Development of Integrated Physics Learning Tools in Virtual Laboratory Platform: Its Implementation through the POGIL Strategy in Indonesian Frontier Areas

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***Abstract* – Limited facilities in frontier areas raised challenges in education. Physics education, in particular, faces difficulties due to abstract concepts, necessitating effective teaching strategies and media. This research aims to develop integrated physics learning tools in a virtual laboratory platform and implement them using the process-oriented guided-inquiry learning (POGIL) strategy. The study employs a development method based on the ADDIE approach and has an urgent need to create adaptive learning technology to enhance learning outcomes, especially in physics. The developed application is named Physics Fun. Research findings validate the effectiveness of the Physics Fun media. A trial involving 54 students from the University of Papua, Indonesia, enrolled in general physics courses was conducted. At the trial's conclusion, participants completed an online technology acceptance model (TAM) questionnaire. Students reported an improved understanding of the subject matter and an increased ability to conduct experiments previously limited by available resources. Physics Fun media proves generally effective, practical, and accessible anytime, anywhere for students.**

***Keywords* – Abstract concepts, physics fun media, POGIL, virtual laboratory.**

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1. Introduction

Many countries, such as Indonesia, continue to require increased access to education despite technological advancements [1]. One of the obstacles to implement online learning in Indonesia is that students do not have access to technologies such as computers and Internet networks especially in frontier areas, which refer to regions that experience difficulties in obtaining adequate educational facilities.

The problems faced in schools such as in West Papua Province, one of the most frontier areas of Indonesia located in the eastern part, are the limited facilities and infrastructure to support practical activities, especially in science learning [2], [3], [4]. Science learning activities experience obstacles, especially in practical activities that require adequate facilities. Practical equipment is challenging to provide because it is expensive. In addition, experiments in natural laboratories are not enough because many science concepts are abstract, causing students to have difficulty in abstracting these concepts.

For instance, one of the abstract science materials, especially physics, is material about electrical circuits. Some students often consider this material complicated, and the ability to visualize and understand concepts in electrical circuits can be challenging. Students require assistance in understanding the relationships between different concepts, particularly the relationships between quantities, which can be grasped through practical processes [5]. Educators need to innovate their teaching by utilizing appropriate media presentations and implementing suitable learning strategies so that students can comprehend abstract scientific material [6]. Teachers must utilize technology to empower their learning and address the issue of learning loss [7]. Consequently, to resolve these challenges, adaptive learning media innovation is required.

One such innovation is using mobile devices as interactive and engaging student learning aids [8], [9]. Most students have smartphones, but not many use them to access learning content [10]. Therefore, they need guidance to use them wisely as a learning medium. The dynamic computing environment of modern mobile devices is the most suitable solution for overcoming learning obstacles, as they are dependable, customizable, and user-friendly [11]. Mobile applications provide adaptive flexibility and accessibility, enhancing the learning process's practicality and interactivity.

Students may utilize mobile applications as a learning medium, which they may access individually and collaboratively. A virtual laboratory (V-Lab) is one of the adaptive learning media that can be employed in scientific education. Using V-Lab, students can gain a more concrete and practical understanding of scientific concepts [12]. The V-Lab application was developed in mobile form for this investigation. A new perspective for more engaging science learning will emerge with the development of the V-Lab mobile application. The primary emphasis is on students' comprehension of concepts and abilities. However, the application of these various media cannot be maximized without appropriate learning strategies.

A strategy generally applied in scientific investigations such as chemistry, physics, biology, and mathematics can use a guided inquiry strategy known as process-oriented guided-inquiry learning (POGIL) [13]. The POGIL strategy can be implemented through practicum activities [14] using virtual practicum or V-Lab in this research. It can effectively support students' learning requirements by integrating strategy, environment, and learning media. Therefore, this research aims to develop physics learning tools in the V-Lab platform and its implementation through the POGIL strategy in Indonesian frontier areas. In its development, it uses an instructional design system, namely ADDIE. ADDIE is an instructional system design model with a systematic approach [15]. The results of this development were then tested to see the acceptability of this media among students.

2. Literature Review

The theoretical foundations supporting this research are discussed in this literature review, which covers instructional strategies, virtual laboratories, and the technology acceptance model. These three aspects provided comprehensive insights and served as a crucial foundation for developing integrated physics learning tools in virtual laboratory platforms and their implementation through the POGIL strategy, particularly in the context of education in frontier areas with their unique challenges.

2.1. Instructional Strategy

There are several ways to apply media using various learning models, such as project-based, problem-based, or inquiry-based, in POGIL learning. There are several ways to apply media using various learning models, such as project-based, problem-based, or inquiry-based, in POGIL learning. Here are several ways this application supports learning models. First, project-based learning (PjBL), a form of media that can provide challenging projects or assignments, allows students to apply concepts in real situations and provides resources like virtual experiments to design or conduct projects. Previous research results show that implementing mobile applications in the PjBL model can increase students' motivation and participation in learning [16], [17]. Second, cooperative learning can have features enabling student collaboration, such as discussion forums, collaborative projects, or platforms for sharing ideas and solutions. Facilitate student interaction and collaboration in solving problems, answering questions, or sharing an understanding of dynamic electrical concepts. Third, problem-based learning (PBL) has features that allow students to collaborate in solving problems, such as collaborative projects in virtual experiments. This collaboration can help students solve problems together. Media can serve as a tool to support PBL by creating a learning environment where students can work together, solve problems, and apply their knowledge to real-life situations [18]. The research results showed that mobile learning physics (MOBLEP) was effectively implemented by implementing the Android-based PBL Approach and could increase students' learning independence [19]. Fourth, POGIL learning is a medium that provides virtual simulations or experiments that allow students to carry out experiments in a safe and controlled environment. POGIL will enable students to observe phenomena directly and understand the concepts through visual experiences [20]. Media can be a valuable tool in supporting inquiry learning, allowing students to be actively involved in discovering and understanding concepts more deeply. Research shows that learning through mobile applications is better through inquiry-based learning strategies than other learning activities. Integrated physics learning tools in the V-Lab platform in frontier areas provide resources, content, and features that support activities related to learning models, not just those that are limited to the learning models delivered. Media can be a valuable tool in supporting various learning strategies according to the needs of students.

Of course, these learning phases must be adjusted to the stages of media use. For example, if learning is carried out in groups, students can take advantage of features in the form of available worksheets or collaboratively carry out activities such as virtual experiments.

2.2. Virtual Laboratory

V-Lab refers to a software-based collection of laboratory tools that use interactive simulations, operated on a computer or device, to replicate laboratory activities similar to those conducted in a real lab [21]. V-Lab has the potential to significantly enhance and make learning experiences more effective [22]. It can also serve as a solution to the challenges posed by limited facilities and infrastructure that are necessary for conducting practical activities [23]. These practical sessions are crucial for helping students grasp concepts, especially in physics, which involves understanding everyday phenomena [24], [25]. Students need a solid conceptual foundation in the subject matter.

V-Lab uses computers to simulate complex and expensive experimental equipment or to replace experiments that would otherwise be conducted in hazardous environments [26], making it particularly effective in frontier areas. It allows students to visualize and simulate concepts [27], interact with phenomena, and engage in hands-on learning [28]. V-Lab acts as a supportive tool that enriches the learning process, motivating students to conduct interactive experiments and hone their experimental skills [29], [30]. Essentially, V-Lab is a series of computer programs designed to make abstract phenomena or complex experiments more accessible, thereby enhancing learning activities and improving problem-solving abilities. Various platforms offer V-Lab programs that are freely accessible for educational purposes. In this research, the V-Lab platform used is the physics education technology (PhET) program, which is a collection of virtual experiments developed by the University of Colorado Boulder.

2.3. Technology Acceptance Model

The technology acceptance model (TAM) is a theoretical framework designed to understand and assess how individuals accept and utilize technology. Originally developed by Fred Davis in 1989, the model emphasizes the importance of perceived usefulness and ease of use in determining users' intentions to engage with a system, which ultimately leads to actual usage [31]. TAM includes key constructs such as perceived usefulness and perceived ease of use, which directly impact behavioral intentions and, consequently, the actual use of the system [32]. However, behavioral intention and actual system use can be replaced by the construct of acceptance of IT [33]. The description of the TAM used in this research is as in Figure 1.

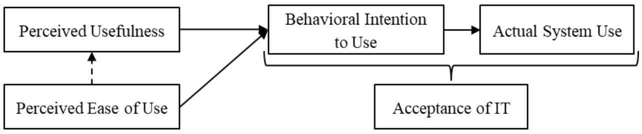


Figure 1. TAM construct

Perceived usefulness is a factor that measures the extent to which students believe that using physics learning tools in the V-Lab platform will provide positive benefits to learning. Perceived ease of use measures the extent to which students believe they can use the media easily, without encountering significant difficulties. Acceptance of IT is students' acceptance of the media which is influenced by the ease and usefulness of the physics learning tools in the V-Lab platform.

3. Methodology

The method for developing physics learning tools in the V-Lab platform for physics learning in frontier areas is using the ADDIE approach. The ADDIE method is a systematic approach to instructional development that consists of five main stages: analysis, design, development, implementation, and evaluation [34]. The ADDIE stages used are as in Figure 2.

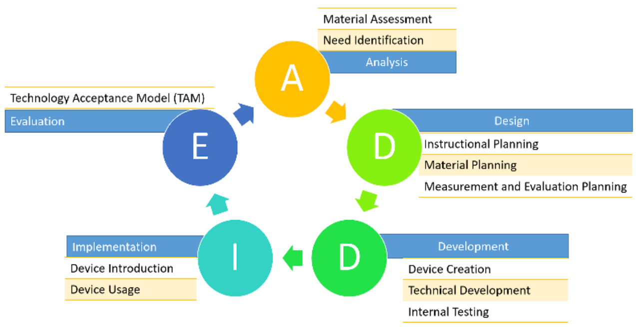


Figure 2. ADDIE stages in developing physics learning tools and instructional strategy in the V-Lab platform for physics learning in frontier areas

In the analysis stage, the identification of requirements entails determining learning objectives and comprehending the target audience, learning objectives, and the significance of this particular learning. This stage also involves the evaluation of the content or learning material that is to be taught. However, material assessment is also conducted.

It encompasses a comprehension of the competencies that can be developed in the course material content, user requirements, and available resources in to the context of the frontier areas.

The design stage includes instructional design and creating a learning plan with structure, objectives, and learning methods. This includes selecting appropriate learning strategies to achieve learning goals. The material design comprises developing learning materials, such as curriculum, modules, or teaching materials. It includes content selection, media selection, and instructional interface design. Designing measurement and evaluation is carried out by planning ways to measure learning success by presenting evaluation questions.

The development stage involves the creation of learning materials planned during the design stage. It includes content development, visual design, and interactive elements. Internal technical development and testing involve developing and testing devices with potential users to identify problems and improvements that may be needed.

Implementation was carried out on 54 students from the Faculty of Teacher Training and Education, University of Papua, who programmed the general physics course. The University of Papua is one of the universities located in the frontier area. Implementing the media developed can overcome various problems faced in this frontier area. At the implementation stage, learning materials are introduced, namely, launching learning materials to target users or students. It is done in class for students who study dynamic electricity material. Use of learning materials in the learning context by the plans made. Teachers can provide necessary guidance and support.

Evaluation is carried out after completion of learning, and an overall assessment is carried out to assess the overall effectiveness of the learning material. This evaluation is also the final assessment of the achievement of learning objectives. TAM questionnaire is given at this stage. The questionnaire aims to determine the user acceptance level of the mobile media used.

The instruments used in this research include validator assessment sheets and TAM instruments to measure the acceptance of the developed application. The assessment analysis by the validator is carried out through content validity for each statement item using the content validity ratio (CVR) equation. In contrast, the validity analysis for each aspect, which consists of several items, uses the content validity index (CVI) [35].

The CVR and CVI values range is $-1 < 0 < 1$. The assessment is valid if the CVR or CVI ranges from 0 to 1 [35]. At the end of the trial, an online TAM questionnaire was administered.

The aim of administering the TAM questionnaire is to measure users' acceptance or adoption of a technology. TAM is a framework used to understand user behavior toward adopting information-based technology. The following is the TAM grid and questionnaire given to students after implementing learning using Physics Fun media (https://bit.ly/surveiphysicsfun). The questionnaire has a negative statement, so students should be careful when filling it out.

Table 1. TAM questionnaire

No	Indicator	Item Code	Statement
1	Perceived Ease of Use	-PEU1	I had a hard time learning how to use Media Physics Fun.
		+PEU2	I am skilled in using Media Physics Fun.
		+PEU3	I can use Media Physics Fun to make it easier for me to learn the material.
		+PEU4	I can interact with Media Physics Fun.
		+PEU5	I can understand well how to interact with Media Physics Fun.
		+PEU6	I think that Media Physics Fun is a flexible program.
		+PEU7	I can use Media Physics Fun easily.
2	Perceived Usefulness	+POU1	I can learn faster with Media Physics Fun.
		+POU2	I think that learning becomes easier by using Media Physics Fun.
		+POU3	I can increase my learning productivity with Media Physics Fun.
		+POU4	I can increase learning effectiveness with Media Physics Fun.
		+POU5	I think that Media Physics Fun can be useful for me.
		+POU6	I was helped in getting study material through Media Physics Fun.
		-POU7	I find it challenging to carry out learning activities through Media Physics Fun.
3	Acceptance of IT	+AOT1	I am comfortable using Media Physics Fun.
		+AOT2	I enjoy using Media Physics Fun.
		-AOT3	I'm bored of using Media Physics Fun.
		+AOT4	Media Physics Fun provides the information I need.
		+AOT5	I studied by referring to the information provided by Media Physics Fun.
		+AOT6	Media Physics Fun provides accurate information.
		+AOT7	I can use Media Physics Fun for a long time.

Source: [32], [36]

The TAM questionnaire was then analyzed using modern analysis techniques and Rasch modeling. Rasch modeling was conducted to investigate the effectiveness and practicality of questionnaire assessments filled in by students during learning activities. Rasch modeling was performed using the Winstep application. This technique provides a more accurate analysis compared to other methods [37].

4. Research Findings

The study results include design and development, namely the framework of instructional strategies and the development of physics learning tools in the V-Lab platform. Furthermore, the implementation of the POGIL strategy and evaluation of the TAM analysis are explained.

This study shows that developing and implementing physics learning tools in the V-Lab platform effectively increases student engagement. Implementing the POGIL strategy strengthens interaction and active learning, while the TAM analysis shows good acceptance and benefits in the context of education in frontier areas.

4.1. Design and Development

4.1.1. Framework of the Instructional Strategy in V-Lab Platform

The learning theory that is influential in media design is constructivism theory, which focuses on student-centered learning, namely that they actively build their understanding through experience and reflection [38]. The material is presented in a way that allows students to explore, and virtual experiments and exercises will enable them to build an understanding of physics concepts through direct interaction. The second is the connective theory, which emphasizes the importance of information networks, relationships, and connectivity in learning. The connectivism theory, developed in 2005 by theorists George Siemens and Stephen Downes, posits that technology has transformed how information is transmitted and received, thereby altering the learning process [39]. The material in the media is presented with a focus on connected resources, linking the concepts of the material studied with other relevant content [40], such as online resources from Google Drive, Google Forms, and PhET simulation, to broaden students' understanding. Third, although behaviorism theory tends toward teacher-centered learning [41], behaviorism underlines the importance of positive reinforcement for desired behavior [42]. Positive reinforcement is provided as immediate feedback when students answer questions correctly or complete tasks well, encouraging motivation and repetition of desired behavior. The influence of these learning theories is reflected in media design by providing interactive content, allowing students to explore independently, providing clear feedback, and facilitating connections between the concepts taught and other relevant resources. By considering these various learning theories, applications can facilitate compelling and exciting learning for students.

The cognitive theory of multimedia learning (CTML) is the theoretical basis for this media development. CTML integrates cognitive principles with multimedia design to understand learning through media such as text, images, sound, animation, and simulation [43]. There are several ways to apply media using various learning models, such as project-based, problem-based, or inquiry-based, in POGIL learning. POGIL will allow students to observe phenomena directly and understand concepts through visual experiences. The theoretical framework is shown in Figure 3.

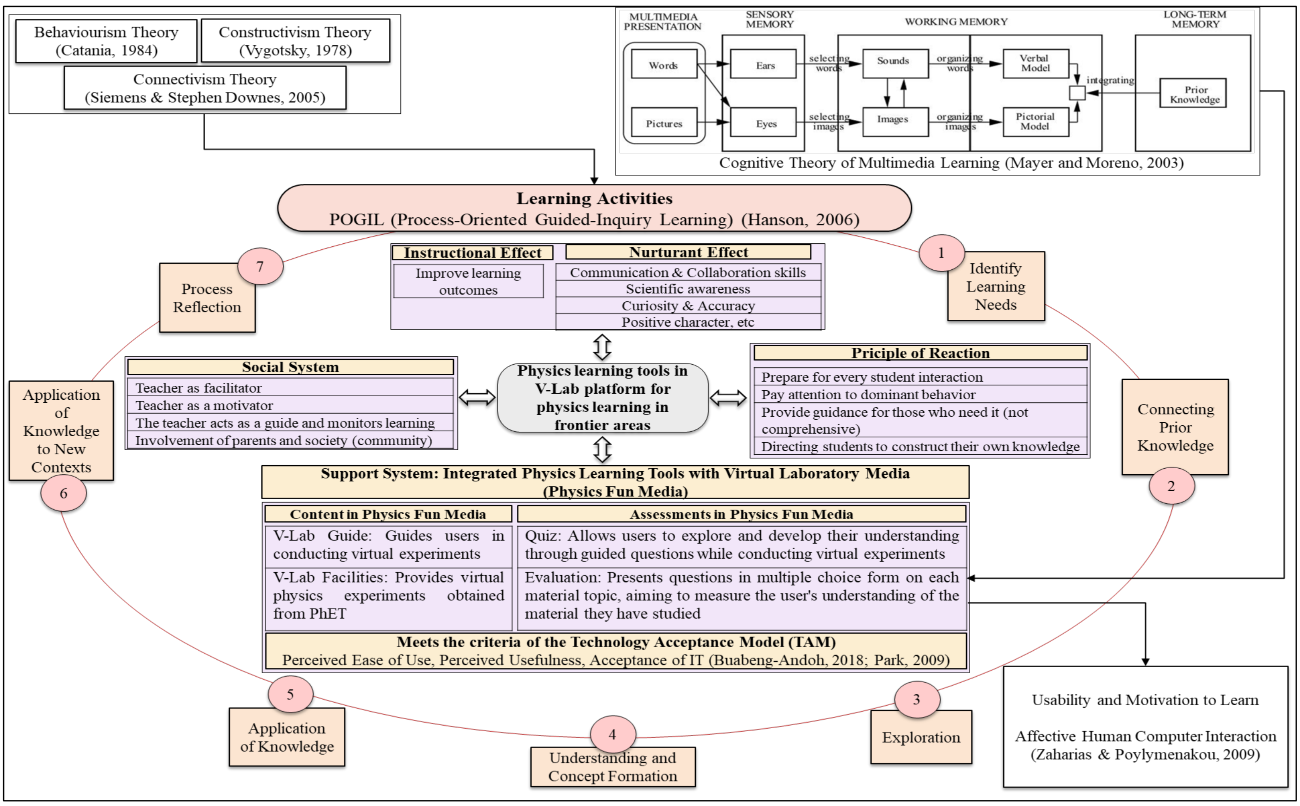


Figure 3. Theoretical framework in developing physics learning tools and POGIL strategy in V-Lab platform for physics learning in frontier areas

The theoretical framework design created, as shown in Figure 3, aims to create an effective learning environment, especially in frontier areas, where every student can achieve academic success in learning with support according to their individual learning needs. This framework consists of elements of the learning model, namely syntax (stages of learning activities), social system (learning situation), reaction principle (teacher behavior towards students), support system (V-Lab integrated physics learning device facilities), and instructional and nurturant effect. This framework is expected to provide an adaptive and meaningful learning experience tailored to the needs of all students. Adaptive technology facilities in this framework are integrated into Physics Fun media to motivate students [44] and organize and facilitate learning well.

4.1.2. Physics Learning Tools in V-Lab Platform

The need to use Physics Fun media varies depending on the context. Users of Physics Fun media require relevant, complete material from the school curriculum.

The material in this application is well structured, provides clear and comprehensive explanations, and offers exercises that support understanding according to the existing curriculum. Students can use this application to carry out virtual experiments that have never been done before. It can increase efficiency in teaching, especially in frontier areas. This media can enrich understanding and provide additional insight regarding physics concepts for users interested in understanding physics concepts more thoroughly. The use of this media varies, depending on the context of use; it has an interface that is intuitive, easy to use, visually attractive, and complies with UI/UX principles. Responsive design and simple navigation can help users navigate media more efficiently. Figure 4 illustrates the user flow of the Physics Fun media under development.

Concept design is carried out at this stage, namely designing media concepts in physics learning. This stage includes user interface design, workflow, and critical features. Instructional design is creating an instructional plan that explains how the application will be used in learning. Technical specifications determine the technical requirements for application development, including the platform, technology, and infrastructure used.

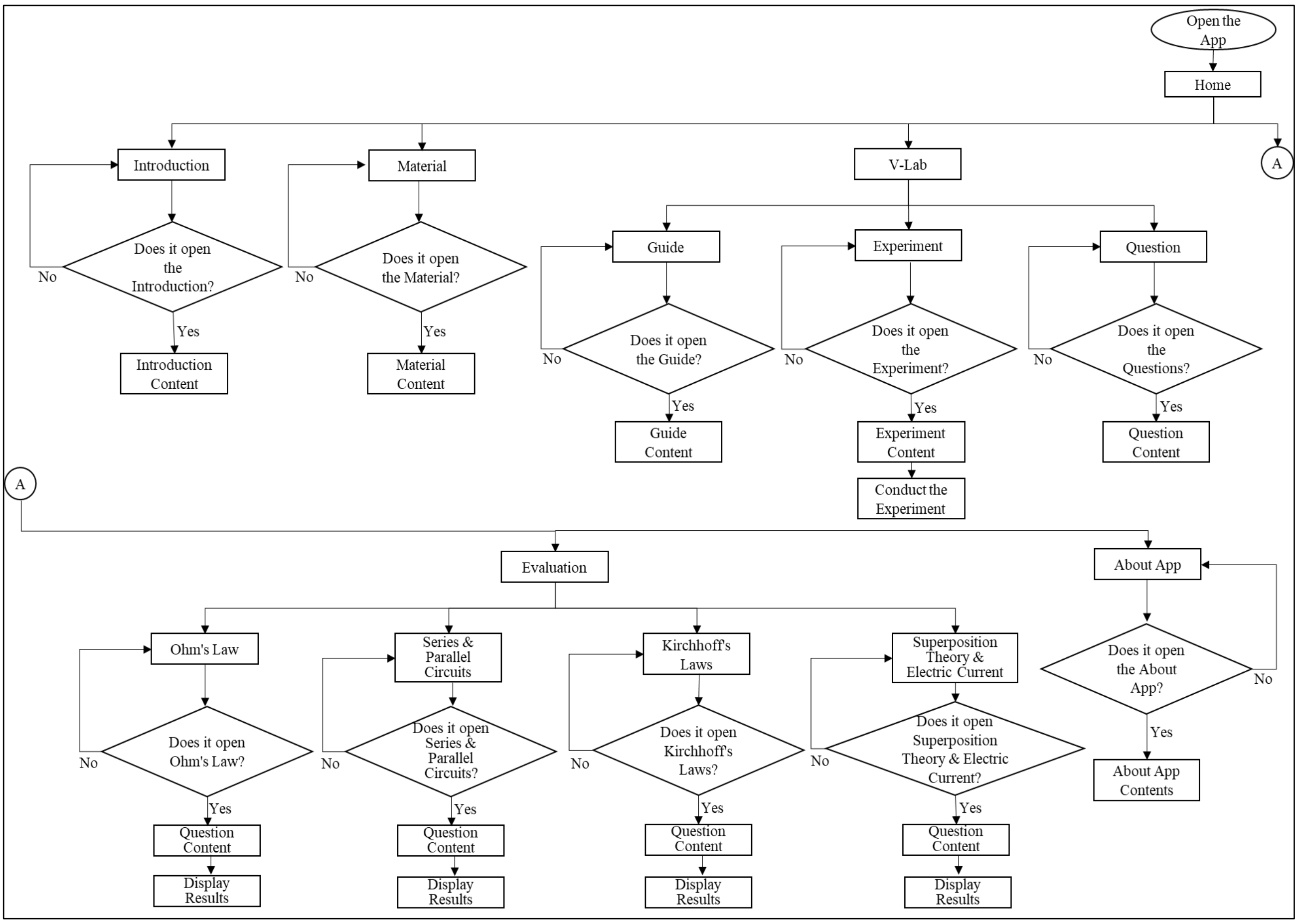
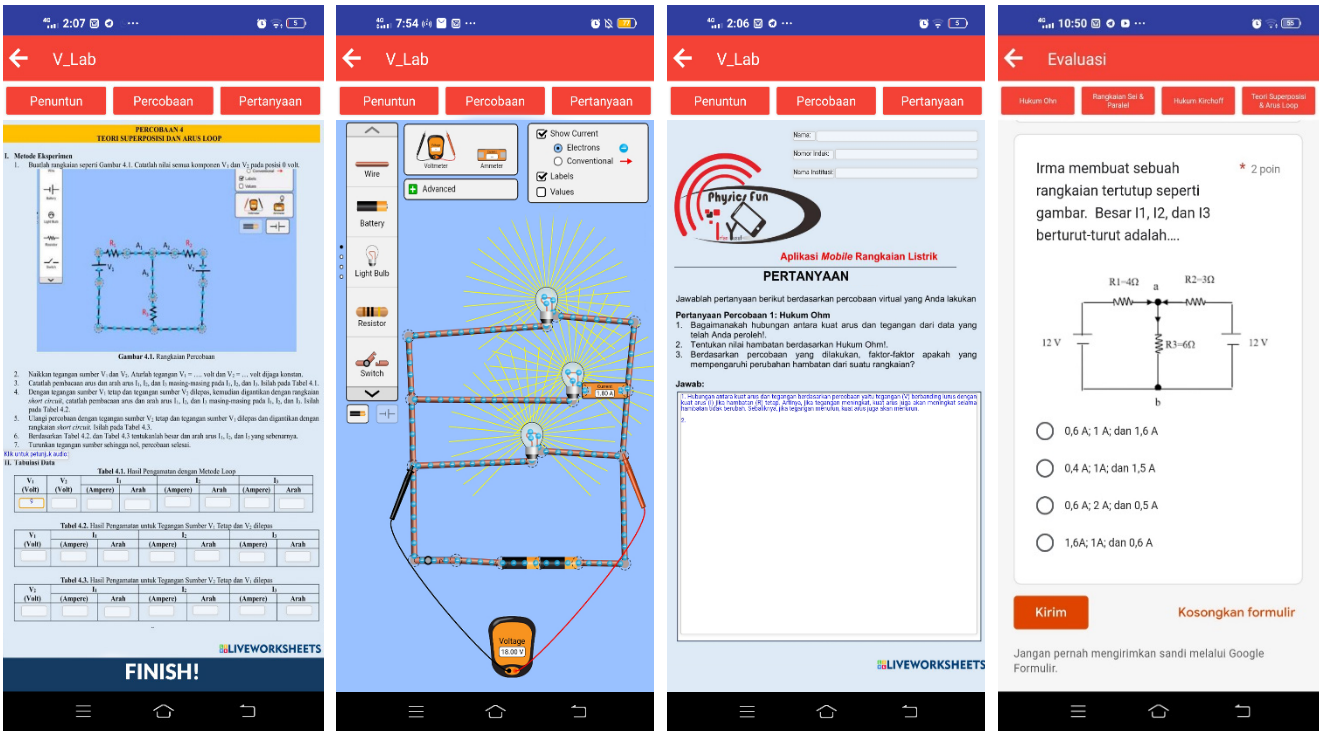


Figure 4. User flow of the Physics Fun media

Content development includes creating or integrating relevant learning content on electrical circuit material. Testing includes running trials to detect issues and needed enhancements. The name of the application being developed is Physics Fun. This application was developed using various platforms: Kodular for creating mobile applications, PhET as a V-Lab platform, Canva for application design, LiveWorksheets for creating interactive worksheets, and Google Forms for presenting quizzes.

The developed application can be exported as an Android app (.apk) or Android app bundle (.aab). The initial results of the Physics Fun mobile development product are shown in Figure 5 (can be downloaded at the link: https://bit.ly/PhysicsFun1).



(a) (b) (c) (d)

Figure 5. User interface of Physics Fun media (a) guide, (b) V-Lab, (c) quiz, and (d) evaluation

This application allows students to run virtual experiments, change parameters, and see the impact of changes in real-time. This Physics Fun media consists of a guide, V-Lab, and evaluation. The guidance facility guides users in conducting virtual experiments. This guide can be used to input experimental data directly via liveworksheets without needing to be printed, or it can also be downloaded as needed. Teachers can directly assess the results of students' inputting data from observations via the LiveWorksheets account. The V-Lab feature provides virtual physics experiments obtained from PhET. Students can modify variables or parameters to see how the results affect electrical circuit experiments. The evaluation feature consists of essay and multiple-choice questions. This feature aims to measure the user's understanding of the material they have studied. The multiple-choice questions feature can provide feedback on how well the user understands the physics material and where areas need more attention. It provides students with an opportunity to enhance their skills in understanding and applying physics concepts, as well as to assess their ability to grasp and utilize the physics concepts they have learned. The teacher can immediately check all students' work results via their account.

This Physics Fun media was designed to consider the curriculum, especially general physics courses at applicable universities, so that it helps students teach material according to curriculum standards. Media supports learning with limited facilities and infrastructure. Physics Fun media can be adapted and customized to particular needs and learning developments. This Physics Fun media provides flexibility in use and further development. This innovation has great potential to enrich physics learning. This Physics Fun media can be an effective medium in supporting physics learning.

Lecturers from three different universities performed the validation. Validation was carried out about Physics Fun media and materials. The media expert validator assessment results showed that all aspects and statements obtained valid results (CVI and CVR obtained a value of 1).

Several suggestions were made by the validator related to inputting observation results directly without requiring the user to print a worksheet. This input has been improved using a live worksheet so users can input answers directly via Physics Fun media. Users are also provided with files that can be downloaded to be studied or printed according to their needs. Media needs to provide convenience regarding what users want so that they are interested in using the press [45]. The assessment of material expert validators is carried out by aspects and statements as per the standards for using media in learning.

Valid assessment results were obtained for each assessment aspect based on the validation results. The validator's suggestion regarding the media being developed is the need to optimize the use of media in learning so that printing documents in the form of worksheets should not be necessary but can be filled in directly online by the user. This has been improved by presenting the worksheet via a live worksheet facility so that users can directly input the results of observations. Likewise, teachers can directly see the results of student work.

4.2. Implementation and Evaluation of Physics Learning Tools in V-Lab Platform through the Implementation of the POGIL Strategy

The treatment in this study used physics learning tools in V-Lab platform (Physics Fun media), which follows POGIL syntax [46], [47]. The integration of POGIL syntax is presented in Table 2.

Table 2. POGIL syntax in Physics Fun media

POGIL Syntax	Use of Physics Fun Media
Identify learning needs	
Connect previous knowledge	
Exploration	Learn the principles of experimentation
Understanding and concept formation	Learn the steps for conducting virtual experiments according to the worksheet provided
Applying knowledge	Conduct experiments virtually
Apply knowledge to new contexts	Obtain observational data
Process reflection	Use of Physics Fun media

Implementation was carried out on 54 University of Papua students taking general physics courses (who attended the learning sessions and completed the questionnaires). Learning with the POGIL strategy is implemented according to the learning stages, and the activities are documented using Physics Fun media, as shown in Figure 6.

The POGIL learning model is used to facilitate the learning process. POGIL activities generally consist of three parts: introduction, content, and conclusion. Preliminary activities include orientation and explaining the inquiry process that can occur before and during learning. Teachers act as motivators in preliminary activities.

Figure 6. Application of Physics Fun in learning

The POGIL model can be effectively implemented by utilizing existing resources, including the technological tools provided. Learning using Physics Fun media can be done not only in the classroom but also outside the classroom. Broad access to all mobile devices and learning opportunities without boundaries of space and time [48] makes mobile learning meaningful in the learning process [49]. Students can access various features available on Physics Fun media. They can collaborate to carry out virtual practicums or study existing material. An instructional system is needed to implement mobile learning; for example, a blended learning approach can be used by educators to deliver lesson material in an integrated manner [50]. In order to enhance student achievement and establish a learning environment that is conducive to learning, it is imperative to implement instructional strategies that are tailored to the material and students' characteristics [51]. Mobile learning technology allows the inclusion of several learning models, thereby successfully involving students in constructing their learning. Comprehensive learning theories must be accommodated in mobile learning by considering user age, learning approach, field of study, user role, and cultural values [52]. Therefore, it is essential to implement mobile learning through appropriate learning strategies.

Evaluation is carried out after the completion of learning, namely, an overall assessment of the overall effectiveness of the learning material. It is essential to evaluate the impact of mobile learning, not only on students' cognitive abilities, and investigate the affective domain during learning [53]. The ADDIE process is a continuous cycle where continuous improvement can occur after each implementation and evaluation. This method allows for structured and effective instructional development. At the end of the lesson, students are given a TAM questionnaire, which they fill out online.

The results of the questionnaire analysis using Rasch modeling are shown in Figure 7.

```
INPUT: 54 Person  21 Item  REPORTED: 54 Person  21 Item  5 CATS    WINSTEPS 3.73
--------------------------------------------------------------------------------

SUMMARY OF 54 MEASURED Person
-------------------------------------------------------------------------------
|          TOTAL                         MODEL         INFIT        OUTFIT    |
|          SCORE      COUNT     MEASURE  ERROR      MNSQ   ZSTD   MNSQ   ZSTD |
|-----------------------------------------------------------------------------|
| MEAN      88.0       21.0       1.20     .31      1.29     .0   1.15    -.1 |
| S.D.      11.2         .0        .86     .15       .99    2.2    .85    2.0 |
| MAX.     104.0       21.0       3.90    1.01      4.06    3.3   4.27    3.4 |
| MIN.      52.0       21.0       -.46     .18       .14   -4.0    .16   -3.5 |
|-----------------------------------------------------------------------------|
| REAL RMSE    .44 TRUE SD     .74  SEPARATION  1.67  Person RELIABILITY  .74 |
|MODEL RMSE    .35 TRUE SD     .79  SEPARATION  2.28  Person RELIABILITY  .84 |
| S.E. OF Person MEAN = .12                                                   |
-------------------------------------------------------------------------------
Person RAW SCORE-TO-MEASURE CORRELATION = .90
CRONBACH ALPHA (KR-20) Person RAW SCORE "TEST" RELIABILITY = .87

SUMMARY OF 21 MEASURED Item
-------------------------------------------------------------------------------
|          TOTAL                         MODEL         INFIT        OUTFIT    |
|          SCORE      COUNT     MEASURE  ERROR      MNSQ   ZSTD   MNSQ   ZSTD |
|-----------------------------------------------------------------------------|
| MEAN     226.2       54.0        .00     .17       .99    -.2   1.15     .2 |
| S.D.      18.2         .0        .41     .02       .62    2.4    .82    2.6 |
| MAX.     251.0       54.0       1.15     .24      3.05    6.3   3.50    6.3 |
| MIN.     166.0       54.0       -.83     .12       .25   -4.2    .27   -3.4 |
|-----------------------------------------------------------------------------|
| REAL RMSE    .18 TRUE SD     .37  SEPARATION  2.01  Item   RELIABILITY  .80 |
|MODEL RMSE    .17 TRUE SD     .38  SEPARATION  2.23  Item   RELIABILITY  .83 |
| S.E. OF Item MEAN = .09                                                     |
-------------------------------------------------------------------------------
UMEAN=.0000 USCALE=1.0000
Item RAW SCORE-TO-MEASURE CORRELATION = -.98
1134 DATA POINTS. LOG-LIKELIHOOD CHI-SQUARE: 2282.87 with 1057 d.f. p=.0000
Global Root-Mean-Square Residual (excluding extreme scores): .8672
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Figure 7. Summary statistics

Figure 7 shows the quality of the TAM questionnaire instrument used. The INFIT and OUTFIT MNSQ values have been ideally used, namely close to 1 (Mean INFIT MNSQ person is 1.29 and Mean INFIT MNSQ item is 0.99, and Mean OUTFIT MNSQ person and item are 1.15 respectively), likewise the INFIT and OUTFIT ZSTD values obtained ideal values which are close to 0 (Mean INFIT ZSTD person is 0.0 and Mean INFIT ZSTD item is -0.2 and Mean OUTFIT ZSTD person is -0.1 and Mean OUTFIT ZSTD item is 0.2). In the final section, person reliability (0.84) and item reliability (0.83) were above 0.67 or good category, which shows that the respondents and items are consistent. Next, Figure 8 shows the difficulty level of the TAM questionnaire items used.

Person: REAL SEP.: 1.67 REL.: .74 ... Item: REAL SEP.: 2.01 REL.: .80

Item STATISTICS: MEASURE ORDER

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PT-MEASURE CORR.	PT-MEASURE EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Item
14	166	54	1.15	.12	1.85	4.2	2.19	4.5	.36	.63	24.1	32.4	POU7
1	200	54	.61	.13	1.87	3.7	2.80	5.5	.24	.56	35.2	39.2	PEU1
2	200	54	.61	.13	1.00	.0	1.23	1.0	.48	.56	40.7	39.2	PEU2
17	213	54	.37	.14	3.05	6.3	3.50	6.3	.17	.53	33.3	46.4	AOT3
5	222	54	.17	.15	.70	-1.3	.68	-1.3	.58	.50	64.8	48.6	PEU5
8	225	54	.10	.16	.59	-2.0	.50	-2.2	.70	.49	61.1	49.4	POU1
9	227	54	.05	.16	.70	-1.3	.70	-1.1	.60	.48	68.5	49.7	POU2
18	227	54	.05	.16	.79	-.8	.85	-.5	.58	.48	64.8	49.7	AOT4
4	228	54	.02	.16	.82	-.7	1.00	.1	.59	.48	57.4	49.8	PEU4
19	228	54	.02	.16	.74	-1.1	1.95	2.8	.51	.48	68.5	49.8	AOT5
3	231	54	-.06	.17	.82	-.7	.72	-1.0	.60	.47	70.4	50.7	PEU3
7	232	54	-.09	.17	.44	-2.8	.51	-1.9	.66	.46	77.8	50.8	PEU7
21	233	54	-.12	.17	1.07	.4	1.42	1.4	.29	.46	44.4	50.8	AOT7
16	236	54	-.21	.18	.47	-2.4	.37	-2.7	.67	.45	77.8	52.6	AOT2
20	236	54	-.21	.18	.25	-4.2	.27	-3.4	.75	.45	77.8	52.6	AOT6
15	237	54	-.24	.18	.82	-.6	.75	-.8	.60	.44	66.7	52.6	AOT1
10	238	54	-.28	.18	.50	-2.2	.66	-1.2	.54	.44	66.7	52.7	POU3
12	238	54	-.28	.18	.92	-.2	.75	-.8	.56	.44	66.7	52.7	POU5
11	240	54	-.35	.19	.77	-.8	.60	-1.4	.53	.42	68.5	55.4	POU4
6	243	54	-.46	.20	.99	.1	1.05	.3	.40	.41	51.9	58.0	PEU6
13	251	54	-.83	.24	1.64	1.8	1.58	1.5	.40	.35	79.6	71.2	POU6
MEAN	226.2	54.0	.00	.17	.99	-.2	1.15	.2			60.3	50.2	
S.D.	18.2	.0	.41	.02	.62	2.4	.82	2.6			15.6	7.4	

Figure 8. Item measurement

Figure 8 shows the order of difficulty level of TAM questionnaire statement items to be approved by students. POU7 is the most challenging statement to agree with, while statement POU6 is the most accessible statement to agree with.

The visualization display in Figure 9 shows the distribution of respondents (left side) with the level of agreement with the TAM questionnaire statement items (right side).

```
                              Person - MAP - Item
                                   <more>|<rare>
 4                                       +
                                  38     |
                                         |
                                         |
                                  47     |
 3                                       +
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                                  21     |
                            10 29 42     |
                         22 23 26 37     |
                                        S|
 2                                32     +
                                  51     |
                            11 25 27     |
                                  33     |
                                  45     |
                                  09     |
                            07 08 13 M|   POU7
                      01 24 31 36 43     |
 1                             06 35     +
                            03 05 20     |
                            10 14 54     |T
   02 04 12 15 16 17 18 19 28 34 39 46 48 |
                                         |  PEU1    PEU2
                               41 44     |S AOT3
                                        S|
                                  30     |  PEU5
                                         |  POU1
 0                                53    +M AOT4    AOT5    PEU4    POU2
                                         |  AOT7    PEU3    PEU7
                                         |  AOT1    AOT2    AOT6
                               40 49     |  POU3    POU4    POU5
                                         |S
                                  52   T|   PEU6
                                         |
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                                   <less>|<frequ>
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Figure 9. Variable maps

In general, students agree with the use of Physics Fun media. Users stated that they were always able to understand the subject matter well and were able to carry out experiments that existing resources had previously limited. There is a most challenging statement for POU7 and PEU1 to agree on: the difficulty of carrying out activities and using the Physics Fun mobile media. Learning activities include various activities in the press, namely virtual experiments that students can carry out directly. This statement is negative, so there is a possibility and tendency for respondents to be less careful when filling out the questionnaire. However, overall, respondents agreed to use Physics Fun media for learning. Likewise, the PEU2 statement is about proficiency in using Physics Fun media. Mitigation that can be done to anticipate this is by introducing the use of Physics Fun media early so that users can get used to using this media because there is a need to use flexible media that can be accessed anytime and anywhere by students.

The TAM assessment of media use in each aspect and statement shows a logit value above zero, which indicates respondent agreement. It indicates that the use of Physics Fun media can be accepted and used by users, in this case, students who study physics subjects according to the existing material topics.

Complete features and security of media use encourage user motivation to use this application. The quality of the information provided, along with factors like relevance, trust, awareness, resource availability, self-efficacy, and perceived security of mobile applications in learning, influences students' willingness to accept and use mobile learning applications [54]. Students look very enthusiastic about learning using Physics Fun media.

5. Discussion

Developing mobile learning media has its challenges. It is related to the characteristics of students with a certain tendency towards independent learning [55], [56]. Taking this into account, the mobile learning application being developed is expected to have an impact on students' academic achievement. As a student-centered design product, mobile learning applications must consider user experience aspects to optimize user interactions between users, systems, and context [57]. In addition, mobile applications also enable students to learn anywhere and at any time [50], strengthening the lifelong learning paradigm.

The developed mobile media user flow focuses on easy-to-understand learning experiences and content exploration. Easy-to-understand content includes no biased information, easy and simple navigation on course pages, and follows usability principles [59]. In the Physics Fun media, there are features to support the user's learning experience through materials, virtual experiments, and evaluations without any login or game-level structure.

Media Physics Fun facilitates effective learning with an organized structure. An organized content structure helps users gradually learn from basic concepts to more complex ones [49]. Media Physics Fun also has diverse content; users can access various types of physics content presented in different ways, allowing them to choose a learning method that suits their preferences. The virtual experiment features and physics questions provide practical and interactive experiences that enrich the understanding of physics concepts. This feature lets users observe, manipulate, and practically test physics concepts. Virtual experiments are carried out using limited equipment, time considerations, abstract learning material, and consideration of the dangers that could arise if actual experiments were carried out in the laboratory, such as the effects of radiation on health [61]. The evaluation feature allows users to track their progress and pinpoint areas where they can improve their understanding of physics concepts. Physics Fun media can provide good feedback to users after completing evaluations, virtual experiments, or answering physics questions through these features. Giving feedback or fast responses in mobile-based learning can increase students' learning motivation in accessing and studying material [53]. It helps users monitor their progress, better understand physics concepts, and improve their understanding through the assessments and feedback provided.

The holistic integration of these features enhances the learning of physics concepts, particularly electrical circuits, by offering diverse content, accurate visualizations, and efficient user navigation. Effective navigation is an essential component of user interface design. Users should easily navigate the application, find the information they want, and engage with the content [58]. Implementing intuitive menus, prominent symbols, and labels is a common approach to developing compelling user interfaces. Additionally, to optimize the user experience on mobile devices, additional features such as sidebars and moving menus can be included [60]. Interactive components such as online exams, quizzes, flashcards, and other features are incorporated to facilitate active learning. Assessment is essential in the learning process to collect student performance and learning progress. Personalization options allow users to set their preferences, monitor their progress in learning, and get specific activity recommendations. Learning support, in general, is interactive learning, which consists of interactive and visual features that facilitate learning that is more interesting and can be understood better. Practical experience consists of virtual experiments that provide practical experience in applying physics concepts without physical equipment. Progress monitoring, which includes evaluations, helps monitor user progress and adjust learning as required. Additional support in the form of the About feature provides access to additional resources and technical assistance if needed.

6. Conclusion

The research results showed that the development of Physics Fun media was in the valid category. At the end of the trial, an online TAM questionnaire was administered. It was generally found that students agreed with the use of Physics Fun media. Users stated that they were always able to understand the subject matter well and were able to carry out experiments that existing resources had previously limited. Some statements are the most difficult to agree with, namely POU7 and PEU1, about difficulties in carrying out activities and using Physics Fun media. Learning activities include various activities in the Physics Fun media, namely virtual experiments that students can carry out directly.

This statement is negative, so there is a possibility and tendency for respondents to be less careful when filling out the questionnaire. However, respondents/students agreed to use Physics Fun media in learning. Likewise, the PEU2 statement is about proficiency in using Physics Fun media. Mitigation that can be done to anticipate this is by introducing the use of Physics Fun media early so that users can get used to using this media. Physics Fun media is effective and practical and can be accessed anytime and anywhere by students.

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