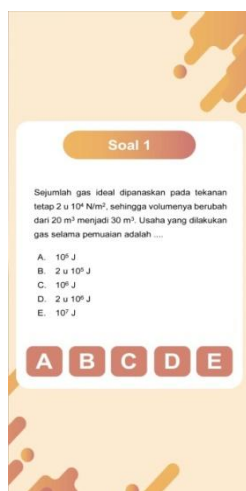
d) Augmented Reality Guide



e) Augmented Reality Display on Thermodynamic Isothermal Processes



f) ) Carnot Cycle Augmented Reality Display



g) Evaluation View      h) Application Usage      i) Application Menu  
 Guide Display      Display

Figure 12 Display of multimedia-augmented reality on thermodynamic material and multimedia in the form of applications installed on smartphones

### Technical Expert Validation Results

The results of the validation stage will be displayed according to each aspect, along with the results of the validation stage using Aiken's V formula presented in

Table 3. Validation Results for the Design Aspect

| No | Indicator                                                                     | $\sum s$ | V    | Category |
|----|-------------------------------------------------------------------------------|----------|------|----------|
| 1  | Display of fun and interactive learning media                                 | 12       | 1    | Valid    |
| 2  | Appropriate and easy to read font usage                                       | 12       | 1    | Valid    |
| 3  | The use of images on the media in accordance with the content of the material | 12       | 1    | Valid    |
| 4  | The use of images helps students' comprehension                               | 12       | 1    | Valid    |
| 5  | The images used help the learning process                                     | 12       | 1    | Valid    |
| 6  | Use of color appropriate for reading                                          | 10       | 0,83 | Valid    |
| 7  | Buttons or marks are easy to recognize                                        | 12       | 1    | Valid    |
| 8  | Learning media instructions and user guides are complete                      | 12       | 1    | Valid    |

Table 4. Validation Results for Pedagogical Aspect

| No | Indicator                                                           | $\sum s$ | V    | Category |
|----|---------------------------------------------------------------------|----------|------|----------|
| 9  | Competency writing is clearly written                               | 12       | 1    | Valid    |
| 10 | Teaching competence can be achieved                                 | 12       | 1    | Valid    |
| 11 | The formulation of competencies becomes a guideline for media users | 12       | 1    | Valid    |
| 12 | Topics according to competence                                      | 12       | 1    | Valid    |
| 13 | The presentation of the topic attracts the attention of students    | 12       | 1    | Valid    |
| 14 | The information conveyed is easy to understand                      | 11       | 0,92 | Valid    |
| 15 | This medium encourages students to think creatively                 | 12       | 1    | Valid    |
| 16 | The presentation of the material is organized and easy to follow    | 11       | 0,92 | Valid    |
| 17 | Examples and exercises are given according to the material          | 12       | 1    | Valid    |
| 18 | Learning methods in accordance with multimedia learning             | 12       | 1    | Valid    |

Table 5. Validation Results for Content Aspect

| No | Indicator                                                   | $\sum s$ | V    | Category |
|----|-------------------------------------------------------------|----------|------|----------|
| 19 | Learning materials in accordance with the K-13 Curriculum   | 12       | 1    | Valid    |
| 20 | Learning materials in accordance with competencies          | 12       | 1    | Valid    |
| 21 | Learning materials according to the student's ability level | 11       | 0,92 | Valid    |
| 22 | Learning materials in accordance with students' basic       | 11       | 0,92 | Valid    |

|    |                                                                   |    |      |       |
|----|-------------------------------------------------------------------|----|------|-------|
|    | knowledge                                                         |    |      |       |
| 23 | Learning materials contain educational value                      | 11 | 0,92 | Valid |
| 24 | Learning materials are accompanied by practice questions          | 11 | 0,92 | Valid |
| 25 | Exercises according to the topic of the lesson                    | 12 | 1    | Valid |
| 26 | The course material is accompanied by formative tests             | 12 | 1    | Valid |
| 27 | Formative tests according to the subject matter of subject matter | 12 | 1    | Valid |

Table 6. Validation Results for Technical Aspect

| No | Indicator                                                 | $\sum s$ | V | Category |
|----|-----------------------------------------------------------|----------|---|----------|
| 28 | Users can control the learning process                    | 12       | 1 | Valid    |
| 29 | Users don't get stuck while browsing media                | 12       | 1 | Valid    |
| 30 | The media has many branches to other parts                | 12       | 1 | Valid    |
| 31 | The journey of presenting media content is easy to follow | 12       | 1 | Valid    |
| 32 | There is more than one acquisition of information         | 12       | 1 | Valid    |
| 33 | Users can easily find the information they need           | 12       | 1 | Valid    |
| 34 | Users can exit the media whenever they want               | 12       | 1 | Valid    |
| 35 | Software is easy to use (operate)                         | 12       | 1 | Valid    |

Based on Tables 3–6, it appears that the results of the validation analysis for all four aspects using the Aiken V formula obtained validation results ranging from 0.9–1 with valid categories. Thus, all aspects of the validation instrument are proven valid, so AR-integrated multimedia is proven valid.

### User Expert Analysis Results

The results of the user expert assessment will also be displayed per aspect shown in Tables 7–9.

Table 7. Results of Attractiveness Aspect

| No | Indicator                                                                                                                                 | $r_{xy}$ | Category |
|----|-------------------------------------------------------------------------------------------------------------------------------------------|----------|----------|
| 1  | The AR multimedia display is interesting so it makes me excited to learn Thermodynamics material                                          | 0,553    | Medium   |
| 2  | I love learning using AR multimedia                                                                                                       | 0,686    | High     |
| 3  | I'm really excited to use AR animation in AR multimedia                                                                                   | 0,728    | High     |
| 4  | AR animation in AR multimedia added to my interest in studying Thermodynamics material                                                    | 0,651    | High     |
| 5  | Examples or phenomena in everyday life presented in AR multimedia increased my curiosity and motivation to learn                          | 0,507    | Medium   |
| 6  | Learning activities on AR multimedia that encouraged me to discover the concept of Thermodynamics myself made me excited to learn physics | 0,704    | High     |
| 7  | Learning using AR multimedia makes me happy to learn physics                                                                              | 0,486    | Medium   |

Table 8. Results of Ease of Use Aspect

| No | Indicator                                               | $r_{xy}$ | Category |
|----|---------------------------------------------------------|----------|----------|
| 8  | The language used in AR multimedia is clear and easy to | 0,538    | Medium   |

|    |                                                                                  |       |        |
|----|----------------------------------------------------------------------------------|-------|--------|
|    | understand                                                                       |       |        |
| 9  | I can follow every activity in AR multimedia easily                              | 0,541 | Medium |
| 10 | LKPD and the questions presented in the evaluation are easily accessible         | 0,627 | High   |
| 11 | QR or Marker given can be scanned easily                                         | 0,766 | High   |
| 12 | I can complete the evaluation according to the allotted time                     | 0,591 | Medium |
| 13 | I can complete learning activities on AR multimedia according to the time given. | 0,571 | Medium |

Table 9. Results of Benefit Aspect

| No | Indikator                                                                                                          | $r_{xy}$ | Category |
|----|--------------------------------------------------------------------------------------------------------------------|----------|----------|
| 14 | AR multimedia can help me in understanding Thermodynamics material                                                 | 0,422    | Medium   |
| 15 | By using AR multimedia I feel encouraged to be more active in learning                                             | 0,473    | Medium   |
| 16 | Learning activities in AR multimedia can encourage me to collaborate (work together) with other students           | 0,798    | High     |
| 17 | By using AR multimedia I can understand problems and phenomena in everyday life related to Thermodynamics material | 0,555    | Medium   |
| 18 | Learning activities with AR multimedia can encourage me to discover the concept of dynamics myself                 | 0,582    | Medium   |
| 19 | Learning activities in AR multimedia can train me to think critically.                                             | 0,541    | Medium   |

Based on tables 7-9, we can see the range of correlation values obtained from the three aspects is 0.4–0.7, with medium and high categories. Then the correlation results are valid because the resulting range of values is greater than 0.4.

#### Reliability Test Results

The results of the reliability test analysis using the Cronbach Alpha formula can be seen in Table 10.

Table 10. Reliability Test

| Cronbach's Alpha | N of Items |
|------------------|------------|
| 0,76             | 25         |

(Ghozali, 2006). (Mustaqim et al., 2017).

Based on Table 10, it appears that Cronbach's alpha value is 0.76; according to Ghozali, the instrument is said to be reliable if the value is greater than 0.60 (Ghozali, 2006). Therefore, the media is declared reliable in accordance with the results of the media assessment analysis through questionnaire items (Mustaqim et al., 2017).

#### Implementation

After multimedia is proven to be valid and realistic, then multimedia mobile learning integrated with augmented reality can be implemented or used in learning.

#### Evaluation

After the validation and implementation process, a product evaluation is carried out and if there are deficiencies or errors, revisions are made.

## Conclusion

Based on the results of the research and development that has been done, we have obtained Multimedia Mobile Learning Integrated Augmented Reality on Thermodynamics material class XI SMA. This medium was developed using the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation). Then the multimedia is validated by experts using four main aspects (design, pedagogy, content, and technical) in the instrument sheet, then tested by users, namely students, using instruments with three aspects, which include attractiveness, ease of use, and benefits. The results of the expert validity analysis show that AR integrated multimedia is tested. Valid, then the product correlation test for users found that AR multimedia has a value in the medium-high range classified as valid. The reliability test results get a value of 0.72 and fall into the realizable category. Thus, AR-integrated mobile learning multimedia on thermodynamic material is proven to be valid and reliable, so that multimedia can be used in the learning process and students can be more interested and motivated in learning. The implications of this research include a technology-based learning process where technology assistance is expected to improve the quality of learning, considering that the multimedia products that have been developed require technological facilities in the form of gadgets and internet networks, but the facts in the field found that there is still uneven technological development in various regions, especially remote areas that are still not reached by internet networks. So this augmented reality-integrated multimedia is difficult to use. It is hoped that in the future, technological equality can be achieved in all parts of the world so that the effectiveness and benefits of this augmented reality integrated multimedia development can be felt by all students in the world and can help them in learning.

## Recommendation

It is recommended that AR-integrated mobile learning multimedia on Thermodynamics be adopted more widely in the classroom to enhance student engagement and understanding of abstract scientific concepts. However, to maximize its effectiveness and accessibility, further development should include offline-compatible versions, and educational stakeholders must ensure equitable access to the necessary technology, especially in remote or underserved areas.

## Acknowledgment

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