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Development of Adventures in the World of Light (AiWoL) Comic: Understanding of the Light Concept

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Abstract

This research aims to develop the Adventures in the World of Light (AiWoL) comic to understand the concept of the duality of light (as particles and waves). AiWoL tells the journey of the concept of the duality of light and is part of an Augmented Reality (AR) development project called Physics Virtual Technology Teaching Tools (PV3T). This development uses the Identify, Design, Development, Evaluation (IDDE) design. Validity sheets are given to physics, media, and conceptual psychology experts to see the feasibility of the AiWoL comic. Respondents at the evaluation stage were 39 students who had studied light waves (in the aspects of image clarity, language usage, and conceptual understanding). Meanwhile, Rasch analysis was used to identify the feasibility of the AiWoL comic based on the respondents' answers. The results showed that the instrument quality value in terms of the suitability of the physics concept (86), media feasibility (92), and psychology of conception (98) (all in the very good category). Meanwhile, the results of the Rasch analysis showed that the AiWoL comic feasibility instrument was reliable (0.94 (excellent)) and valid (56.1% (appropriate)). In addition, the AiWoL comic has aspects of Image clarity (83%), Language usage (85%), and Conceptual understanding (85%) (all in the very good category). These results also confirm no bias towards the semester and gender. Furthermore, the AiWoL comic will be used as part of the design for developing Physics Virtual Technology Teaching Tools (PV3T), which is an application based on Augmented Reality (AR).

Keywords: AiWoL; conceptual understanding; comic; light concept

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INTRODUCTION

Conceptual understanding is one of the fundamental parts of learning physics. Concepts fully understood by students can last for a long time (Anfusiyah et al., 2024; Garcia I Grau et al., 2021; Phanphech et al., 2019). Often, students have a conceptual understanding or what

is known as a conception resulting from various factors, such as experience, previous learning, reading books, myths, and others (Mason & Zaccoletti, 2021; Saputra & Mustika, 2022; Wadhwa et al., 2020). If the students' conceptual understanding is based on scientific concessions, then learning it will only strengthen their understanding. However, if the understanding is not by scientific conception, this will impact further learning in class. The incompatibility of the conception held by students with scientific conception is called misconception (Listianingrum et al., 2022; Samsudin et al., 2024; van Ginkel et al., 2020). Misconceptions can hinder learning and understanding the concept. Thus, understanding the concept becomes fundamental in understanding or learning a concept, such as in physics.

Some concepts in physics have varying degrees of difficulty, depending on the type of phenomena that can be observed. However, phenomena in physics generally can only be seen as their cause and effect, without seeing the abstract phenomena that occur in them (Banda & Nzabahimana, 2021; Cai et al., 2021). Thus, it is very difficult to understand the concept of physics because almost all concepts in physics are abstract (Samsudin et al., 2024; Samsudin, Suhandi, et al., 2023). One of the abstract concepts of physics is the concept of light (Aminudin et al., 2019; Samsudin et al., 2021; Usta et al., 2020).

Light concept is one of the physics concepts that is often found in everyday life. This concept has several behaviours: reflection, refraction, dispersion, diffraction, interference, and polarization. However, several studies still need to be made aware of the concept of light (Aminudin et al., 2019; Samsudin et al., 2021; Usta et al., 2020). In addition, there is a concept of light which historically can be confusing in determining the characteristics of light, namely light as particles and waves (Cvenic et al., 2021; Métioui, 2023; Persson, 2021).

Scientists initially debated light as a particle and a wave. Until now, both theories can be used simultaneously or complement each other. One phenomenon that combines the two is the photoelectric effect (Cvenic et al., 2021; Métioui, 2023; Persson, 2021). The photoelectric effect is a phenomenon where light waves fall on a metal surface, causing electrons to jump from the metal surface (Balabanoff et al., 2020; Ha & Jho, 2022). In short, this phenomenon describes light that was originally a wave but can behave simultaneously as a particle in one phenomenon. Thus, we consider the journey of the concept of light as a particle to a wave, and now a combination of the two is one of the important concepts to learn. In this study, we tell the history of light dualism in comics.

Comics are a reading medium that combines text and images. The use of comics several researchers have used teaching materials to improve student literacy and convey messages that are easy to understand or make it easier to understand concepts (Rosdiana & Kholiq, 2021; Septiawan et al., 2023; Suri et al., 2021). In addition, because it contains images that convey information, it is hoped that it can become a long-term memory in understanding the concept and motivation in learning (Pathoni et al., 2024). Information conveyed in images will be remembered longer than text (Vanichvasin, 2020). Meanwhile, several researchers have implemented comics as a learning medium (Pathoni et al., 2024; Sari et al., 2020; Suri et al., 2021).

Currently, comic development has been carried out for various purposes, for example to improve critical thinking on temperature and heat (Rosdiana & Kholiq, 2021), creativity on parabolic motion (Sari et al., 2020), conceptual understanding (Badeo & Ong Kian Koc, 2021), motivation (Pathoni et al., 2024)

and use in the concept of Newton's laws (Baifeto et al., 2022). However, it is still rare to find comics that discuss the concept of light and the history of light dualism. Thus, this research aims to develop a comic entitled Adventures in the World of Light (AiWoL) to understand the concept of the duality of light (as particles and waves). Meanwhile, the history of the dualism of light was taken because it is still difficult to get stories from scientific figures, especially in comic form.

METHOD

The development of AiWoL uses the Identify, Design, Development, Evaluation (IDDE) design. This design adapts the Analysis, Design, Development, Implementation and Evaluation (ADDIE) stages (Arisanti et al., 2022; Mahbubah et al., 2020; Spatioti et al., 2022). However, we summarize the Analysis stage into Identify, because this stage is still in the early stages, so it needs to be analyzed but identified. The analysis stage is still being carried out, and this research uses VOSviewer analysis at the identification stage. However, we highlight the Identification stage as a sub in this design as an initial action before analysis. Furthermore, ADDIE's implementation and evaluation stages are combined into Evaluation only in IDDE. This summarises the stages so that the results can be directly evaluated. Meanwhile, the IDDE stages will be a guide in presenting the results of this study, where each stage has a description as in Figure 1.

Based on Figure 1, at the Identify stage, we analyzed the needs of teaching materials such as comics developed in this research. The results of the analysis will be the basis for making a design and are carried out at the Design stage. For the Development stage, we conducted development based on the previous design. Furthermore, the Evaluation stage is carried out to determine the comics' feasibility.

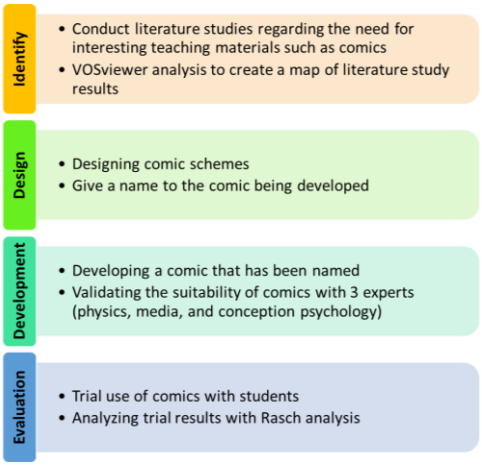


Figure 1 The IDDE design

The research instruments are the validity sheet and the comic feasibility questionnaire. The validation sheet is given to the relevant experts: 1) The physics concept contained in the AiWoL comic; 2) The feasibility of the AiWoL comic media, and 3) The relevance of the conception instrument to the content contained in the AiWoL comic. Meanwhile, the comic feasibility questionnaire is given to respondents using a Likert scale (score 1 (Very Poor) to 5 (Very Good)). There are nine indicators (Table 1) represented by one question for each indicator.

Table 1 Questionnaire indicator

Aspects	No	Indicators
Image clarity		Images are presented clearly
		Image layout is kept according to the reading flow of the AiWoL comic
		Each image looks interesting
Language usage		There are no typos in each AiWoL comic writing
		The font size in each writing is appropriate and can be read
		The language in each dialogue is easy to understand

Conceptual understanding	The story in the AiWoL comic is easy to understand
	The physics concept in the AiWoL comic is presented clearly
	The AiWoL comic makes it easier to understand the concept of Light Waves

Respondents

The respondents in this study were 39 students who had studied light waves (either at school or on campus). Respondents came from various campuses because they were inputted based on their willingness to assess the AiWoL comic. Meanwhile, the students who became respondents consisted of students in semesters 1 (74%), 2 (3%), 3 (18%), 4 (3%), and 7 (3%). Meanwhile, based on gender, we have 33 Males and 6 Females. The respondents' distribution looks uneven, but we do not condition the respondents obtained; we research based on the respondents obtained. Respondent data was then arranged based on serial number, gender, and semester when this data was collected. For example, a respondent with code 01M4, meaning that the student is a student with serial number 01, gender category M (Male), and semester 1 when this data was taken. For the gender code, we created categories M (Male) and F (Female).

Data analysis

The analysis of validity results uses percentages with categories Very Poor (% ≤ 20), Poor (20 <% ≤ 40), Sufficient (40 <% ≤ 60), Good (60 <% ≤ 80), and Very Good (80 <% ≤ 100) (Iskandar et al., 2023; Nursanni et al., 2024; Susanti et al., 2021). Meanwhile, Rasch analysis is used to identify the feasibility of AiWoL comics based on respondents' answers. The software used is ministep 5.7.4.0 with outputs including Output Tables: Table 3.1. Summary Statistics (questionnaire reliability), Table 23 Dimensionality Map (construct validity), Table 1 Variable (Wright) maps and WrightMaps R Statistics (comparison of Person and Item abilities), and Table 30 ITEM: DIF, between/within (bias identification) for semester and gender.

RESULTS AND DISCUSSION

The results of the AiWoL development in this study will be presented based on the Identify, Design, Development, Evaluation (IDDE) design.

Identify

At this stage, a literature review was conducted using VOSviewer analysis. VOSviewer analysis has been used by several researchers as a literature review (Amiruddin et al., 2024; Majid & Buyamin, 2024; Samsudin, et al., 2023). The articles used came from the Scopus database with the following search: (TITLE (comic) AND TITLE (physics)) AND PUBYEAR > 2015 AND PUBYEAR < 2024). The results obtained 18 articles that were directly identified by VOSviewer for keyword search (Figure 2).

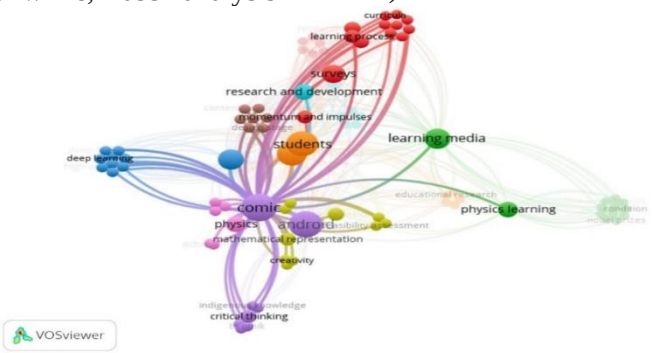


Figure 2 Keyword analysis results

Based on Figure 2, we identified that comics in physics are related to various aspects such as curriculum, learning process, surveys, momentum and impulse (red), research and development (light blue), students (orange), learning media, physics learning (green), feasibility assessment, mathematical representation, creativity (yellow), android, critical thinking (purple), physics (pink), and deep learning (blue). The colors in Figure 2 show the classification produced by the VOSviewer analysis based on its cluster and are connected by a network between colors that indicate a relationship between one and another. In total, 87 keywords are included in 9 clusters as shown in Table 2.

Table 2 VOSviewer analysis cluster

No	Keyword	Occurrences	Total Link Strength	No	Keyword	Occurrences	Total Link Strength
Cluster 1 (19 items)				**Cluster 4 (10 items)**			
1	Character education	1	14	4	Feasibility assessment	1	8
2	Computer games	1	14	5	Gain analysis	1	9
3	Curricula	1	14	6	Hopscotch	1	5
4	E-learning	1	14	7	Local wisdom	1	5
5	Field trial	1	14	8	Mathematical representation	2	14
6	Junior high schools	1	14	9	Research data	1	8
7	Learning physics	1	14	10	Scientific approach	1	8
8	Learning process	2	28	**Cluster 5 (8 items)**			
9	Learning systems	2	28	1	Android	9	73
10	Momentum and impulses	2	23	2	Benthik	1	5
11	Needs analysis	1	14	3	Comic	10	82
12	Output values	1	14	4	Critical thinking	2	9
13	Product assessment	1	14	5	Indigenous knowledge	1	4
14	Research designs	1	14	6	Kofie gebol	1	5
15	Research instruments	2	28	7	Vector representation	1	5
16	Student response	1	14	8	Verbal representation	1	4
17	Students' perceptions	1	14	**Cluster 6 (7 items)**			
18	Surveys	4	53	1	Addie model	1	11
19	Teachers' perceptions	1	14	2	Cameras	1	11
Cluster 2 (13 items)							
1	Condition	1	12	4	Developing product	1	11
2	Ejected electrons	1	12	5	Optical devices	1	11
3	Electron sources	1	12	6	Product design	2	25

No	Keyword	Occurrences	Total Link Strength	No	Keyword	Occurrences	Total Link Strength
4	Emitted electron	1	12	7	Research and development	3	39
5	Energy	1	12	**Cluster 7 (7 items)**			
6	Field emission cathodes	1	12	1	Concept analysis	1	9
7	High frequency hf	1	12	2	Education computing	7	76
8	Learning media	5	60	3	Design products	1	11
9	Light color	1	12	4	Learning objectives	1	9
10	Nobel prizes	1	12	5	Media components	1	9
11	Photoelectricity	1	12	6	Physical aspects	1	9
12	Physics learning	3	29	7	**Students**	8	88
13	Short wavelengths	1	12	**Cluster 8 (7 items)**			
Cluster 3 (10 items)				1	Content validity indices	1	14
1	Deep learning	1	12	2	Cooperate attitude mapping	1	14
2	Deep questions	1	12	3	Design stage	1	14
3	High order thinking skills	1	12	4	Mapping	1	14
4	High school	5	54	5	Material-based	1	14
5	Lkpd	1	12	6	Model development	1	14
6	Lup	1	12	7	Thermodynamics	1	14
7	Maximum accommodation eyes	1	12	**Cluster 9 (6 items)**			
8	Student learning	1	12	1	Achievement	1	3
9	Systematic learning	1	12	2	Conceptual understanding	1	8
10	Thinking skills	1	12	3	Development model	1	8
Cluster 4 (10 items)				4	Motivation	1	3
1	Creativity	1	5	5	Newton's gravity	1	8
2	Data collection	2	17	6	Physics	3	20
3	Experimental research	1	9				

Table 2 shows the Occurrences and Total Link Strength data that interpret Figure 2. The Occurrences data shows the frequency of occurrence of the identified keywords (Ding & Yang, 2022; Wang et al., 2022). This data can be used to determine how often the keyword appears in the article. The higher the frequency in the occurrences data, the more popular the keyword is, and the circle shape size is determined in the VOSviewer analysis results. The highest occurrence value in Table 2 is for the keyword Comic (10 (yellow)). This means that the keyword comic has the most popularity among other keywords.

Meanwhile, the lowest value is 1 and is found in 69 keywords (orange color) (cluster 1 (14), cluster 2 (11), cluster 3 (9), cluster 4 (8), cluster 5 (5), cluster 6 (5), cluster 7 (5), cluster 8 (7), and cluster 9 (5). This result is because the setting we made to the VOSviewer threshold is 1. This means that at least 1 article that mentions the keyword will appear in the analysis results. Meanwhile, the Total Link Strength in Table 2 identifies the strength of the relationship between two or more keywords. Keywords with a high Total Link Strength show how often the keyword relates to other keywords. The highest Total Link Strength value in Table 2 is in the keyword Students at 88 (yellow color (cluster 7)). The lowest value is 3 and is in the keywords Achievement and Motivation (orange color (cluster 9)). Meanwhile, the keyword Comic has the second highest size after Students, which is 82. Thus, if you look at the average value of Occurrences and Total Link Strength, the highest value is the student (48), and the lowest is the achievement and Motivation (2). Meanwhile, the value for the keyword comic is 46, the second highest after the keyword Students. The results of this analysis illustrate that the use of comics is often aimed at students with various variables, such as achievement and motivation, even though the results of the VOSviewer analysis show the lowest results.

Design

The design in this section is not a research design but a design as a stage in developing a comic. At this stage, we design the comic scheme and give a name to the comic that is being developed. The comic is designed with a storyline about how light can be considered particles and waves. In general, the stages in designing a comic can be seen in Table 3.

Table 3 Comic design

No	Design Stages
1.	Compiling a short story about the journey of light dualism as particles and waves.
2.	Looking for physicists involved.
3.	Compiling a multi-tier open-ended instrument relevant to the comic's content.
4.	Naming the comic.
5.	Validating the eligibility of the comic to experts in physics, media, and conceptual psychology.

Development

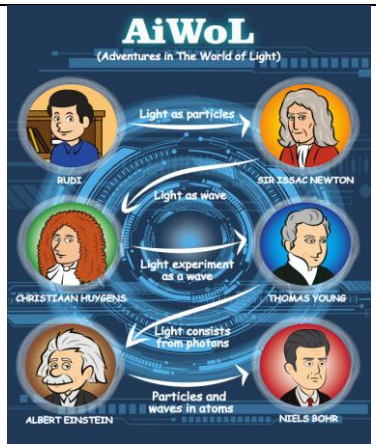
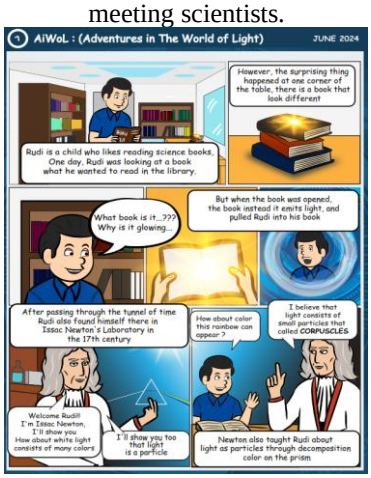
At this stage, we developed the comic according to the design made in Table 3. After a short story about the journey of light as particles and waves was made, then a character was created with Rudi as the main character who likes to read, especially books about science. Briefly, the story in the comic is as follows.

While in the library, Rudi saw a glowing book. He was curious about the book and approached it. After holding the book, Rudi opened it, but he was instead carried into the book through a time tunnel. After entering the book, Rudi met Isaac Newton, Christiaan Huygens, Thomas Young, Albert Einstein, and Niels Bohr. These characters briefly describe the story of the dualism of light as particles and waves. This story describes Rudi's journey in exploring the world of light. Thus, the name was taken for the title of this comic, AiWoL (Adventures in the World of Light). Several scenes based on the story above can be seen in Table 4.

Before the AiWoL comic was implemented, we conducted a feasibility test using an instrument that had been given to 3 experts (physics, media, psychology of conception). The reason was to check and validate the AiWoL story and the physics concept; thus, it was given to physics experts for validation. In terms of media, the feasibility of the comic and language were given to media experts. In terms of the psychology of conception, it was used to validate the

multi-tier open-ended instrument. The validation results can be seen in Figure 3.

Table 4 AiWoL comic scene example

No	Scene on AiWoL
1.	 The cover depicts Rudy's journey meeting scientists.
2.	 Rudi meets Newton to discuss light as a particle
3.	 Rudi meets Thomas Young to discuss the superposition of light waves

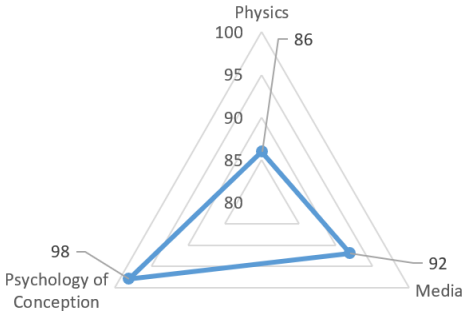


Figure 3 AiWoL validation results by experts

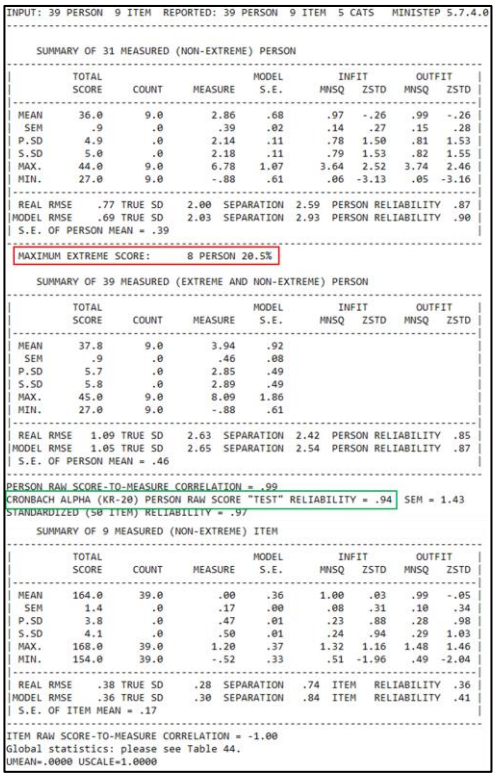
Based on Figure 3, the results show that the quality of the comic in terms of physics, media, and psychology concepts received scores of 86, 92, and 98 (very good category), respectively. Thus, the three experts recommend that it be used with some revisions. Several comments were made on the AiWoL comic, and the suggestions made became revision materials before being implemented for students.

Evaluation

The evaluation stage was carried out on the feasibility of the AiWoL comic. The feasibility of the comic was assessed based on nine questions referring to the questionnaire indicators (Table 1). First, we identified the reliability of the questionnaire used, to describe the feasibility of the questionnaire instrument, and the results of further interpretation can be considered. The results obtained based on the Rasch analysis of the reliability of the questionnaire can be seen in Figure 4.

Figure 4 shows an extreme score (8 person 20.5%) (red box). This value is based on respondents who answered extremely such as answering all questions with only one category at the extreme score (score 0 or 5 only on the Likert scale). Based on the identification results, 8 respondents were students with codes 07M1, 12M1, 15M1, 16M1, 25F1, 34M1, 36F1, and 38M1. These

respondents answered nine questions with a score of 5 (Strongly Agree), so they are included in the extreme score category. However, in the reliability results, we found that Cronbach Alpha (KR-20) has a value of 0.94 (green box), which means it is included in the very good category in the Rasch analysis (Ilfiandra et al., 2022; Muslihin et al., 2022). These results indicate that there is consistency from the sample in assessing the comics that were developed.



INPUT: 39 PERSON 9 ITEM REPORTED: 39 PERSON 9 ITEM 5 CATS MINISTEP 5.7.4.0

SUMMARY OF 31 MEASURED (NON-EXTREME) PERSON

	TOTAL SCORE	COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
MEAN	36.0	9.0	2.86	.68	.97	-.26	.99	-.26
SEM	.9	.0	.39	.02	.14	.27	.15	.28
P.SD	4.9	.0	2.14	.11	.78	1.50	.81	1.53
S.SD	5.0	.0	2.18	.11	.79	1.53	.82	1.55
MAX.	44.0	9.0	6.78	1.07	3.64	2.52	3.74	2.46
MIN.	27.0	9.0	-.88	.61	.06	-3.13	.05	-3.16

REAL RMSE .77 TRUE SD 2.00 SEPARATION 2.59 PERSON RELIABILITY .87
MODEL RMSE .69 TRUE SD 2.03 SEPARATION 2.93 PERSON RELIABILITY .90
S.E. OF PERSON MEAN = .39

MAXIMUM EXTREME SCORE: 8 PERSON 20.5%

SUMMARY OF 39 MEASURED (EXTREME AND NON-EXTREME) PERSON

	TOTAL SCORE	COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
MEAN	37.8	9.0	3.94	.92				
SEM	.9	.0	.46	.08				
P.SD	5.7	.0	2.85	.49				
S.SD	5.8	.0	2.89	.49				
MAX.	45.0	9.0	8.09	1.86				
MIN.	27.0	9.0	-.88	.61				

REAL RMSE 1.09 TRUE SD 2.63 SEPARATION 2.42 PERSON RELIABILITY .85
MODEL RMSE 1.05 TRUE SD 2.65 SEPARATION 2.54 PERSON RELIABILITY .87
S.E. OF PERSON MEAN = .46

PERSON RAW SCORE-TO-MEASURE CORRELATION = .99
CRONBACH ALPHA (KR-20) PERSON RAW SCORE "TEST" RELIABILITY = .94 SEM = 1.43
STANDARDIZED (50 ITEM) RELIABILITY = .97

SUMMARY OF 9 MEASURED (NON-EXTREME) ITEM

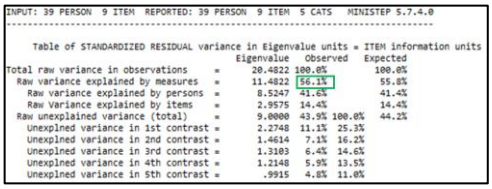
	TOTAL SCORE	COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
MEAN	164.0	39.0	.00	.36	1.00	.03	.99	-.05
SEM	1.4	.0	.17	.00	.08	.31	.10	.34
P.SD	3.8	.0	.47	.01	.23	.88	.28	.98
S.SD	4.1	.0	.50	.01	.24	.94	.29	1.03
MAX.	168.0	39.0	1.20	.37	1.32	1.16	1.48	1.46
MIN.	154.0	39.0	-.52	.33	.51	-1.96	.49	-2.04

REAL RMSE .38 TRUE SD .28 SEPARATION .74 ITEM RELIABILITY .36
MODEL RMSE .36 TRUE SD .30 SEPARATION .84 ITEM RELIABILITY .41
S.E. OF ITEM MEAN = .17

ITEM RAW SCORE-TO-MEASURE CORRELATION = -1.00
Global statistics: please see Table 44.
UMEAN=.0000 USCALE=1.0000

Figure 4 Questionnaire reliability

Meanwhile, the results of construct validity (unidimensionality) are used to ensure that the questionnaire can measure the construct or dimensions consistently and validly (Indihadi et al., 2022; Lia et al., 2020; Ridzuan et al., 2020). The results of the analysis can be seen in Figure 5.



INPUT: 39 PERSON 9 ITEM REPORTED: 39 PERSON 9 ITEM 5 CATS MINISTEP 5.7.4.0

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

	Eigenvalue	Observed	Expected
Total raw variance in observations =	20.4822	100.0%	100.0%
Raw variance explained by measures =	11.4822	56.1%	55.8%
Raw variance explained by persons =	8.5247	41.6%	41.4%
Raw Variance explained by items =	2.9575	14.4%	14.4%
Raw unexplained variance (total) =	9.0000	43.9%	100.0% 44.2%
Unexplned variance in 1st contrast =	2.2748	11.1%	25.3%
Unexplned variance in 2nd contrast =	1.4614	7.1%	16.2%
Unexplned variance in 3rd contrast =	1.3103	6.4%	14.6%
Unexplned variance in 4th contrast =	1.2148	5.9%	13.5%
Unexplned variance in 5th contrast =	.9915	4.8%	11.0%

Figure 5 Raw variance explained by measures

Based on Figure 5, it can be seen that the Raw variance explained by the measured value is 56.1%, which shows that the unidimensionality of the instrument has been fulfilled (>40%) (Ridzuan et al., 2020). These results indicate that the main dimensions mostly explain the variance in the data. Identification was also carried out on the Unexplained Variance in the 1st contrast, where the eigenvalue is 2.2748 (11.1%), slightly larger than the accepted limit. These results indicate a few additional dimensions beyond the main dimensions measured. As a dimension scale, an acceptable value is <2 or 5%-10% (Lia et al., 2020). However, the value obtained is only slightly more significant than the set limit and depends on the purpose of the study. This is because this research focuses on the quality of comics rather than on the development of the instrument. Thus, we still consider this result acceptable. After the instrument is reliable and valid, the next step is the students' responses to the AiWoL comics identified through their answers to the questionnaire instrument. The results can be seen in Figure 6.

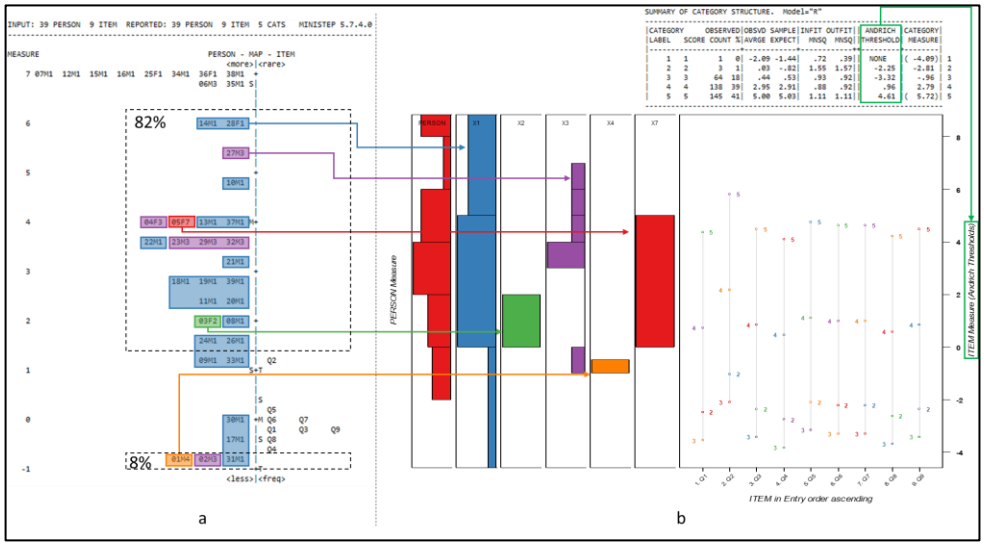


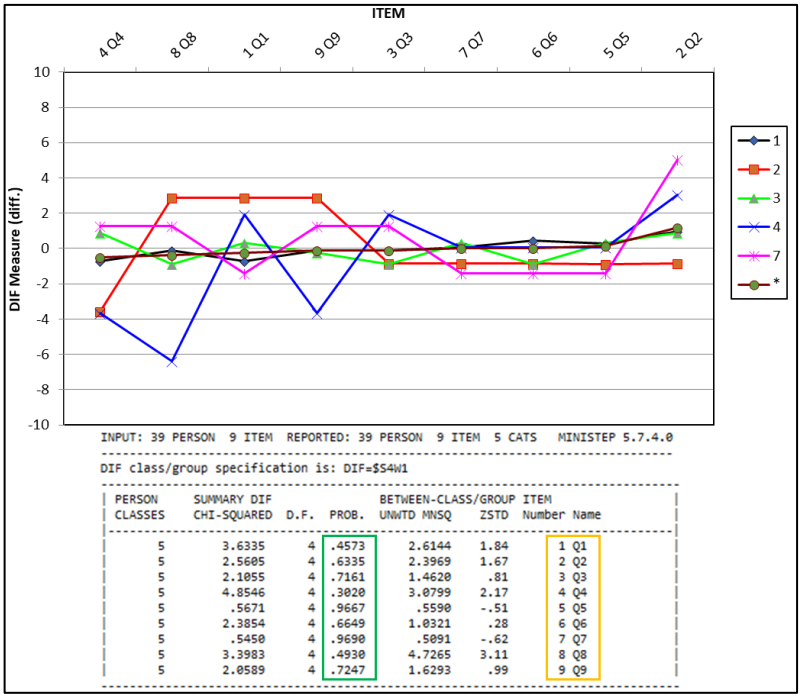
Figure 6 Map: a) Variable (Wright) maps; b) WrightMaps R Statistics

Figure 6 combines outputs from a) Variable (Wright) maps; b) WrightMaps R Statistics. Both outputs confirm the information obtained. Figure 6a shows the distribution of student answers (Person) to the questionnaire instrument (Item). It can be seen that 82% of students gave good responses to the AiWoL comic. Meanwhile, 8% of students did not give answers that exceeded the quality of the questionnaire. The results of this mapping indirectly show that the AiWoL comic has good images and language and can facilitate understanding the concept of light dualism. However, Figure 6b shows the Andrich Threshold analysis. The Andrich Threshold analysis shows the threshold value on an ordinal scale like Likert, which separates the probability of choosing one category to move to the next category (Caronni et al., 2023; Chong et al., 2022). It can be seen that the Andrich Threshold values for each item (Q1 to Q9) are not sequential. Where the order from top to bottom and the Andrich Threshold values owned are 5 (4.61), 4 (0.96), 2 (-2.25), and 3 (-3.32). While the value 1 does not exist because its value is (none). A positive value of the Andrich Threshold indicates that the category is only obtained from respondents (Person) with high abilities, while a negative value is the opposite. However, if re-identified, the highest position value is in the question with code Q2 (Image layout is saved according to the reading flow of the AiWoL comic) (Chong et al., 2022). This means that the question is more difficult to answer than the others. While the lowest question is the question with the code Q4 (There are no typos in every AiWoL comic writing). This means that this question is the easiest question to answer.

These results were then confirmed by a bias analysis of the student semester's data. This was done to confirm that the questions about the AiWoL comic only benefited one category of respondents. The results can be seen in Figure 7.

Figure 7 shows the identification of bias in terms of student semesters. This is because the identification of respondents consists of semesters 1, 2, 3, 4, and 7. However, the results show that no bias occurs, as indicated by the probability value (green box) is <5% for each question number (orange box) (Wahyuni, 2022). Thus, it can be said that all the results obtained from the Rasch analysis did not have any bias towards the

semester category of students when this data was taken.



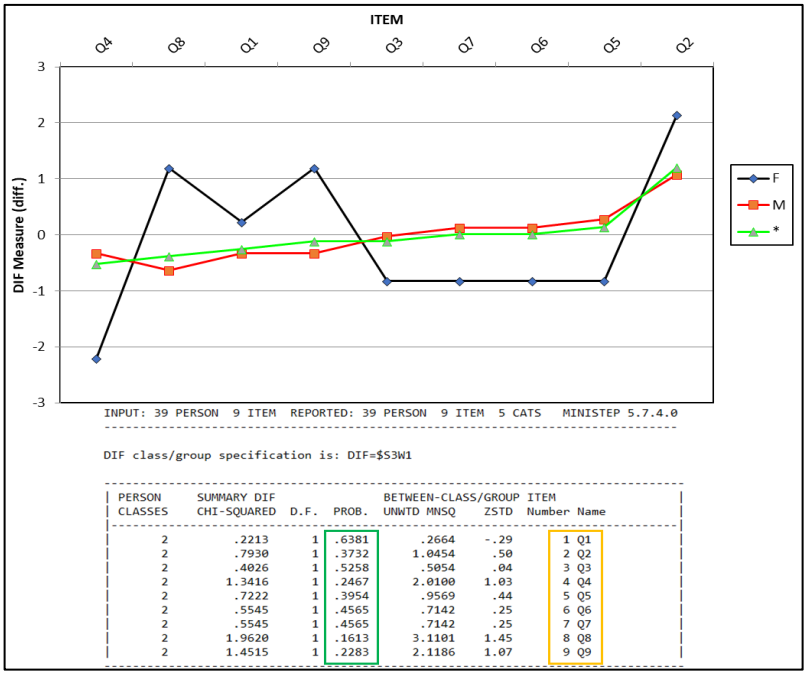
INPUT: 39 PERSON 9 ITEM REPORTED: 39 PERSON 9 ITEM 5 CATS MINISTEP 5.7.4.0

DIF class/group specification is: DIF=$S4W1

PERSON CLASSES	SUMMARY DIF CHI-SQUARED	D.F.	PROB.	BETWEEN-CLASS/GROUP ITEM UNWTD MNSQ	ZSTD	Number	Name
5	3.6335	4	.4573	2.6144	1.84	1	Q1
5	2.5605	4	.6335	2.3969	1.67	2	Q2
5	2.1055	4	.7161	1.4620	.81	3	Q3
5	4.8546	4	.3020	3.0799	2.17	4	Q4
5	.5671	4	.9667	.5590	-.51	5	Q5
5	2.3854	4	.6649	1.0321	.28	6	Q6
5	.5450	4	.9690	.5091	-.62	7	Q7
5	3.3983	4	.4930	4.7265	3.11	8	Q8
5	2.0589	4	.7247	1.6293	.99	9	Q9

Figure 7 Raw variance explained by measures for semester bias

Meanwhile, gender bias was also analyzed; the results can be seen in Figure 8.



INPUT: 39 PERSON 9 ITEM REPORTED: 39 PERSON 9 ITEM 5 CATS MINISTEP 5.7.4.0

DIF class/group specification is: DIF=$S3W1

PERSON CLASSES	SUMMARY DIF CHI-SQUARED	D.F.	PROB.	BETWEEN-CLASS/GROUP ITEM UNWTD MNSQ	ZSTD	Number	Name
2	.2213	1	.6381	.2664	-.29	1	Q1
2	.7930	1	.3732	1.0454	.50	2	Q2
2	.4026	1	.5258	.5054	.04	3	Q3
2	1.3416	1	.2467	2.0100	1.03	4	Q4
2	.7222	1	.3954	.9569	.44	5	Q5
2	.5545	1	.4565	.7142	.25	6	Q6
2	.5545	1	.4565	.7142	.25	7	Q7
2	1.9620	1	.1613	3.1101	1.45	8	Q8
2	1.4515	1	.2283	2.1186	1.07	9	Q9

Figure 8 Raw variance explained by measures for gender bias

The results in Figure 8 show the same thing as Figure 7 that there is no bias towards gender from each question asked to respondents. This is because no

probability value (green box) is <5%. Thus, the results obtained are free from semester and gender bias. In general, the results obtained from the instruments distributed to students based on their aspects can be seen in Figure 9.

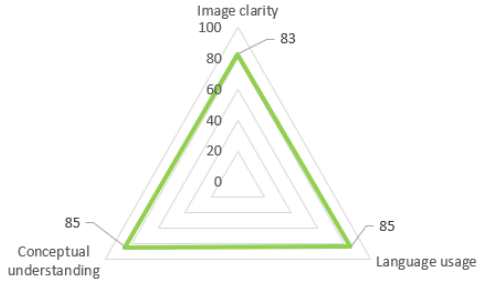


Figure 9 Respondents' Responses to AiWoL

Figure 9 shows the respondents' responses to the AiWoL comic, with the results obtained for each aspect in the Very Good category (>80%). This shows consistency between the results obtained during validity and the respondents' results. Thus, we can get mutually supportive results for the development of the AiWoL comic, with all in the Very Good category.

CONCLUSION

The development of the AiWoL comic is part of the AR development research called Physics Virtual Technology Teaching Tools (PV3T). Based on the results of expert validation, the instrument quality value was produced in terms of the suitability of the physics concept (86), media suitability (92), and psychology of conception (98) (all in the very good category). Meanwhile, the results of the Rasch analysis based on respondents' answers showed that the instrument used to assess the suitability of the AiWoL comic was reliable (Cronbach Alpha (KR-20) 0.94 (excellent)) and valid (56.1% (appropriate)). In addition, the AiWoL comic has aspects of Image clarity (83%), Language usage (85%), and Conceptual understanding (85%) (all in the very good category). The results of the bias analysis of the semester and gender have a score of >5%, meaning there was no bias in the answers produced. Thus, the development of the AiWoL comic has passed the expert test and received a good response from respondents. Furthermore, the AiWoL comic will be used as part of the design for developing the PV3T) which is an AR-based application.

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