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VirtumFi: Development of Android-integrated Instructional Media, Teaching Materials and HOTS Questions on the Topic of Quantum Phenomena for Senior High Schools

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ABSTRACT

Objective: *One of the physics materials that are very important for students is quantum phenomena because it cannot be separated in everyday life. This research aims to develop a learning media "VirtumFi: Quantum Phenomena" for high school students that is feasible and practical.* ***Method:*** *This research is development research that used the 4D design (Define, Design, Develop, Disseminate) in the development process. Development was carried out using Adobe Animate software as an Android application development software.* ***Results****: VirtumFi has been tested valid in content and construct. In addition, VirtumFi is equipped with teaching materials and HOTS question instruments to evaluate student understanding related to Quantum phenomena.* *Furthermore, VirtumFi is accessed using Android so that it can be used anywhere.* ***Novelty:*** *The novelty that can be multiplied in this research is the VirtumFi (Virtual Laboratory Fisika) product in the form of Android with a combination of teaching material (text materials and worksheets), HOTS questions, and virtual laboratories.*

INTRODUCTION

Quantum phenomena is one of the crucial physics topics for humans to understand. Quantum phenomena fall into the realm of modern physics, where this realm contributes a lot to the development of human civilization (Pagels, 2012). Modern physics shapes the human mindset for activities (Gunawan et al., 2018). This is evidenced by the existence of Nuclear Power Plants (PLTN) and solar panels that would not be possible if humans could not think about the characteristics of light, atoms, nuclei, and elementary particles in them. This understanding of these can be obtained by studying the topic of quantum phenomena in modern physics (Ginges & Flambaum, 2004; Kalkanis et al., 2003). However, the importance of the quantum phenomena topic differs from the students' good understanding of the topic. This can be seen from the experience of concepts, laboratory skills, and learning outcomes of physics students in various universities regarding modern physics including the topic of quantum phenomena, which is still very lacking (Baily & Finkelstein, 2015; M. Hanif et al., 2008; Stadermann et al., 2019).

In line with Sartika and Humairah (2017), their research stated that physics education students in a public university have difficulty solving problems in modern physics courses on the topic of quantum phenomena with an average percentage of students who have difficulties reaching above 67% at each stage of problem-solving. Given that understanding something depends on a person's initial understanding, then the understanding of physics students, who lack in modern physics courses containing the topic of quantum phenomena can represent the understanding of quantum in high school students. Supporting this statement, modern physics questions regarding quantum phenomena in the 2015 and 2019 National Examinations (UN) at the high school level were able to be answered correctly by only 45.25% and 53.63% of students from all over Indonesia (Puspendik, 2020). This figure is considered to have yet to meet the minimum standard amount, where the minimum standard amount is 55% of students answering questions correctly. Not only in Indonesia, but students in other countries also have weak concepts in interpreting quantum phenomena (Krijtenburg-Lewerissa et al., 2017; Stadermann & Goedhart, 2020). Therefore, high school students in most countries still have a lack of understanding of quantum phenomena. To overcome this, knowledge of the causes of these problems is needed.

In general, the causes of students' incomprehension on the topic of quantum phenomena can be divided into two: the topic internal and the topic external. The internal cause is that modern physics has difficult concepts for students to understand. Substantially, quantum phenomena have abstract concepts and microscopic objects, so students cannot visualize them well (Montagnani et al., 2023; Schaffer & Barreto Lemos, 2021; Stefani & Tsaparlis, 2009). In addition, physics teachers also claimed to find it difficult to demonstrate the phenomenon of the photoelectric effect and the Compton effect at the high school level (Çoban & Erol, 2020; Klassen, 2011; Mahmudah et al., 2022) In addition, there are external causes of problems. Facilities and infrastructure as well as time to conduct modern physics practicum on the topic of quantum phenomena tend to be less fulfilled (Tawil & Said, 2022; Wong et al., 2019). The cause of this problem causes student interest and enthusiasm to be lacking. This is supported by Budiyono (2018) which found that the number of students who had an interest in physics was only 43.48%. Likewise, Rahim (2020) in his research stated that the average percentage of student's interest in physics was only 48.4%. Students' interest and enthusiasm ultimately affect their understanding of quantum phenomena. Thus, there needs to be a solution that arouses students' interest and enthusiasm in physics subjects and can visualize the concept of abstract quantum phenomena to be concrete.

The solution that can handle problems regarding student interest and enthusiasm is the use of instructional media. Furthermore, Puspitarini (2019) stated that instructional media can facilitate the process of delivering material and encourage students to be more active and motivated. Several solutions have been implemented to deal with this problem. These solutions are several virtual lab-based guided discovery model learning tools (Habibbulloh et al., 2017), interactive multimedia (Wiyono, 2017), virtual-lab media (Yusuf & Widyaningsih, 2017), and LCDS-based interactive module teaching materials (Naj'iyah et al., 2020). The online tool developed by Habibbulloh et al. (2017) was able to reduce misconceptions, multimedia developed by Wiyono (2017) was able to facilitate students in learning modern physics concepts, virtual lab media developed by Yusuf and Widyaningsih (2017) and module teaching materials developed by Naj'iyah et al. (2020) were able to improve the critical thinking skills of students. Reduction of misconceptions, increased ease of mastering concepts and improved critical thinking skills are a form of handling student motivation and interest as well as the visualization of concepts.

However, these solutions still have shortcomings that need to be addressed. The shortcomings that need to be addressed are the flexibility of using teaching media and materials, the availability of procedural knowledge in class XII high school textbooks, and the assessment of higher-order thinking skills (HOTS). Previously developed teaching media and materials still do not have high flexibility because they still can be used on laptops (Naj'iyah et al., 2020) and computers (Habibbulloh et al., 2017; Wiyono, 2017; Yusuf & Widyaningsih, 2017), so students have not been able to use them wherever and whenever they are. Based on the results of a survey and analysis conducted by Ari et al.(2019), class XII physics textbooks used in several schools still provide insufficient procedural knowledge. This reduces the opportunity for students to develop their practical skills. In addition, some of these media do not have assessment questions integrated into them (Habibbulloh et al., 2017; Wiyono, 2017; Yusuf & Widyaningsih, 2017). Therefore, it is necessary to innovate media and teaching materials that can provide opportunities for students to self-assess and develop their abilities anywhere and anytime.

Based on the previous explanation, there are several solutions, namely the use of instructional media in the form of virtual laboratories, the use of teaching materials in the form of student worksheets, the use of Android, and the use of HOTS questions. To obtain maximum results, these solutions are combined into a virtual laboratory application equipped with teaching materials and HOTS questions on Android. This application is then named "VirtumFi: Quantum Phenomena". As described earlier, this solution is expected to enable students to be able to learn actively, independently, anywhere and anytime. Therefore, this research aims to develop an instructional media "VirtumFi: Quantum phenomena" for high school students that is feasible and practical.

RESEARCH METHOD

Research Design

The VirtumFi application was developed by using the 4D model (Define, Design, Develop, Disseminate) that was adopted by Thiagarajan (1974). VirtumFi is equipped with student worksheets and HOTS questions on the topic of quantum phenomena for high school students. The detailed applied research design is shown in Figure 1.

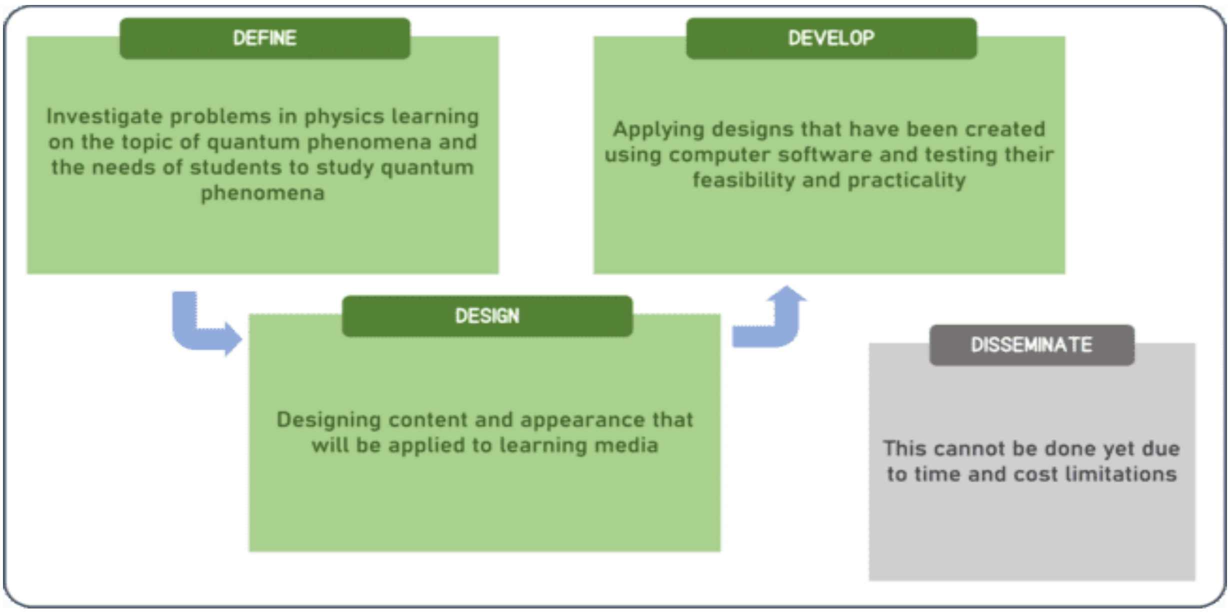


Figure 1. The research design of VirtumFi

Research Participants

A total of 37 high school students were participants in this study. However, 37 of them were involved in the practicality test of instructional media. In addition, two public high school physics teachers and one physics lecturer from one of the state universities were expert validators of the media feasibility test and the validity of HOTS questions. During the feasibility test, an empirical test of the HOTS questions in the media was also conducted. The empirical test of the questions involved participants who had studied the topic of quantum phenomena, namely students of the physics department. The physics students involved were 48 undergraduate students.

Instrument and Procedures

The research data was collected at the developmental stage of the learning media. During testing the feasibility of the media, a 4-point Likert scale was used (Joshi et al., 2015), a media validation questionnaire. This questionnaire assesses the aspects of conceptual correctness, curriculum suitability, user suitability, language, layout, and integration in the instructional media. To measure the quality of HOTS questions, construct validity and empirical tests were conducted. Construct validity test data for HOTS questions were collected using a questionnaire for validating questions on a Likert scale of 4 points, while empirical test data were obtained through working on valid questions by students. After the instructional media and questions were declared valid and qualified, the media practicality test was conducted for high school students as the target users of the instructional media. The media practicality test data was obtained through a Guttman scale (Guttman, 1944) practicality questionnaire instrument ("yes" and "no").

Data Analysis

To determine the feasibility of the instructional media, an analysis using the Rasch Model (Wright, 1977, 1996), was conducted. To determine the validity of the VirtumFi instructional media, a Many-facet Rasch Measurement (MFRM) analysis was conducted. Codification of terms and variables needs to be done in this analysis. The code used in MFRM Analysis for the validity of VirtumFi: Quantum phenomena is presented in Table 1.

Table 1. VirtumFi app validity code in MFRM analysis

Element Code	Explanation
V1	1st Validator
V2	2nd Validator
V3	3rd Validator
EF	Photoelectric Effect Sub-Topic
EC	Compton Effect Sub-Topic
ConsAccurate	Accuracy of concepts (the concepts explained suit the truth of scientific theory and do not give rise to many interpretations)
ClearGuidance	Clarity of laboratory rules
EasyUse	Ease of practical implementation
ClearAnimation	Clarity of the animations that appear in the practicum with the real scientific phenomena
ClearStep	Clarity of analysis direction/step based on practical data
CorContent	Correctness of content material with Basic Competencies (KD)
CorIndicator	Correctness of Indicators with Basic Competencies (KD)
Deepness	Depth of content material (the concepts explained suit the level of student's development)

Element Code	Explanation
Communicative	The language used is communicative and clear so that it is easy for readers to understand
LangStructure	The language structure used is following Indonesian language rules (KBBI) correctly
LangVocabulary	The correct use of terms is following scientific principles and the depth of the content material
Attractive	Attractive background design & color selection
UnifiedColor	Coordinate the background color with the size and type of text
ButtonFunc	The buttons/links work well
ButtonPlace	Proportional button placement
ClearIcon	Clarity of images/icons used
Orderliness	Orderliness of virtual laboratory application component layout

The codes in Table 1 were used to analyze the validity of the media in terms of material content, teaching materials (students' worksheets), and virtual practicum. Using the codes in Table 1, MFRM analysis used Minifacets software. The interpretation of the analysis results in the software was analyzed with certain provisions and instructions presented in Table 3.

Table 2. HOTS item validity code in MFRM analysis

Element Code	Explanation
V1	1st Validator
V2	2nd Validator
V3	3rd Validator
Q1	1st Item Question
Q2	2nd Item Question
Q3	3rd Item Question
Q4	4th Item Question
Q5	5th Item Question
Q6	6th Item Question
Q7	7th Item Question
Q8	8th Item Question
Q9	9th Item Question
Q10	10th Item Question
AttrStimulus	Item using interesting stimulus (new, encourage students to read)
CtxtStimulus	Item using contextual stimulus (images/graphics, text, visualization, etc., according to the real world)
ReasoningLvl	The item measures the cognitive level of reasoning (analyzing, evaluating, creating) which in solving them is characterized by one or more of the following stages of the thinking process.
Ans-Stim	The stimulus in the item provides clues regarding the correct answer, implicitly
CorConcept	The concept used in the item is correct
ProperLang	Using good and correct Indonesian terms and language
SuitIndicator	Suit with the item indicators

The codes in Table 2 were used to analyze the validity and reliability of the HOTS items in the instructional media application. MFRM analysis used Ministep to produce processed data on item content validity. Construct validity and reliability are generated using Rasch analysis through Winstep software. The interpretation of the analysis results in the software was analyzed with the provisions and instructions presented in Tables 3, 4, and 5 (Sumintono & Widhiarso, 2015).

Table 3. Item content quality

Criteria	Acceptable Score Range
MnSq	$0.00 \leq MnSq \leq 1.50$
ZStd	$-2.00 \leq ZStd \leq 2.00$
Pt- Measure Corr.	$0.38 \leq PtMea \leq 0.85$

Table 4. Item construct quality in the context of unidimensionality

Criteria	Score Range	Interpretation
Raw variance explained by measures	>20%	Fulfilled
	>40%	Compliant
	>60%	Special
Unexplained variance 1st contrast (Eigenvalue)	<3	Fulfilled
Unexplained variance 1st contrast (Observed)	<15%	Fulfilled

Table 5. Item construct quality in the context of item difficulty

Score Range	Interpretation
$1SD < Measure$	Very difficult
$0 < Measure \leq 1SD$	Difficult
$-1SD \leq Measure \leq 0$	Easy
$Measure < -1SD$	Very Easy

RESULTS AND DISCUSSION

Define

The Define stage is carried out by analyzing the problems in the field, the characteristics of the party to be targeted as a solution, the characteristics of the physics content at issue, and the expected solution product. Based on the results of the studies from the literature, the problem in the field is about students' understanding of the topic of quantum, which is still low (Hadi & Samdara, 2012; Huseby & Bungum, 2019; Krijtenburg-Lewerissa et al., 2017; Wiyono, 2017; Yusuf & Widyaningsih, 2017). With the abstract and difficult content characteristics of the topic of quantum (Bouchée et al., 2022; Marshman & Singh, 2015), the characteristics of students, who tend to be enthusiastic about using electronic devices (Hanif et al., 2019; Team, 2018), an instructional media is needed that can arouse students' enthusiasm for learning. The media is practicum media (Choi & Park, 2022; Mena et al., 2023; Salmaan et al., 2023), where to make this media feasible, the media is made based on Android. The instructional media is called "VirtumFi: Quantum phenomena" which is targeted at physics teachers and senior school students. Following the current curriculum, the physics content in this media is in the form of photoelectric effect and Compton effect. The features in this media include content-related materials, virtual practicum, worksheets for students, and HOTS questions.

Design

The design stage is done by creating a display design for each frame. At this stage, design is also carried out regarding the division of frames based on features and button links that connect between frames. Then, the design results are applied to Adobe Animate software as Android application development software.

Develop

The result of the design application produces several displays. The appearance of each feature is presented in Figure 2.

Figure 2. Home Display

Figure 2 is the home page that users will see when opening the VirtumFi application. Users can proceed to the next section by pressing the “Start!” button. The next display is shown in Figure 3.

Figure 3. Main menu display

Figure 3 is a display of the features menu in the VirtumFi application. Users can go to "Virtual Laboratory" to conduct virtual labs, "Materials" to read and understand physics concepts related to quantum topic and "Evaluation Questions" to self-evaluate the user's understanding of quantum phenomena content. This self-evaluation consists of ten HOTS questions. In addition, users can also find out the purpose of instructional media, developer profiles, and the basic competencies of instructional media on the three buttons below the display. The Virtual Laboratory feature consists of several facilities, namely laboratory regulations, practicum tools, students’ worksheets, and practicum rides. The display of these facilities is presented in Figures 4, 5, 6, and 7.

Figure 4. Display of laboratory rules and practical tools

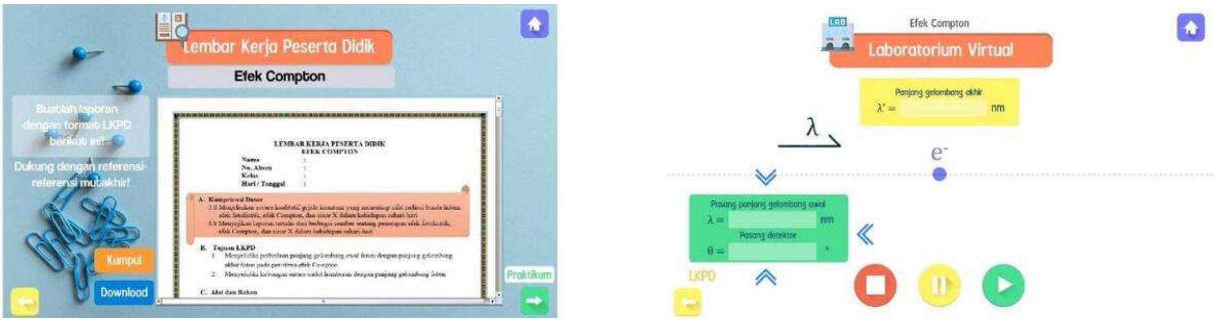


Figure 5. Display of worksheets and practicum forum

The practicum forum as shown in Figure 5 (right) allows users to do the practicum virtually. To conduct the lab in a meaningful way, users can utilize the student's worksheet in Figure 5 (left) as an instruction for conducting the lab in an inquiry manner. In addition, users can have knowledge about the rules in a real laboratory as in Figure 4 (left), and practical tools in a real lab as in Figure 5 (right). This is by the function of a virtual practicum which can be used as a preparation area before users do the real practicum (Singh et al., 2021). Thus, users can do the real practicum properly and correctly. The material feature consists of material in theory and application. The material presentation displayed on this instructional media is as in Figure 6.

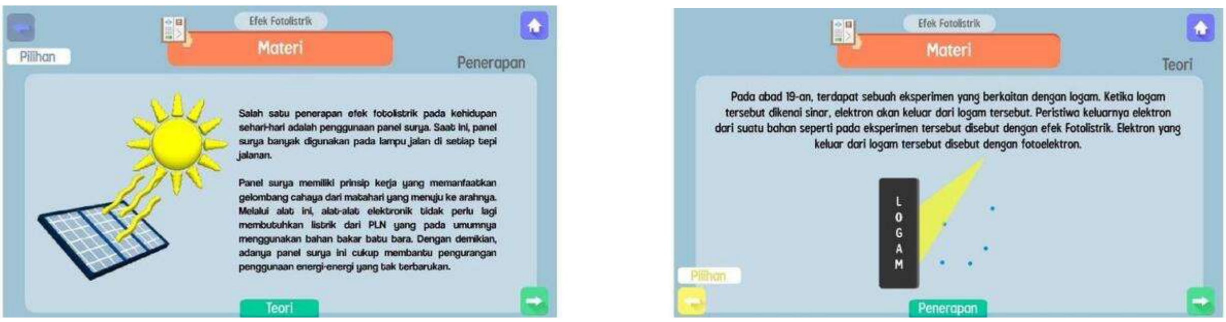


Figure 6. Display of material presentation

The theoretical presentation of material such as Figure 6 (right) allows users to learn the basic concepts and principles of quantum phenomena. Not only understanding the theory, users can also understand the application of the theory presented in Figure 6 (left). Through this presentation, it is expected that users not only understand physics content theoretically but also understand physics content practically and can apply it. The Evaluation Problem feature consists of several HOTS questions presented in Figure 7.

Figure 7. Display of evaluation questions

The HOTS questions presented as in Figure 6 can be an assessment instrument for users to conduct self-evaluation. With this evaluation, it is hoped that users will be able to have knowledge about which content is less understandable and immediately complete the understanding that is still lacking. After all the features have been presented in the form of an Android application, each feature is validated by experts. The validation results for the virtual practicum feature are shown in Figure 8.

Figure 8. Assessment results by indicator for virtual practicum

Figure 8 shows that several indicators are above all validators, namely ClearAnimation, ClearIcon, Communicative, Deepness, ButtonPlace, and CorContent. This shows that the virtual practicum in this media already has clear icons and animations, communicative grammar, appropriate depth of material, proper button placement, and scientific truth of concepts. However, several indicators below are all validators, namely Attractive, ButtonFunc, ClearGuidance, ConsAccurate, CorIndicator, EasyUse, LangStructure, LangVocabulary, Orderliness, and UnifiedColor. This shows that the media still needs improvement in the aspects of attractiveness, button functionality, clarity of instructions, concept accuracy, suitability to learning indicators, ease of use, language structure, vocabulary suitability, display orderliness, and color tone harmony on the display. According to Ahir et al. (2014) and Rao et al. (1999), validation is very important in the development process to produce a quality product. Meanwhile, the results of the validation of instructional media material features are presented in Figure 9.

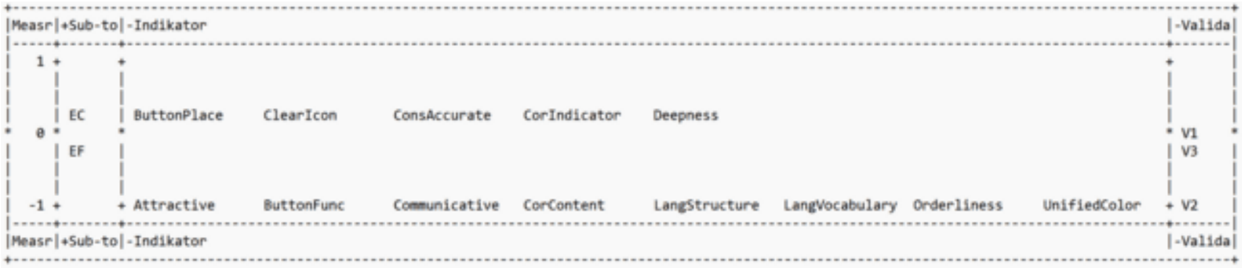


Figure 9. Assessment results based on indicators for content material

Figure 9 shows that all assessment indicators are at least in line with the validators. There are no indicators that are below the validator. This shows that all validators agreed that the material featured in this media already has clear icons and animations, communicative grammar, appropriate depth of material, appropriate button placement, scientific correctness of concepts, attractiveness, button functionality, clarity of instructions, concept accuracy, compatibility with learning indicators, ease of use, language structure, vocabulary suitability, display order, and color tone alignment on the display. The validity of instructional media's student's worksheets is presented in Figure 10.

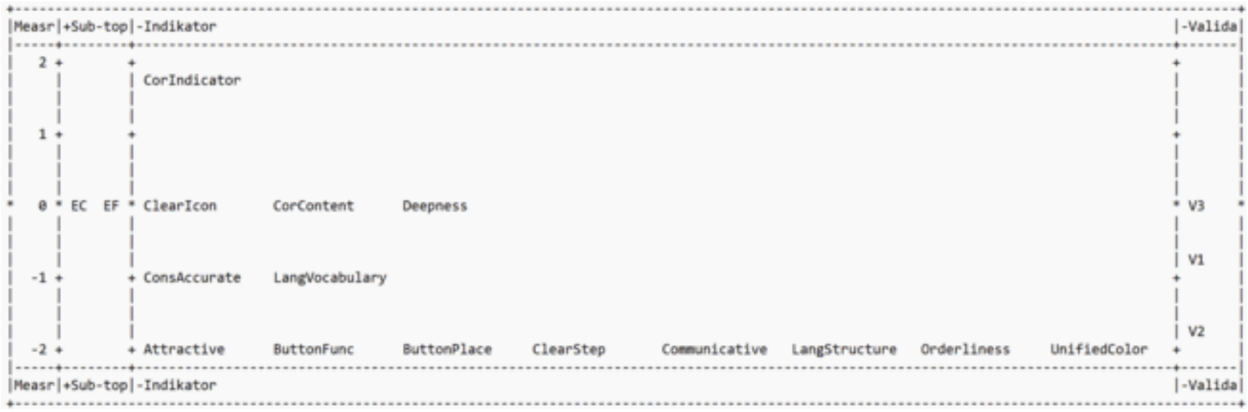


Figure 10. Assessment results by indicator for student worksheet

Based on Figure 10, several indicators have been fulfilled in the student's worksheet in the instructional media. These indicators are those in the yellow color box. Therefore, the aspects that have been fulfilled are the suitability of students' worksheets with learning indicators, clarity of icons, correctness of content, and depth of material with the psychological level of students. In addition, there are several indicators that are only declared valid by two indicators, namely the indicators in the blue color box. This shows that the students' worksheets already have sufficient quality on the accuracy of the concept and the accuracy of the use of vocabulary. However, there are still some indicators that have not been declared valid, namely the indicators in the green color box. These indicators represent aspects of appearance attractiveness, button functionality, button placement, clarity of students' worksheets steps, communicative, language structure, layout order, and display color integration. The Evaluation Problem feature in the instructional media contains HOTS items that need to be analyzed in different ways. Item analysis was conducted on this HOTS question. The results of item analysis in the context of content validity are presented in Figure 11.

```
                                             Count   Mean   S.D.
Responses non-extreme estimable      =        210   3.60   0.63
Count of measurable responses        =        210
Raw-score variance of observations   =      0.402 100.00%
Variance explained by Rasch measures =      0.171  42.49%
Variance of residuals                =      0.231  57.51%
```

Figure 11. Results of analysis of variance of HOTS question validity measurement

Figure 11 shows that 42.49% of the variance can be explained by the Rasch measurement (Linacre, 1999; Medvedev & Krägeloh, 2022). Based on Table 4, this figure results in the interpretation that the measurements made have the criteria of "Fit" with the existing theory. Therefore, the results of this measurement can be analyzed and interpreted correctly.

```
+------------------------------------------------------------------------+
|Measr|+Item                |-Indicator                   |-Valida|Scale|
|-----+---------------------+-----------------------------+-------+-----|
|   2 +                     +                             +       + (4) |
|     |                     |                             |       |     |
|     |                     |                             |       |     |
|     |                     |                             |       |     |
|   1 + Q5                  + ReasoningLvl  SuitIndicator +       + --- |
|     |                     | CtxtStimulus                |       |     |
|     | Q2                  |                             |       |     |
|     | Q9                  |                             |       |     |
*   0 * Q10  Q3   Q4   Q8   * AttrStimulus                *       *  3  *
|     | Q6   Q7             |                             |       |     |
|     |                     | Ans-Stim                    |       |     |
|     |                     |                             |       |     |
|  -1 +                     + ProperLang                  + V1    + --- |
|     | Q1                  | CorConcept                  | V3    |     |
|     |                     |                             |       |     |
|     |                     |                             |       |     |
|  -2 +                     +                             +       +     |
|     |                     |                             |       |     |
|     |                     |                             |       |     |
|     |                     |                             |       |     |
|  -3 +                     +                             +       +     |
|     |                     |                             |       |     |
|     |                     |                             | V2    |     |
|  -4 +                     +                             +       + (2) |
|-----+---------------------+-----------------------------+-------+-----|
|Measr|+Item                |-Indicator                   |-Valida|Scale|
+------------------------------------------------------------------------+
```

Figure 12. All facets of vertical analysis results

Figure 12 shows that 9 out of 10 questions are above the position of all validators. This indicates that these nine questions are considered valid, namely Q2 to Q10. On the other hand, question Q1 was only approved by one validator. The question was considered only to have the correctness of the concept in physics but had not fulfilled the match of the level of reasoning of the question, the suitability of the question indicator, the suitability of the stimulus to the context, the attractiveness of the stimulus, the availability of implicit information about the answer in the stimulus, and the suitability of the use of language. However, question Q1 was still considered valid by the other two validators. To obtain in-depth item validity, an item fit analysis was conducted. The results of the analysis are shown in Figure 13.

Total Score	Total Count	Obsvd Average	Fair(M) Average	+ Measure	Model S.E.	Infit MnSq	Infit ZStd	Outfit MnSq	Outfit ZStd	Estim. Discrm	Correlation PtMea	Correlation PtExp	Nu	Item
68	21	3.24	3.37	-1.21	.37	.39	-2.6	.36	-1.8	1.73	.85	.67	1	Q1
78	21	3.71	3.84	.43	.47	1.13	.4	.88	.1	.91	.41	.47	2	Q2
76	21	3.62	3.77	.02	.43	1.01	.1	3.16	2.1	.65	.37	.53	3	Q3
76	21	3.62	3.77	.02	.43	.81	-.4	.48	-.6	1.36	.64	.53	4	Q4
80	21	3.81	3.90	.94	.55	1.44	.9	6.95	2.7	.58	.16	.40	5	Q5
74	21	3.52	3.69	-.32	.40	.88	-.2	2.28	1.6	.90	.52	.58	6	Q6
75	21	3.57	3.73	-.15	.42	.78	-.6	.51	-.6	1.35	.65	.55	7	Q7
76	21	3.62	3.77	.02	.43	.81	-.4	.48	-.6	1.36	.64	.53	8	Q8
77	21	3.67	3.81	.22	.45	.89	-.1	1.19	.4	.78	.39	.50	9	Q9
76	21	3.62	3.77	.02	.43	1.31	.9	3.22	2.1	.59	.36	.53	10	Q10
75.6	21.0	3.60	3.74	.00	.44	.94	-.2	1.95	.6		.50			Mean (Count: 10)
3.0	.0	.14	.14	.52	.04	.28	1.0	1.97	1.4		.19			S.D. (Population)
3.1	.0	.15	.14	.55	.05	.30	1.0	2.08	1.5		.20			S.D. (Sample)

Figure 13. Results of fit item analysis

The results of the item fit analysis in Figure 13 show that there are items that do not fulfill the Rasch model measurement. The criteria that have not met the fit requirements are given a red color box on each item. There are several items that do not fulfil one criterion, namely items Q1, Q4, Q6, and Q8. Some of these items can still be used with minor improvements. On the other hand, items Q3, Q5, and Q10 have three criteria that do not meet the suitability requirements. Therefore, these three items will be dropped. After these three items are dropped, the remaining items that are considered valid are Q1, Q2, Q4, Q6, Q7, Q8, and Q9. These valid questions will be empirically tested to determine their construct validity presented in Figure 13.

Table of STANDARDIZED RESIDUAL variance in Eigenvalue units = Item information units

		Eigenvalue	Observed		Expected
Total raw variance in observations	=	8.2464	100.0%		100.0%
Raw variance explained by measures	=	1.2464	15.1%		15.0%
Raw variance explained by persons	=	.7073	8.6%		8.5%
Raw Variance explained by items	=	.5391	6.5%		6.5%
Raw unexplained variance (total)	=	7.0000	84.9%	100.0%	85.0%
Unexplned variance in 1st contrast	=	2.0817	25.2%	29.7%	
Unexplned variance in 2nd contrast	=	1.3843	16.8%	19.8%	
Unexplned variance in 3rd contrast	=	1.2641	15.3%	18.1%	
Unexplned variance in 4th contrast	=	1.0897	13.2%	15.6%	
Unexplned variance in 5th contrast	=	.6662	8.1%	9.5%	

Figure 13. Results of unidimensionality analysis of hots problem items

Based on Figure 13, the HOTS questions in the instructional media have some notes regarding their unidimensionality. Three criteria values must be met. Of these three values, there is only one value that fulfills the unidimensionality requirement, namely the eigenvalue of Unexplained variance in 1st contrast whose value is 2.0817. On the other hand, the conditions that have not been met are the percentage of Observed Raw Variance that can be detected by the measurement and the percentage of Unexplained variance in 1st contrast whose values are 15.1% and 25.2%, respectively. This figure has not fulfilled the unidimensionality requirement that has been set. This situation proves that HOTS questions in instructional media do not only measure one student's ability. Based on the eigenvalue of Unexplained variance in 1st contrast, this HOTS test instrument measures two student abilities. Of course, this follows the number of sub-topics presented in this instrument, namely two. In addition to measuring the quality of the questions in measuring students' abilities, the validity test was also conducted to measure the suitability of the items in measuring students' abilities (Qomariyah, 2023; Suherman, 2022; Istiyono, 2020).

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	JMLE MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PTMEASUR-AL CORR.	PTMEASUR-AL EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Item
1	10	47	.23	.39	1.02	.18	1.13	.57	.38	.42	75.0	74.2	Q1
2	12	47	-.07	.38	1.08	.57	1.05	.30	.40	.45	63.9	69.7	Q2
3	15	47	-.47	.36	.84	-1.34	.77	-1.55	.61	.50	69.4	65.5	Q4
4	16	47	-.60	.36	1.06	.51	1.08	.56	.47	.51	61.1	65.4	Q6
5	13	47	-.21	.37	1.02	.19	1.09	.55	.44	.47	72.2	67.5	Q7
6	12	47	-.07	.38	.99	.01	1.03	.23	.45	.45	69.4	69.7	Q8
7	5	47	1.19	.50	.97	.01	.79	-.31	.34	.31	86.1	86.1	Q9
MEAN	11.9	47.0	.00	.39	1.00	.02	.99	.05			71.0	71.2	
P.SD	3.4	.0	.55	.05	.07	.59	.14	.71			7.6	6.7	

Figure 14. Item fit-statistic and item difficulty analysis results

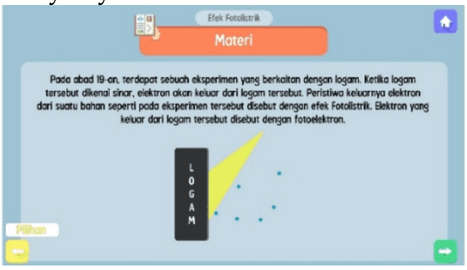
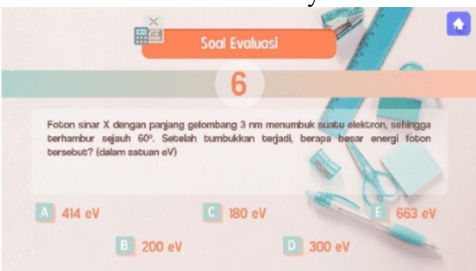
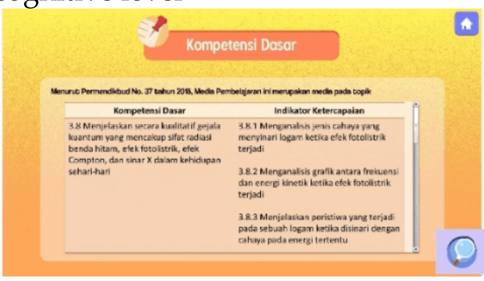
Item suitability is measured through the Outfit MnSq, Outfit ZStd, and PtMeasure-Al Corr values. Each item had values that met the acceptance requirements except item Q9. However, Q9 did not qualify on only one criterion, namely Pt Measure-Al Corr. The other two criteria were sufficient to be able to make Q9 remain a suitable item. In addition to suitability, item validity is also seen through the distribution of question difficulty. Question difficulty is obtained through the JMLE Measure criterion in Figure 4. This value is interpreted following Table 5. Based on Table 5, five questions belong to easy questions, namely Q2, Q4, Q6, Q7, and Q8. On the other hand, there is one difficult and very difficult question each, namely Q1 and Q9 respectively. The distribution of these questions is fairly even, but it can be further improved by adding very easy questions so that each level of questions is covered in one instrument.

Table 6. Critics and suggestions for instructional media improvement

Validator	Interpretation
V1	Overall, it is very good, but it needs to be developed further, especially by giving examples of its application in everyday life. It is necessary to revise questions that are not in accordance with the indicators.
V2	Very good. It is better not to use the word how many in multiple-choice questions.
V3	This is good. However, re-examine the suitability of operational verbs with question indicators to match the cognitive level.

Table 7. Display before and after instructional media improvement

Before	After
• Overall, it is very good, but it needs to be developed further, especially giving examples of its application in	• The application of the photoelectric effect and the Compton effect to everyday life has been added to the

Before	After
everyday life. 	material feature. 
• Multiple choice questions should not use the word "how many". 	• After analysis, it was revealed that the questions containing the word "how much" did not fulfill the criteria of HOTS questions, so the questions were replaced with new questions without the word "how much". 
• Need to revise questions that are not in accordance with the indicators • There are some questions that are not HOTS questions • Look again at the suitability of operational verbs with question indicators so that they match the cognitive level	• Some questions and indicators have been revised by considering the operational verbs of Bloom's taxonomy. Questions that were considered not HOTS have been revised into HOTS questions.
	
	

After being tested for validity, the HOTS questions were then tested for reliability. This test shows how consistent the items are in measuring students over time (Kalkbrenner, 2023; Tavakol & Dennick, 2011). The reliability test of HOTS questions resulted in a

Cronbach-α value of 0.35. This figure indicates that the questions fall into the Rather Reliable category (Ahdika, 2017). With such results, this HOTS question can be improved for further use. The validity test opens up knowledge about the shortcomings that exist in the instructional media developed. Some of these deficiencies need to be corrected so that the instructional media can be used properly. In this regard, several validators provided criticism and suggestions for improvement to the instructional media being developed as in Table 6. Based on the criticisms and suggestions in Table 6, improvements were made to the instructional media. The situation before and after improvement is presented in Table 7. One that can contribute to solutions to previous research's shortcomings is Android. This is supported by data that Indonesia is now ranked the fourth most active country using smartphones, where 25% of the total population, around 65 million people, are Android smartphone users (Kemenristekdikti, 2017; Wahyudi, 2015). Android can provide high flexibility (Holla & Katti, 2012; Liu et al., 2023). It also allows students to access the internet more easily. In 2017, the 19-34 age range has become the main contributor to internet users, of which 70.54% are high school students (Team, 2018).

CONCLUSION

Fundamental Finding: This research develops an Android instructional media named VirtumFi (Virtual Laboratorium Fisika) which has been tested valid and practical. **Implication**: VirtumFi can have an impact on the learning of quantum for high school students, especially in increasing understanding and adjusting technological developments. In addition, VirtumFi can also be accessed where teachers and students are offline. **Limitation**: This research is limited only to the developmental stage with content and construct validity tests. The material presented only focuses on quantum phenomena. Besides, VirtumFi was only tested in one class to see its practicality. **Future Research**: Through VirtumFi, it is hoped that it can be widely disseminated and can be developed again on other physics materials so that it adapts to developments.

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