Development of PHYVAR (Physics in 3d Virtual Reality) on Solar Energy Material to Support Students' Spatial Intelligence

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Abstract *- Spatial intelligence, as proposed by Howard Gardner's theory of multiple intelligences, is one of eight different intelligences that every individual has. The 9 intelligences include: visual-spatial intelligence, linguistic-verbal intelligence, logical-mathematical intelligence, physical-kinesthetic intelligence, musical intelligence, interpersonal intelligence, intrapersonal intelligence, naturalistic intelligence and existential intelligence. Spatial intelligence includes a person's ability to visualize objects complexly in three dimensions, manipulate an object to make it appear realistic and understand spatial relationships with physical phenomena. This form of intelligence plays an important role in various fields, including but not limited to physics, engineering, architecture, and scientific exploration. In this field, the capacity to conceptualize and work with spatial elements is fundamental to problem solving and innovation. Solar energy, also known as solar power or solar radiation, is a renewable and sustainable energy source that comes from the sun. Its significance is critical in overcoming global challenges related to energy security, climate change mitigation and environmental sustainability. The integration of solar energy topics into the class is critical. In particular, point 7 of the goal emphasizes the ambition to achieve universal access to affordable, reliable, sustainable and modern energy services by 2030, making solar energy education an integral part of preparing students for a sustainable future. The main objective of the research discussed is to test the feasibility of PHYVAR (Physics in 3D Virtual Reality) on Solar Energy material to support students' spatial intelligence. This research uses Research and Development (R&D) approach by utilizing the Rowntree development model which includes planning, development and evaluation stages. The software used for development includes: Blender 3D 4.0 and Unity Hub 2022, which is used to create a virtual reality environment, displaying a combination of technological advances in education. The evaluation process for PHYVAR media and solar energy materials is carried out with validation by experts, which include material experts and media experts. Apart from that, input and assessment of media suitability were taken from the responses of 35 Class X students from a high school in Pandeglang. Validation results from both experts and students show a high level of agreement, meeting the criteria for the "very good" category, which shows the potential of PHYVAR media in increasing spatial intelligence and facilitating effective learning experiences. The integration of virtual reality technology and interactive learning materials such as PHYVAR in educational environments offers a transformative learning approach. Not only does it increase students' understanding of complex concepts, but it also fosters creativity, critical thinking, and problem-solving competence. By utilizing innovative educational methods such as virtual reality simulations, educators can create engaging and immersive learning environments tailored to diverse learning preferences and abilities, thereby creating a more engaging and effective educational landscape.*

Keywords: *Solar Energy; Spatial Intelligence; Virtual Reality; PHYVAR*

INTRODUCTION

The development of industry 4.0 has led to the rapid development of digitalization in all fields, especially in the field of education. Currently the curriculum implemented in Senior High Schools is the Merdeka curriculum. From 2022 until now, the Merdeka curriculum is mandated to be able to improve students' spatial intelligence. Spatial intelligence is the intelligence possessed by every student to be able to understand, remember and imagine visual phenomena (Rohmadi, 2023).

Then, in the Merdeka curriculum, less physics material is taught in class, because it is focused on the existing urgency and its relationship to everyday life, as in renewable energy material which focuses on utilizing solar energy into electricity which is usually referred to as solar energy. According to Alisjahbana & Murniningtyas (2018), currently, energy plays a very important role in human life. Energy supports national economic activities and is used as a tool to achieve social, economic and environmental goals. World fossil fuel reserves (in 2002) were oil for 40 years, natural gas for 60 years and coal for 200 years. With the depletion of fossil energy sources, there is a global transition from the use of non-renewable energy sources to renewable energy sources. Even though the potential of renewable energy sources such as biomass, geothermal energy, solar energy, water energy, wind energy, marine energy and hydropower has not been widely exploited, the potential of renewable energy is very important, especially in the education sector, so that it can provide insight regarding how to use it. As for solar energy, solar energy material is included in the topic of renewable energy in physics learning. Apart from that, this discussion is included in one of the SDG (Sustainable Development Goals) points.

According to Statistics Indonesia or Badan Pusat Statistik (2014), point 7 of the SDGs regarding Affordable, Reliable, Sustainable and Modern Energy has several goals, including:

1. By 2030, ensuring that everyone can experience affordable, reliable and modern energy services
2. By 2030, substantially increasing the use of renewable energy in the global energy mix
3. By 2030, doubling the rate of improvement in energy efficiency for the better.
4. Increasing energy efficiency with targets for 2030 and 2050 by utilizing environmentally friendly energy.

Several previous studies also explained, according to Samsurizal et al. (2021), that students are required to have an understanding of renewable energy because dependence on fossil energy which is capable of producing electricity continues to increase. Then according to Khaerunnisa et al (2019), Indonesia is a country that has quite large sources for solar energy, because it is located on the equator which can then convert solar energy into electrical energy.

Then, based on an interview with Mr. Aji Nugraha S.Pd (2023), who is a physics teacher at SMAN 7 Pandeglang, the learning media that are often used in schools to deliver renewable energy material are usually Power Point, whiteboard, learning videos, and direct practice (Project Creation). This media helps in the learning process, but there are still many shortcomings so it must undergo development to be more technologically savvy, and able to improve children's understanding of visualization. According to Dewanti & Retnowati (2021), power point media is used as a learning medium to increase student motivation and improve learning outcomes in the cognitive domain. However, this media must undergo further development because it is still in the medium category with a value of 0.38. Then, according to (Hafizah, 2020), many physics learning videos have been developed on physics materials, all of which are valid for use as learning media. Technological developments provide opportunities for further research to be able to develop videos with available software and disseminate the results of video development to be more interactive. Apart from that, material that is delivered using interactive media is easier to

understand and be delivered quickly (Gumelar et al., 2019).

Then, according to Kartika & Firmansyah (2022), Spatial Intelligence is one of the multiple intelligences possessed by every individual. This intelligence needs to be improved in every student, because it can support them in understanding the visual world through their imagination.

So, based on the conclusions and solutions to the problems above, the author tries to develop learning media with a 360^0 design based on Virtual Reality or known as PHYVAR which can record, reconstruct, simulate, describe and preserve an object.

RESEARCH METHODS

The method used in this research is the R&D (Research and Development) method. According to Sugiyono (2019), the R&D method is a research method used to produce certain products and test the validity and effectiveness of these products. According to Keislaman (2022), Research and Development (R&D) is a research method used to produce certain products and test the effectiveness of the method. In the field of education, Research and Development (R&D) is a research method used to develop or validate products used in education and learning. Then, the model used in this research is the Rowntree development model which is a learning media development model which consists of 3 main stages, namely: Planning, Development and Evaluation. According to Hasanah (2015), the development of Rowntree explains that the implementation of all learning design activities is concentrated on the production of certain teaching materials so that each step is easy to follow, and the way it works is relatively simple. According to Nugroho et al (2019), the Rowntree development model was chosen for various reasons, including: it can be used to achieve learning outcomes in the media used; it can be used to develop learning media; it is structured and widely used in the world of education, etc. This method and model were chosen because it aims to produce a product in the form of 3D learning media. The media was created using the Unity application with the help of the 3D Blender application.

The research instrument used in this research was filling out a questionnaire in the form of the results of the media suitability test using TAM (Technology Acceptance Model) which is a model built to analyze and understand the factors that influence whether or not a media will be used. According to Islami et al (2021), TAM as an adaptation of TRA has 5 (five) main perceptions, namely perceived usefulness, perceived ease of use, attitude toward using, behavioral usefulness, perceived ease of use, attitude toward using, behavioral intention to use, and actual intention to use, and actual system use. Then, the data collection technique is carried out by providing several questions and statements that must be answered by the respondent. Apart from that, the type of questionnaire in this research is a closed or structured questionnaire, meaning that the questions have been previously determined. Meanwhile, the questionnaire or questionnaire sheet in this research was created based on a Likert scale with a check list (√) as the type of answer used. According to Nempung et al (2015), the Likert scale is a psychometric scale commonly used in surveys and is also often used in survey-based research. The name of this scale is taken from Rensis Likert, who published a report explaining its use. When answering questions on a Likert scale, respondents determine their level of agreement with a statement by selecting one of the available options. The assessment weights include:

7 = Strongly Agree
6 = Agree
5 = Slightly Agree
4 = Neutral
3 = Slightly Disagree
2 = Disagree
1 = Strongly Disagree

Table 1. User response scoring rules

Scale	Score
Strongly agree	7
Agree	6
Slightly agree	5
Neutral	4
Slightly Disagree	3
Don't agree	2
Strongly Disagree	1

To find out the scores obtained, researchers developed the following data processing techniques:

$$NP = \frac{n}{N} \times 100\% \quad \text{(Equation 1.1)}$$

Information:
Np = Feasibility percentage value (%)
n = Number of scores obtained in each aspect
N = Total score in each aspect
100 = Fixed number

From the calculation results that have been obtained, whether the media is suitable or not can then be interpreted based on the interpretation value of the feasibility test criteria.

Table 2. Interpretation of media appropriateness

Scale	Score
86% - 100%	Very good
72% - 86%	Good
57% - 72%	Quite Good
43% - 57%	Enough
29% - 43%	Quite Not Good
15% - 29%	Not good
≤ 15%	Very Not Good

The following is a form of questionnaire used by researchers:

1. Expert and user validation questionnaire
   Validation questionnaires in research are used to collect data about the accuracy of media design, material accuracy, and interest in the learning media used. This questionnaire is given during product trials of this media development, which is then analyzed for the suitability of the media. The following is the grid of the instruments used:

Table 3. Media Expert Assessment Instrument

No	Assessment Aspect	Scoring Scale						
		1	2	3	4	5	6	7
1.	Suitability of media delivery strategies to student characteristics							
2.	The accuracy of the media delivery strategy allowing ease, speed of understanding, mastery of material, concepts and skills							
3.	The level of possibility in facilitating students' science processing skills							
4.	Accuracy of media selection compared to other media							

No	Assessment Aspect	Scoring Scale						
		1	2	3	4	5	6	7
5.	The accuracy of selecting simulations with the objectives and content of the material							

Table 4. Material expert validation instrument

No	Assessment Aspect	Scoring Scale						
		1	2	3	4	5	6	7
1.	The truth of the content of the material							
2.	Up to date material							
3.	Material coverage (on learning outcomes)							
4.	Depth of material (whether the material is deep or not)							
5.	Adequacy of the references used							

Table 5. User assessment instrument

Assessment Aspect	Scoring Scale						
	1	2	3	4	5	6	7
Perceived usefulness							
Using PHYVAR can increase understanding of Solar Energy material							
The use of PHYVAR really supports understanding Visualization							
I believe that PHYVAR will be useful if used as a learning medium							
Using PHYVAR was able to increase my motivation in carrying out learning							
Perceived ease of use							
I find PHYVAR easy to use							
Learning how to use PHYVAR was no problem for me							
Learning how to use PHYVAR is clear and easy to understand							
Perceived enjoyment							
Using PHYVAR is fun							
I enjoy using PHYVAR because it is more interactive and feels real							
I think PHYVAR makes it possible to learn while playing							
Attitude towards use							
The use of PHYVAR makes the lessons more interesting							
I don't get bored using PHYVAR							
I think using PHYVAR in the classroom is a great idea							
Intention to use							
I would like to use PHYVAR in the future if I have the opportunity because it is flexible							
I want to use PHYVAR to study Solar Energy, as well as other subjects.							

RESULTS AND DISCUSSION

Results

Findings regarding the development, feasibility, and limited trials of PHYVAR (Physics in 3D Virtual Reality) as a video- and simulation-based learning media to support students' spatial intelligence on solar energy material.

This media was created using the Unity application with the C-Sharp programming language. According to Maulana & Suryana (2023), the C# (C-Sharp) programming language is an object-

oriented programming language and is the successor to the C++ programming language developed by Microsoft and is one of the programming languages that supports .NET programming via Visual Studio. PHYVAR is intended for class X (10^{th} grade) high school students who are studying renewable energy material, so that it can facilitate and provide further understanding regarding this material. PHYVAR was developed using the Research and Development (R&D) research method with the Rowntree research model which has 3 stages, namely the planning stage, development stage and evaluation. Meanwhile, the results of the research and development stages are as follows:

Planning Stage: The first thing that was done to plan this research was to look for information related to the current use of physics learning media in schools, namely by conducting online interviews with physics teachers and Literature Studies from various journals. Then, the results are used as material for analyzing student needs regarding the development of learning media. The second thing that was done were looking for information related to the material that still requires further understanding of visualization, is related to everyday life and of course really needs to be conveyed, that is, the renewable energy material on the use of solar energy for electricity, usually referred to as solar energy, in class X physics learning. This is because most students only know the basics without knowing the content and events that actually occur. Third, the researcher also looked for the media that will be created or developed to support spatial intelligence because Gen Z or students definitely have their own intelligence which needs to be improved through learning physics. So, from the planning stage above, it can be concluded that a media that is capable of supporting children's visualization of solar energy material to support spatial intelligence will be developed. Therefore, this media will be named "PHYVAR" or commonly referred to as Physics in 3D Virtual Reality.

Development Stage: The results of the analysis that have been carried out have become a reference in the product development process, namely PHYVAR Development. In the PHYVAR Development stage there are the following stages:

Material collection stage. The material collection stage is carried out by studying literature from books, journals, articles and websites which are then adapted again to the learning outcomes and PHYVAR media that will be created.

Instrument development stage. The instrument development stage was carried out by reviewing articles about media development research instruments. Based on the previous article, it was concluded that the instruments used in this research were divided into 2, namely expert instruments and user instruments. The expert instrument consists of material and media expert instruments which refer to the Educational Information and Communication Technology Center of the Ministry of Education and Culture and then modified to suit PHYVAR media needs. The instrument for users refers to the Technology Acceptance Model (TAM) instrument which has been readjusted to the PHYVAR media.

Media development stage: Flowchart creation (PHYVAR media creation flowchart). Making a flowchart is the initial stage in developing PHYVAR media on solar energy material. This flowchart is used to illustrate the flow of PHYVAR media development. The flowchart includes: (1) Making Storyboards; storyboard is a visual depiction of PHYVAR media created to facilitate the product development process.

The PHYVAR storyboard is attached in attachment A.2; (2) Media Object Collection; media objects are collected by creating and searching from various websites. 2D designs were created via Canva, Pinterest and Corel Pallet applications. Meanwhile, the 3D design was created using the Blender application which was then exported as an FBX file so that it could be opened in the Unity application. Apart from that, there were several other assets taken from the Unity assets store, Sketchfab and Cgtrader.

Media Development. The core stage of the development stage is to develop the PHYVAR media itself. In the development process everything is done through the Unity application with a 3D project. All object designs are collected in the application. The programming language used in developing this media is C-Sharp using the Visual Studio 2022 application. According to Ningsih et al (2022), Visual Studio Code is a light and reliable text editor created by Microsoft for multiplatform operating systems, meaning it is also available for Linux, Mac and Windows. This text editor directly supports Javascript, Typescript and Node programming languages. Js, as well as other programming languages with the help of plugins that can be installed via the Visual Studio Code marketplace such as: C++, C#, Python, Go, Java, PHP, etc. Meanwhile, according to Ismail Setiawan (2022), VS Code is the Microsoft project with the highest number of contributors on GitHub. This initiative has increased Microsoft's fame and positioned it as one of the major players in community software. Developers can add new languages to the environment, such as Python using VS Code. The result of this development stage is PHYVAR learning media with Solar Energy material to support students' spatial intelligence. PHYVAR consists of a menu of instructions for use, pretest, description, visualization, posttest and developer information.

Evaluation Stage. At this stage, validation is carried out by material experts, media experts and users of the PHYVAR media.

The results of the development of PHYVAR (Physics in 3D Virtual Reality) on solar energy material to support students' spatial intelligence are as follows:

The assessment aspects for material expert validation consist of the correctness of the content of the material, the recency of the material, the coverage of the material (to learning outcomes), the depth of the material (whether the material is deep or not) and the adequacy of the references used. The material validation results are presented in Table 6.

Table 6. Material expert validation results

Aspects of Assessment	Analysis	Validator Assessment
The correctness of the content of the material	n	6
	N	7
	NP	85.71%
	Criteria	Good
Contemporary Material	n	7
	N	7
	NP	100.00%
	Criteria	Very Good
Coverage of material (to learning outcomes)	n	6
	N	7
	NP	85.71%
	Criteria	Good
Depth of material (whether the material is deep or not)	n	6
	N	7

Aspects of Assessment	Analysis	Validator Assessment
	NP	85.71%
	Criteria	Good
Adequacy of the references used	n	6
	N	7
	NP	85.71%
	Criteria	Good
Average		**88.57%**
Media Quality Score in PHYVAR		**Very Good**

Based on Table 6, after assessing the material experts on the PHYVAR (Physics in 3D Virtual Reality) media on solar energy material to support students' spatial intelligence, it can be seen that, based on the validation of material experts with the assessment aspects previously presented, the solar energy material is very well presented in the media PHYVAR because it is in accordance with the interpretation of the material suitability category.

Then, the assessment aspects for media expert validation consist of the suitability of the media delivery strategy with student characteristics, the accuracy of the media delivery strategy so as to enable convenience, speed of understanding, mastery of material, concepts and skills, the level of possibility of facilitating students' spatial intelligence, the accuracy of media selection compared to other media and the accuracy of selecting simulations according to the objectives and content of the material. The following are the results of media expert validation (Table 7):

Table 7. Media expert validation results

Aspects of Assessment	Analysis	Validator Assessment
Suitability of media delivery strategies with student characteristics	n	7
	N	7
	NP	100.00%
	Criteria	Very Good
The accuracy of the media delivery strategy allows for ease, speed of understanding, mastery of material, concepts and skills	n	7
	N	7
	NP	100.00%
	Criteria	Very Good
The level of possibility facilitates students' spatial intelligence	n	6
	N	7
	NP	85.71%
	Criteria	Good
Accuracy of media selection compared to other media	n	7
	N	7
	NP	100.00%
	Criteria	Very Good
The accuracy of selecting simulations with the objectives and content of the material	n	7
	N	7
	NP	100.00%
	Criteria	Very Good
Average		**97.14%**
Media Quality Value in PHYVAR		**Very Good**

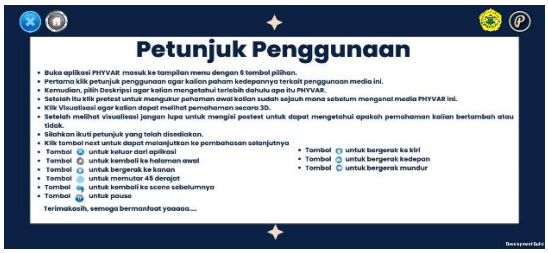
Finally, there is user assessment, which is carried out by conducting media feasibility trials on high school students. The number of students who were users in this research was 35 class X-8 students of SMAN 7 Pandeglang. The results can be seen in Table 8 below.

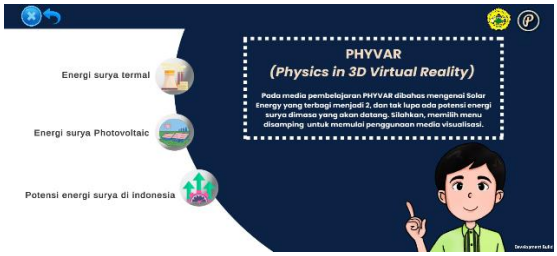
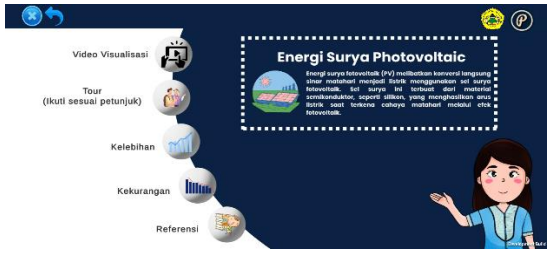
Table 8. User rating results

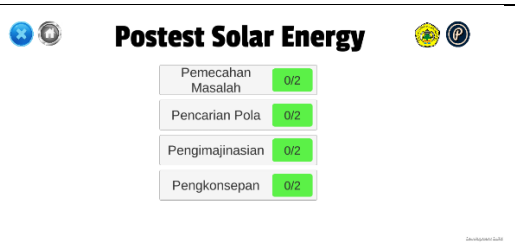
Aspects of Assessment	Analysis	Validator Assessment
Perceived Usefulness	n	894
	N	980
	NP	91.22%
	Criteria	Very Good
Perceived ease of use	n	646
	N	735
	NP	87.89%
	Criteria	Very Good
Perceived enjoyment	n	644
	N	735
	NP	87.62%
	Criteria	Very Good
Attitude towards use	n	673
	N	735
	NP	91.56%
	Criteria	Very Good
Intention to use	n	454
	N	490
	NP	92.65%
	Criteria	Very Good
Average		**90.19%**
Media Quality Value in PHYVAR		**Very Good**

Meanwhile, the final results of the development of PHYVAR (Physics in 3D Virtual Reality) on solar energy material to support spatial intelligence are as follows:

Table 9. PHYVAR media final results

Menu	Image	Description
Home		• There are a PHYVAR and university logo, as well as the application's exit button. • There are 6 selection buttons that can be used sequentially.
Instructions for use		• There are PHYVAR logo, university logo, return to home button and exit application button. • There is a detailed explanation regarding the procedures for using PHYVAR media.
Pretest		• There are PHYVAR logo, university logo, return to home button and exit application button. • There are 4 spatial indicators which contain 2 questions in them,

Menu	Image	Description
		each question is given 60 seconds.
Description		• There are PHYVAR logo, university logo, return to home button and exit application button. • There is a definition of PHYVAR.
Visualization		• There are PHYVAR logo, university logo, return to previous button and exit application button. • There are buttons for thermal solar energy, photovoltaic and potential solar energy.
		• There are PHYVAR logo, university logo, return to home button and exit application button. • There are visualization tour, video, discussion of the advantages, disadvantages and references of thermal solar energy.
		• There are PHYVAR logo, university logo, return to previous button and exit application button. • There are a visualization tour, video, discussion of the advantages, disadvantages and references of solar photovoltaic energy.
		• There are PHYVAR logo, university logo, return to previous button and exit application button. • There is an explanation regarding the potential of solar energy in Indonesia.
Postest		• There are PHYVAR logo, university logo,

Menu	Image	Description
		return to previous button and exit application button. • There are 4 spatial indicators which contain 2 questions in them, each question is given 60 seconds.
Developer information		• There are PHYVAR logo, university logo, return to previous button and exit application button. • There are names and photos of the media developer, supervisor 1 and supervisor 2.

Discussion

The use of learning media is very important to achieve learning goals, especially in physics learning which is able to present a phenomenon in a more complex way and is able to increase spatial intelligence. Spatial intelligence is the intelligence to be able to remember, understand and visualize objects in a more complex way. Meanwhile, based on previous research related to the development of physics learning media, spatial intelligence and solar energy materials are as follows.

Firstly, Kartika & Firmansyah, (2022) underscore the significance of enhancing students' visual-spatial acumen through scaffolded interventions facilitated by 3D media, which not only augments their understanding but also prepares them for collegiate and vocational assessments. Secondly, the research conducted by Khaerunnisa et al., (2019) highlights the potential of solar energy as a sustainable alternative, elucidating its conversion mechanisms and underlying physics principles, thereby enriching high school curriculum and fostering environmental consciousness. Thirdly, Syefrinando et al., (2020) advocate for the efficacy of Adobe Flash-based learning media in enhancing learning outcomes, substantiated by robust validation metrics encompassing experts' assessments and practicality evaluations, thereby endorsing its suitability as an educational tool.

Moreover, further investigations by Tazkiyah et al., (2020) and Amalina et al., (2021) corroborate the suitability of electronic modules and computer-assisted programs in augmenting student learning experiences, as evidenced by validation scores and feasibility tests. Additionally, Pratiwi et al., (2023) and Rahman et al., (2023) shed light on the efficacy of virtual laboratory simulations and Monopoly Physics Science Media (MOFIN), respectively, in engendering positive student engagement and achieving learning objectives, as evidenced by student feedback and assessment outcomes. These collective findings underscore the pivotal role of innovative learning resources in fostering enhanced understanding and attainment of educational goals in physics education.

So, several of the studies above are in line with research conducted regarding the development of learning media in physics

lessons, especially renewable energy related to the use of solar energy into electrical energy which is able to improve students' spatial intelligence and it has been proven that if media development is carried out continuously, there will be increased improvements in implementation. student learning, this is done not only to be able to keep up with technological developments, to take advantage of technology but also the media used is flexible, able to be used anywhere and at any time. The results obtained are based on expert validation results and user assessments regarding the suitability of PHYVAR media.

Based on Table 4, after assessing the material experts on the PHYVAR (Physics in 3D Virtual Reality) media, solar energy material to support students' spatial intelligence, it can be seen based on the validation of material experts with the assessment aspects previously presented that the solar energy material is very well presented in the media. PHYVAR learning. Because, in accordance with the interpretation of the material suitability category. Then, based on Table 5, after assessing the PHYVAR (Physics in 3D Virtual Reality) media, solar energy material to support students' spatial intelligence, it can be seen based on media expert validation with the assessment aspects presented previously that the PHYVAR media is very good for use as a learning media and in accordance with the interpretation of the media suitability category. A more complete explanation of the research results is as follows:

1. Material assessment of PHYVAR media with the aspect of truth of material content has a percentage value of 85.71%; the contemporary aspect of the material has a percentage value of 100.00%; the material coverage aspect (to learning outcomes) has a percentage value of 85.71%; the depth aspect of the material (whether the material is deep or not) has a percentage value of 85.71% and the aspect of the adequacy of the references used has a percentage value of 85.71%. Based on 5 aspects of material expert assessment, it can be concluded that the solar energy material in PHYVAR media obtained a percentage of 88.57% which can be categorized as very good. The results of the material expert assessment can be seen in Figure 1.

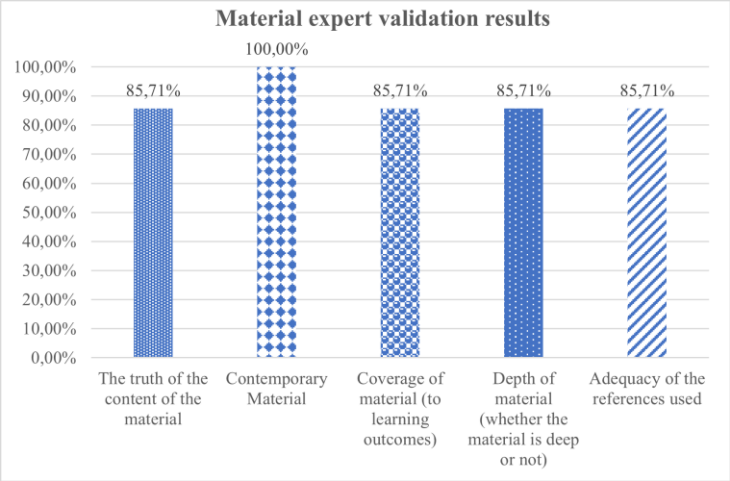


Figure 1. Material expert validation results

2. Assessment of the PHYVAR media regarding solar energy with the aspect of suitability of the media delivery strategy with student characteristics has a percentage value of 100.00%; the aspect of accuracy of media delivery strategy so

as to enable ease, speed of understanding, mastery of material, concepts and skills has a percentage value of 100.00%; the aspect of the level of possibility of facilitating students' spatial intelligence has a percentage value of 85.71%; the aspect of media selection accuracy compared to other media has a percentage value of 100.00%; The aspect of accuracy in choosing a simulation with the aim and content of the material has a percentage value of 100.00%. Based on 5 aspects of media expert assessment, it can be concluded that the PHYVAR media on energy prayer material obtained a percentage of 97.14% which can be categorized as very good. The results of the media expert assessment can be seen in Figure 2.

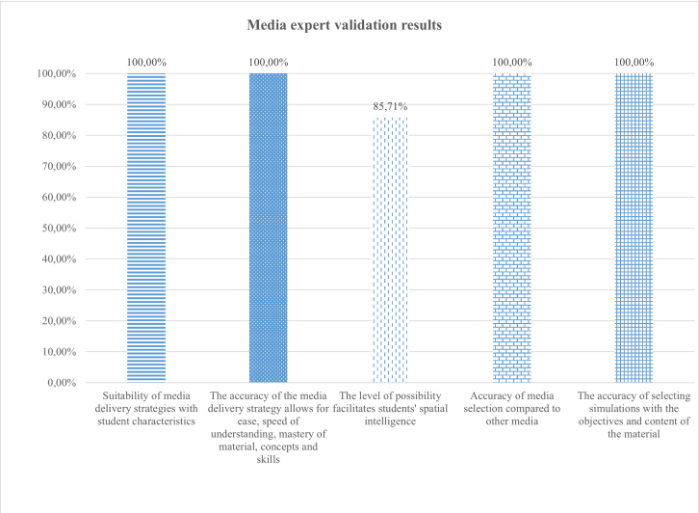


Figure 2. Media expert validation results

Based on Table 8, it can be seen that the assessment of each aspect by 35 students regarding PHYVAR media can be categorized as very good with an average of 90.19%. The explanation regarding the results of each aspect is as follows:

1. The perceived usefulness aspect received a percentage score of 91.22% in the very good category. The points for each aspect consist of the use of PHYVAR being able to increase understanding in the Solar Energy material, obtaining a percentage score of 93.87% in the very good category; the use of PHYVAR really supports understanding. Visualization obtained a percentage score of 91.02% in the very good category; I believe that PHYVAR will be useful if used as a learning medium, obtaining a percentage score of 88.97% in the very good category; Using PHYVAR was able to increase my motivation in carrying out learning, obtaining a percentage score of 91.02% in the very good category. So, it can be concluded that the PHYVAR media is suitable for use as a learning medium for the physics of solar energy.
2. The perceived ease of use aspect received a percentage score of 87.89% in the very good category. The points for each aspect consist of I think PHYVAR is easy to use, obtaining a percentage score of 88.57% in the very good category; learning how to use PHYVAR was not a problem for me, getting a percentage score of 89.80% in the very good category; learning how to use PHYVAR is clear and easy to understand, getting a percentage score of 85.31% in the very good category. So, it

can be concluded that PHYVAR media is easy to use.

3. The perceived comfort aspect received a percentage score of 87.62% in the very good category. The points for each aspect consist of: using PHYVAR is fun, getting a percentage score of 88.98% in the very good category; I like using PHYVAR because it is more interactive and feels real, getting a percentage score of 85.31% in the very good category; I think PHYVAR allows for learning while playing by obtaining a percentage score of 88.57%. So, it can be concluded that PHYVAR media is comfortable to use as a learning medium.
4. The attitude aspect towards use obtained a percentage score of 91.56% in the very good category. Meanwhile, the points for each aspect consist of using PHYVAR to make lessons more interesting, obtaining a percentage score of 91.02% in the very good category; I don't get bored using PHYVAR, getting a percentage score of 91.84% in the very good category; I think using PHYVAR in class is a good idea, getting a percentage score of 91.84% in the very good category. So, it can be concluded that PHYVAR media is more interesting and not boring so it can be used as a learning medium.
5. The objective aspect for use is to obtain a percentage score of 92.65% in the very good category. Meanwhile, the points for each aspect consist of I want to use PHYVAR in the future if I have the opportunity because it is flexible to use, obtaining a percentage score of 91.43%% in the very good category; I want to use PHYVAR to study Solar Energy, as well as other subjects, getting a percentage score of 93.88% in the very good category. So, it can be concluded that PHYVAR media is suitable for use in the future and even in other learning. The results of students' assessments of PHYVAR media on Solar Energy material are presented in Figure 3.

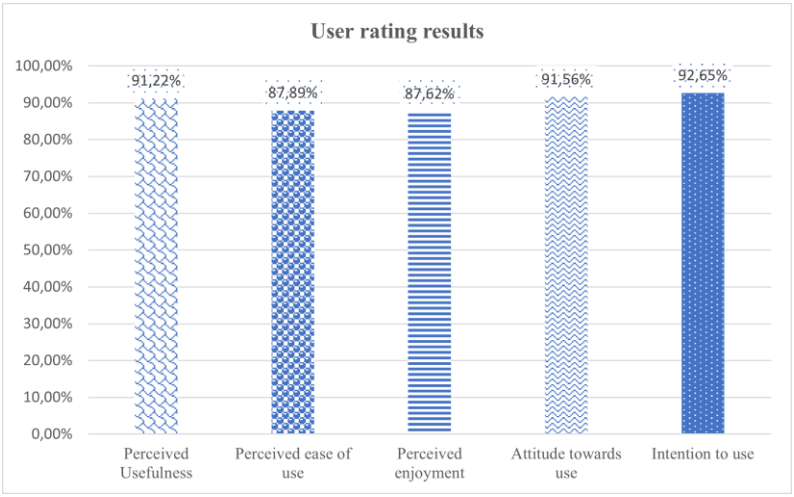


Figure 3. User rating results

Based on Figure 3, the perceived comfort aspect received the lowest score, namely 87.62%, because some students had problems in the installation process because the memory was full, so it had to be emptied first. Then for the purpose aspect for use it has the highest score, namely 92.65%, because children are very motivated to use this media, apart from learning, but can also play simple games in general. So it can be concluded that PHYVAR media is suitable for use in terms of usability, convenience, comfort, use and sustainable purposes.

CONCLUSION

The research conclusions regarding the development of PHYVAR (Physics in 3D Virtual Reality) Solar Energy material, to enhance students' spatial intelligence, are as follows:

The PHYVAR Solar Energy material has been developed through multiple stages of the Rowntree development model, which creates a mobile phone compatible application. PHYVAR features six main menus: instructions for use, pretest, description, visualization, posttest, and developer information. A feasibility test conducted by one material expert, one media expert, and user assessments from 35 high school students in class X-8 at SMAN 7 Pandeglang demonstrated high usability. The media expert validation yielded a 97.14% rating, while the user assessment averaged 90.19%. Overall, the combined average score of 91.97% falls within the 86%-100% range, indicating that PHYVAR is a highly suitable learning media.

Further development of PHYVAR should support spatial intelligence aligned with learning outcomes. This is because spatial intelligence aids students in grasping conceptual aspects of solar energy more effectively through the visualizations provided by PHYVAR. These visualizations allow for a clearer understanding and foster connections between theoretical and practical aspects. Future research should develop more realistic and complex media that emphasizes color and clarifies physical principles. This will make the learning experience more engaging and structured for students.

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