

Enhancing Student Learning Motivation Through Interactive Augmented Reality-Based E-Modules on Global Warming

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Article Info	Abstract
Article history: Received: December 11, 2024 Revised: January 21, 2025 Accepted: February 1, 2025 Keywords: Interactive e-module Learning motivation Rash model This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License © 2025 Berkala ilmiah Pendidikan Fisika	The students' learning motivation in high school is still relatively low to participate in physics learning. This research aims to enhance students' learning motivation using <i>Augmented Reality</i> (AR)-based interactive <i>E-Modules</i> in physics learning on global warming materials. The method used is pre-experimental, with the design of one pretest-posttest group and analysis techniques using the Rasch stacking model. The research sample comprised 36 students in class X at Sukabumi City High School. The data collection instrument is in the form of a learning motivation questionnaire that three lecturers have validated. The analysis showed that all students experienced increased positive learning motivation. The use of AR-based interactive E-Module was able to increase the learning motivation of students in the medium category by 64% (23 students), the high category by 11% (4 students), and the low category by 25% (9 students). These findings show that AR technology in physics learning can significantly increase students' motivation to learn and increase their engagement and understanding of physics subjects. Thus, AR technology has the potential to be an effective tool in more interesting future learning methods, especially in complex subjects such as physics.
To cite this article: Rifa'i, A., Aviyanti, L., Sari, I. M., Gani, A. W., Salam, A., & Khairunnisah, K. (2025). Enhancing student learning motivation through interactive augmented reality-based e-modules on global warming. <i>Berkala Ilmiah Pendidikan Fisika</i>, 13(1), 141-156.	

INTRODUCTION

Teaching and learning activities are the most basic aspect of education. The success of the learning process depends on how the learning process is experienced by students ([Pathonah & Siddik, 2024](#)). One of the internal factors important in learning success is learning motivation ([Cudney & Ezzell, 2017](#); [Hakam et al., 2023](#)). In addition to playing an important role in education, motivation also plays a very important role in a person's self-development ([Ding, 2024](#); [Peng et al., 2023](#)), as without strong motivation, students often find it difficult to maintain focus and commitment to their studies ([Azhar, & Wahyudi, 2024](#)). [Melinda et al. \(2024\)](#) explained that motivation is the fundamental drive that drives a person to take action to achieve success. Learning motivation can encourage students to learn enthusiastically and earnestly and do their best to achieve the desired goals ([Alhieza, 2019](#); [Cahyani et al., 2020](#); [Ricardo & Meilani, 2017](#)). However, the reality in the field shows that the learning motivation of high school students is still relatively low, namely only 47.60%, which is characterized by a lack of active

involvement of students in learning, an easy tendency to give up when faced with difficult tasks, a lack of participation in discussions, and quickly feeling bored with the learning materials provided ([Kartika et al., 2024](#)). The same results were also found in a preliminary study conducted by researchers at a high school in Sukabumi City through teacher interviews. The low learning motivation of students is due to the learning method that is still focused on teachers (teacher-centered) and the lack of selection of interesting learning media, so students become passive and quickly feel bored. In addition, the lack of interaction and use of technology in the learning process is also a factor causing low learning motivation for students. Motivation in learning is one of the things that needs to be aroused in school learning efforts.

In the context of physics learning, it was found that only 18.89% of students had high motivation to follow the physics learning process from beginning to end ([Sari et al., 2018](#)). Strong motivation can improve students' learning achievement by encouraging them to think, concentrate, and learn more effectively ([Bakar, 2014](#)). In addition, strong motivation also plays a role in improving academic achievement ([Rukiyanto et al., 2023](#)) because motivated students tend to be more disciplined, diligent, and diligent in learning activities. Motivation also helps students try harder to complete their tasks ([Filgona et al., 2020](#)). Learning motivation comes from the internal students and external factors such as teachers, the learning environment, and the learning media used ([Afjar et al., 2020](#); [Filgona et al., 2020](#)).

One of the external factors that can increase students' motivation to learn is the selection of learning media ([Polonia & Yuliati, 2019](#)). Learning media plays an important role in the learning process, namely as a medium for delivering learning messages that must be accounted for by a teacher, especially in achieving the desired learning goals ([Purba & Nirmala, 2023](#); [Ramli, 2012](#)). Learning media that can increase learning motivation are Interactive E-Modules ([Sari et al., 2019](#); [Wiyoko et al., 2016](#)). The presence of E-Modules integrated with interactive media such as Augmented Reality can increase students' motivation to learn, provide new impressions, and adapt to the times ([Afifah & Mulyani, 2022](#)). The combination of E-Module and Augmented Reality (AR) aims to make learning media more interesting and interactive. Each page has Augmented Reality (AR) to combine real and virtual objects in real-time ([Afifah, 2019](#); [Barsom et al., 2016](#)). Interactive e-modules serve as reading materials for students, help develop their potential, and stimulate the five senses through various available features, such as audio, video, visuals, text, and animation ([Belanisa et al., 2022](#)). Based on the results of research conducted by [Kartika et al. \(2024\)](#), the use of Augmented Reality (AR)-based interactive E-Modules in physics learning received a very good response from students. It increased students' learning motivation with an average score of N-Gain 0.71, included in the high category. In addition, using Augmented Reality (AR)-based learning media in physics learning can improve students' learning outcomes and make learning more varied ([Akçayır, 2017](#); [Chang et al., 2022](#); [Lin et al., 2017](#)). The material on global warming is complex and abstract, requiring learning media like AR to help visualize these concepts effectively ([Parvathy et al., 2022](#)). This urgency is underscored by the global significance of understanding climate change and its impacts, making it critical for students to grasp these important concepts to foster environmental awareness and action. This is because visualization from electronic devices can improve students' understanding compared to traditional learning methods ([Gargrish et al., 2020](#); [Thees et al., 2020](#)). Therefore, augmented reality (AR) can be used in E-Modules as an alternative learning media for students.

There are two theories of measurement used in educational evaluation: classical and modern measurement theories, namely the Rasch Model ([Hakam et al., 2024](#)). The advantage of Rasch Model analysis is the ability to predict lost data and analyze it based on individual responses ([Hamdu et al., 2020](#)). This makes the results of the statistical

analysis of the Rasch Model more accurate compared to classical measurements ([Fauzi et al., 2020](#)). Rasch modeling offers a different approach to using raw test scores or data in educational evaluations. It tends to produce uniform interval measurement scales, thus providing accurate information about students' abilities and question quality ([Hamdu et al., 2020](#)). Grain analysis with the Rasch Model also provides information about the characteristics of the grain and students in the same measurement ([Erfan et al., 2020](#)). In the development of modern test theory, the Rasch Model has advantages over other methods, especially classical test theory, namely the ability to predict lost data based on individual response patterns. This difference can cause variations in students' responses to questionnaire questions, so students with the same ability may have different chances of answering correctly, called Differential Item Functioning (DIF) ([Sumintono & Widhiarso, 2015](#)). Previous research generally used the classical test theory approach, which had limitations in capturing the complex dynamics between questions and respondents ([Azizah & Wahyuningsih, 2020](#); [Sumintono & Widhiarso, 2014](#)). Using the Rasch Model can provide deeper insights into the quality of interaction in learning motivation by categorizing respondents based on the abilities shown through assessment instruments, thereby providing a more accurate picture of the condition of learning motivation ([Ardiyanti, 2017](#)).

METHOD

This quantitative study uses a pre-experimental one-group pretest-posttest design to compare the state before and after being given treatment in the form of AR-based interactive e-modules. The population in this study is class X students at one of the high schools in Sukabumi City. Meanwhile, the sample of this study is students selected using non-random sampling techniques. With this sampling technique, the sample was only one group of 36 students in class X. In addition, sampling is determined based on the classes the school has provided. Data collection techniques to measure learning motivation: The researchers used an instrument in the form of a learning motivation questionnaire that adapted the learning motivation instrument by Salma in 2023, which three lecturers have validated as validators. The questionnaire instrument used in this study consisted of 20 questions. These questions are divided into seven learning motivation indicators that include various aspects such as interest in the material, self-confidence, desire to achieve, effort made, perseverance, outlook on the learning process, and social support. The division of the questions into these seven indicators is shown in Table 1.

Table 1 Student learning motivation questionnaire

No	Indicator	Question numbers
1	Perseverance in learning	1, 2, 3
2	Tenacious in the face of adversity	4, 5, 6
3	Interest in lessons	7, 8, 9
4	Be able to defend his opinion	10, 11, 12
5	It is not easy to let go of what you believe	13, 14
6	Enjoys searching and solving problems	15, 16, 17
7	Performing well in learning	18, 19, 20
Total		20

The assessment criteria used in this study is a Likert scale with five answer options, ranging from 'never' (1) to 'always' (5). The Likert Scale measures individuals' or groups' attitudes, opinions, or perceptions toward certain educational phenomena. Data was analyzed using the Rasch model through WINSTEPS software version 3.73. The data from the questionnaires that have been distributed are then collected in Excel and processed using WINSTEPS software version 3.73 to assess the validity and reliability of the instrument. Furthermore, to measure the increase in learning motivation, the results of the pretest-posttest questionnaire from students were analyzed using the Rasch model of

the stacking technique through WINSTEPS software version 3.73. The stacking technique is used to see the increase in the logit value and the change in position on the vertical ruler to observe the increase at the individual level.

Several criteria must be met to guarantee that the instrument used is suitable. Based on the Rasch Model, an item's quality is determined by its validity if it meets the criteria in Table 2.

Tabel 2 Kriteria outfit MNSQ, ZTSD, dan Pt measure corr

Criterion	Accepted Values
Outfit Mean-Square (MNSQ)	$0.5 < \text{MNSQ} < 1.5$
Outfit Z-Standard (ZSTD)	$-2.0 < \text{ZSTD} < 2.0$
Pt Measure Corr	$0.4 < \text{Pt Measure Corr} < 0.85$

(Sumintono & Widhiarso, 2015)

The results of the values of each of these criteria are then interpreted based on the fit-statistical value criteria in Table 3.

Table 3 Interpretation of question item quality

Criteria of Fit-Statistical Value	Interpretation
The three value criteria are met	Very suitable
Two of the three value criteria are met	Suitable
One of the three value criteria met	Less suitable
All value criteria are not met	Not suitable

(Sumintono & Widhiarso, 2014)

Then, the reliability of the learning motivation questionnaire can be measured by the values of Person Reliability and Item Reliability, as well as the Cronbach Alpha value. Table 4 shows the criteria for the three indicators.

Table 4 Interpretation of person reliability and item reliability values

Person Reliability and Item Reliability Value Range	Interpretation
> 0.94	Excellent
$0.91 - 0.94$	Very good
$0.81 - 0.90$	Good
$0.67 - 0.80$	Enough
< 0.67	Weak

(Sumintono & Widhiarso, 2015)

Table 5 Interpretation of cronbach alpha values

Cronbach Alpha Value Range	Interpretation
> 0.80	Very good
$0.71 - 0.80$	Good
$0.61 - 0.70$	Enough
$0.50 - 0.60$	Ugly
< 0.50	Bad

(Sumintono & Widhiarso, 2015)

RESULT AND DISCUSSION

Results of Validity and Reliability Analysis

In item response theory, items that meet the validity requirements are called fit items, while items that do not meet the validity requirements are called misfit or outlier items. The validity test analysis for each question item using Rasch modeling was obtained by looking at the values of Mean-Square outfit (MNSQ), Z-Standard outfit (ZSTD), and Point Measure Correlation (Pt Measure Corr). The analysis results can be seen in the output tables menu of Table 10: Item fit order in WINSTEP software version 3.73, as seen in Figure 1.

ENTRY	TOTAL	TOTAL		MODEL	INFIT	OUTFIT		PT-MEASURE		EXACT	MATCH		
NUMBER	SCORE	COUNT	MEASURE	S.E.	MNSQ	ZSTD	MNSQ	ZSTD	CORR.	EXP.	OBS%	EXP%	Item
18	17	51	-.42	.35	1.34	2.0	2.12	2.5	A .30	.50	66.0	76.1	S18
8	7	51	1.12	.46	1.30	1.0	1.82	1.1	B .24	.41	84.0	88.0	S8
9	11	51	.39	.39	1.19	.9	1.37	.8	C .35	.46	82.0	81.9	S9
2	37	51	-2.79	.38	1.28	1.4	1.26	.6	D .39	.52	76.0	80.6	S2
3	6	51	1.35	.49	1.28	.9	1.27	.6	E .26	.39	86.0	89.5	S3
19	2	51	2.81	.78	1.27	.6	.84	.3	F .18	.27	96.0	96.0	S19
12	11	51	.39	.39	.75	-1.2	1.19	.5	G .55	.46	86.0	81.9	S12
13	31	51	-2.02	.34	1.04	.3	.97	.0	H .52	.53	68.0	74.2	S13
14	23	51	-1.12	.33	1.03	.3	.88	-.3	I .52	.52	72.0	73.0	S14
6	29	51	-1.79	.34	.96	-.2	1.00	.1	J .54	.53	76.0	73.1	S6
5	14	51	-.04	.37	.96	-.1	.96	.1	j .50	.48	80.0	78.1	S5
15	8	51	.91	.44	.96	-.1	.66	-.3	i .46	.42	86.0	86.5	S15
7	24	51	-1.23	.33	.93	-.5	.91	-.2	h .56	.53	74.0	72.7	S7
17	3	51	2.30	.65	.92	.0	.92	.3	g .32	.31	96.0	94.3	S17
1	44	51	-4.04	.49	.76	-.7	.84	.1	f .56	.48	92.0	89.0	S1
4	9	51	.73	.42	.83	-.6	.56	-.6	e .53	.44	88.0	84.9	S4
11	19	51	-.66	.34	.76	-1.6	.60	-1.3	d .64	.51	80.0	74.8	S11
20	23	51	-1.12	.33	.71	-2.2	.57	-1.6	c .68	.52	80.0	73.0	S20
10	5	51	1.61	.53	.67	-.9	.55	-.2	b .50	.37	94.0	91.0	S10
16	1	51	3.62	1.05	.62	-.2	.07	-.8	a .36	.20	98.0	98.0	S16
MEAN	16.2	51.0	.00	.46	.98	-.1	.97	.1			83.0	82.8	
S.D.	11.9	.0	1.86	.18	.23	1.0	.45	.9			9.1	8.2	

Figure 1 Item fit order learning motivation

Figure 1 shows the results of measuring fit items obtained from field trials of learning motivation questionnaire instruments given to 51 students. From the image above, it can be seen that items S12, S13, S14, S6 are included in the category of very suitable, for items S9, S2, S3, S5, S7, S15, S17, S1, S4, S11, S20, S16 are included in the category of suitable, items S8, S19, S16 are included in the category of not suitable and item S18 is one of the items included in the category of misfit (not suitable). The data in Figure 1 can be interpreted in the graph shown in Figure 2.

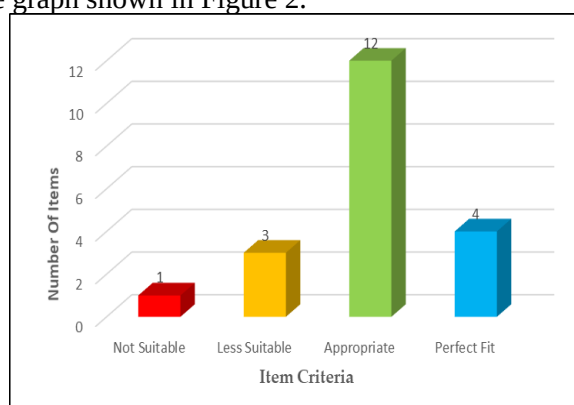


Figure 2 Number of item spreads based on item criteria

Reliability testing using WINSTEP software version 3.73 can be seen in the output tables menu of Table 3.1: summary statistics. The indicators used in this study include person reliability, item reliability, and Cronbach Alpha. Person reliability indicates consistency in students' answers; item reliability indicates the quality of questions in the instrument. Meanwhile, the Cronbach Alpha value measures reliability, the interaction

between individuals and items. The interpretation of the reliability of the student learning motivation instrument can be seen in Figure 3.

SUMMARY OF 118 MEASURED Person								
	TOTAL SCORE	COUNT	MEASURE	MODEL ERROR	INFIT		OUTFIT	
					MNSQ	ZSTD	MNSQ	ZSTD
MEAN	72.8	20.0	.97	.29	1.02	-.1	1.04	-.2
S.D.	6.8	.0	.57	.02	.58	1.6	.74	1.7
MAX.	92.0	20.0	2.99	.41	3.32	4.9	5.80	5.1
MIN.	49.0	20.0	-.84	.27	.23	-3.7	.24	-3.6

REAL RMSE	.32	TRUE SD	.48	SEPARATION	1.47	Person RELIABILITY		.68
MODEL RMSE	.29	TRUE SD	.50	SEPARATION	1.72	Person RELIABILITY		.75
S.E. OF Person MEAN = .05								

Person RAW SCORE-TO-MEASURE CORRELATION = .99								
CRONBACH ALPHA (KR-20) Person RAW SCORE "TEST" RELIABILITY = .72								

SUMMARY OF 20 MEASURED Item								
	TOTAL SCORE	COUNT	MEASURE	MODEL ERROR	INFIT		OUTFIT	
					MNSQ	ZSTD	MNSQ	ZSTD
MEAN	429.5	118.0	.00	.12	1.01	-.2	1.04	.0
S.D.	89.6	.0	1.23	.03	.29	2.3	.35	2.4
MAX.	569.0	118.0	2.27	.23	1.51	3.9	1.99	4.3
MIN.	243.0	118.0	-2.58	.11	.58	-4.0	.58	-4.0

REAL RMSE	.14	TRUE SD	1.22	SEPARATION	8.92	Item RELIABILITY		.99
MODEL RMSE	.13	TRUE SD	1.22	SEPARATION	9.57	Item RELIABILITY		.99
S.E. OF Item MEAN = .28								

Figure 3 Summary of people and items learning motivation

Based on Figure 3, the person reliability value of 0.68 is in the "adequate" category, meaning that the level of consistency of students' answers is still quite adequate. Then, the item reliability value of 0.99 is in the "special" category, meaning that the quality of the question items used in the learning motivation instrument has a very good reliability aspect. As for the Cronbach Alpha score of 0.72 in the "good" category, it shows that the learning motivation instrument has a good reliability aspect because it can identify the interaction between students and question items ([Kusmaryono et al., 2022](#)).

Results of Analysis of Increased Learning Motivation

This research aims to increase the learning motivation of research students using learning media developed together with the learning media development team. The learning media developed is in the form of Interactive AR-Based E-Modules on Global Warming, consisting of 3 materials that discuss (1) the symptoms and impacts of global warming, (2) the causes of environmental change, and (3) solutions to overcome global warming. This E-Module is equipped with Augmented Reality using WebGL and JavaScript technologies to create a more interactive learning experience and simplify explanations through 3D animation to provide a comprehensive overview of several complex concepts. This E-Module is also equipped with multimedia such as images, videos, and PhET Interactive "Greenhouse Effect" simulations that allow students to learn independently as

well as practice students' higher-order thinking skills. One of the developed augmented reality technologies can be seen in Figure 4.

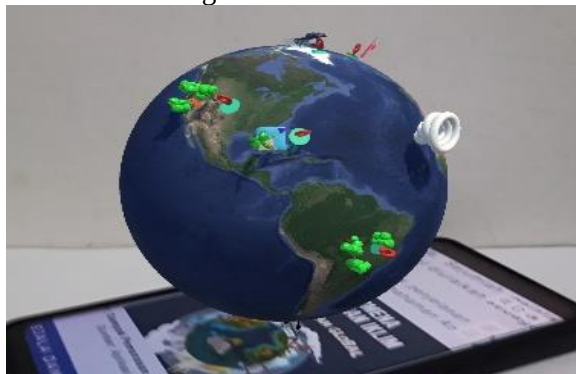


Figure 4 AR of the impact of global warming in different regions of the earth

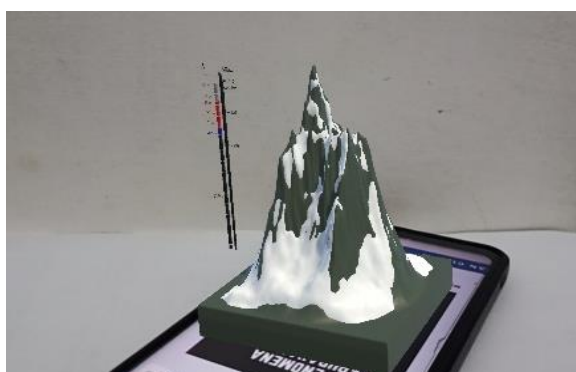


Figure 5 AR of the melting process of ice in the mountains

Based on the Figure 4 & 5, we can see this by using the camera feature found in the developed special application; the camera is directed to the barcode available on each e-module so that a related 3D object will appear on the camera. Six validators first validate this learning media before using it for researchers to declare its feasibility. After being declared feasible, this media was implemented for students in one of the schools in Sukabumi City to see an increase in students' learning motivation before and after using the Interactive AR-Based E-Modules on Global Warming.

The increase in learning motivation was obtained from the data from students' pre-test-posttest questionnaire results, which was analyzed using Rasch modeling using WINSTEPS software version 3.73 with stacking techniques. The stacking analysis technique was used to compare students' learning motivation before and after treatment using AR-based interactive e-modules. The learning motivation profile of students before and after treatment based on seven indicators obtained from the pretest and posttest results is interpreted in Figure 6.

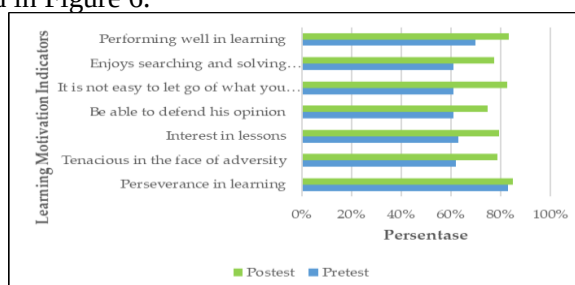


Figure 6 Learning motivation profile before and after the intervention

Based on Figure 6, the blue bar shows the results before the intervention, while the green bar shows the results after the intervention. In the figure above, seen from the seven assessment indicators, there is a significant improvement seen before and after the intervention was carried out. The indicator of achievement in learning showed an increase of 13%, the indicator of being happy to find and solve problems showed an increase of 16%, the indicator of not being easy to let go of things that were believed to show an increase of 22%, the indicator of interest in lessons showed a percentage of 17%, the indicator of tenacity in facing difficulties showed a percentage of 17%, and the indicator of perseverance in learning showed a percentage of 2%. Meanwhile, to see a clearer increase in learning motivation, you can see the analysis results using the rash analysis of the stacking technique model from the logit value shown in Table 6.

Table 6 Measures of increased learning motivation

Learners	Measure		Logit Improvements	Information
	Pretest	Posttest		
01P	1.53	2.87	1.34	Positive
02L	0.02	2.29	2.27	Positive
03L	-0.64	2.63	3.27	Positive
04P	2.18	2.29	0.11	Positive
05P	1.53	2.75	1.22	Positive
06P	0.02	2.29	2.27	Positive
07P	-0.09	1.10	1.19	Positive
08L	-0.20	2.40	2.60	Positive
09P	1.85	2.40	0.55	Positive
10L	0.02	2.63	2.61	Positive
11P	0.02	2.51	2.49	Positive
12P	1.53	2.63	1.10	Positive
13L	1.10	2.40	1.30	Positive
14P	2.40	2.75	0.35	Positive
15P	-0.09	2.63	2.72	Positive
16L	1.31	2.40	1.09	Positive
17P	0.02	2.40	2.38	Positive
18P	1.42	2.40	0.98	Positive
19P	1.63	2.51	0.88	Positive
20P	0.88	2.29	1.41	Positive
21P	1.53	2.51	0.98	Positive
22P	0.02	2.75	2.73	Positive
23P	-0.09	2.29	2.38	Positive
24P	0.02	2.51	2.49	Positive
25L	1.20	2.29	1.09	Positive
26L	2.07	2.07	0.00	Positive
27L	1.53	1.96	0.43	Positive
28L	0.77	2.40	1.63	Positive
29L	-0.09	0.67	0.76	Positive
30P	0.99	2.29	1.30	Positive
31L	1.20	2.40	1.20	Positive
32L	-0.09	2.18	2.27	Positive
33P	-0.31	2.40	2.71	Positive

Learners	Measure		Logit Improvements	Information
	Pretest	Posttest		
34P	0.88	1.42	0.54	Positive
35P	0.02	1.96	1.94	Positive
36P	2.07	2.51	0.44	Positive
Average	0.78	2.31	1.53	Positive

Based on Table 6, the average learning motivation of students at the time of the pretest was 0.78 on the logit scale. After learning to use AR-based interactive e-modules, there was an increase in the average value of logits by 1.53 logits, from 0.78 to 2.31 logits. The increase in the average score of the logit indicates that the use of AR-based interactive e-modules has a positive impact on increasing students' learning motivation. This, in accordance with the findings of the [Damanik dan Nugraha \(2023\)](#) research, shows that interactive e-modules assisted by professional flip PDFs can increase students' learning motivation with a sig value of 0.001.

Table 6 shows that the difference in the logit score of the posttest-pretest of all students is in the positive category, meaning that all students experience an increase in learning motivation. Furthermore, the increase in learning motivation is represented in Figure 7.

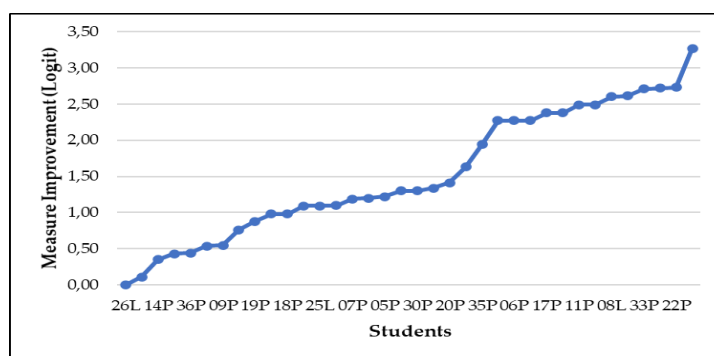


Figure 7 Increased learning motivation

Figure 7 shows that 100% of students experience a positive increase in motivation. The highest increase in learning motivation occurred in students with code 22P, while the lowest increase in student learning motivation occurred in students with code 26L. In addition, changes in the level of students' learning motivation can also be seen through the analysis vertical ruler, which visualizes the location of the student's motivation level at the time of the pretest and posttest ([Sukarelawan et al., 2024](#)). The analysis vertical ruler is shown in Figure 8.

Based on Figure 8, the student's learning motivation level at the pretest and posttest is listed in the second column on the left. The code "pre" after the sequence number encodes the level of the learner at the time of pretest, while the code "Post" after the sequence number encodes the level of the learner at the time of posttest1. Students' learning motivation is spread from -3 to +3 logits. The distribution of students with low levels of learning motivation is centered in the lower left, while the distribution of students with high levels of learning motivation is centered in the upper left ([Sukarelawan et al., 2024](#))¹. This distribution pattern aligns with findings from recent studies, such as those by [Ishida and Sekiyama \(2024\)](#), who explored variables influencing student learning motivation, and [Liu et al. \(2024\)](#), who examined the impacts of learning motivation on academic performance.

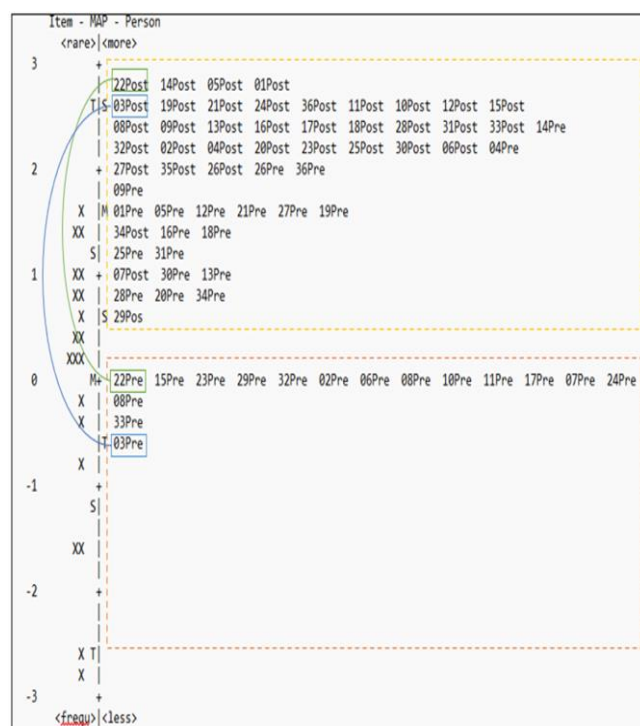


Figure 8 Vertical ruler increases learning motivation

In general, in the Figure 8, the distribution of low learning motivation of students is the initial motivation of students before the intervention, namely at the time of the pretest. Students with code 03L at the time of the pretest have the lowest location, meaning that the student has low motivation to learn. Meanwhile, students with code 14P showed high motivation to learn during the pretest. In addition, students with codes 01P, 05P, 14P, and 25P are the students who have the highest motivation to learn at the posttest. Students are still in a low distribution of learning motivation after the intervention are 29L students. The standard deviation obtained was 1.03, and the average value was 1.53 on the logit scale. For this reason, the grouping criteria for increasing students' learning motivation are presented in Table 7.

Table 7 Improvement clustering criteria

Logit Value	Criterion
$> \text{logit } 3.56$	Top Outlier
$2.56 < \text{logit} \leq 3.56$	Very High
$1.53 < \text{logit} \leq 2.56$	High
$0.5 < \text{Logit} \leq 1.53$	Medium
$-0.53 < \text{logit} \leq 0.5$	Low
$\text{logit} < -0.53$	Lower Outlier

The following are the results of grouping the increase in learning motivation after being given treatment in the form of AR-based interactive e-modules.

Table 8 Analysis of grouping criteria for increasing learning motivation

Criterion					
Top Outlier	Very High	High	Medium	Low	Outlier Below
-	03L, 08L, 10L, 15P, 22P, 33P,	02L, 06P, 11P, 17P, 23P, 24P, 28L, 32L, 35P	01P, 05P, 09P, 12P, 13L, 16L, 18P, 19P, 20P, 21P, 25L, 29L, 30P, 31L, 34P,	04L, 07P, 14P, 26L, 27L, 36P	-

Based on Table 8, the distribution of increasing students' learning motivation is based only on the very high, high, medium, and low criteria. Students with codes 04L, 07P, 14P, 26L, 27L, and 36P experience increased learning motivation in the low category. The increase in students' learning motivation with the 22P code, which has the highest motivation at the pretest and posttest, is in the very high category. Further, the data in the table above is represented in a graph shown in Figure 9.

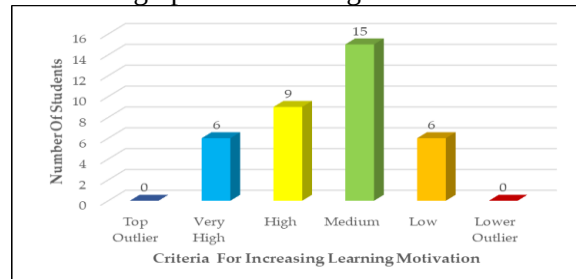


Figure 9 Increasing learning motivation based on criteria

Based on Figure 9, the use of AR-based interactive e-modules was able to increase the learning motivation of students in the very high category by 17% with the number of 6 students, the high category by 25% with the number of students as many as 9 people, the medium category by 42% with the number of students as many as 15 people, and the low category by 17% with the number of students as many as 6 people. This finding is consistent with previous research, such as the study by Widia et al. (2023), which demonstrated that AR-based learning media significantly enhances student motivation and learning outcomes. Additionally, Sabrina et al. (2023) found similar results in their research on AR-assisted e-modules, further supporting the positive impact of AR technology on student motivation. The comparison of the level of learning motivation of students at the time of the pretest and posttest is presented in the graph in Figure 10.

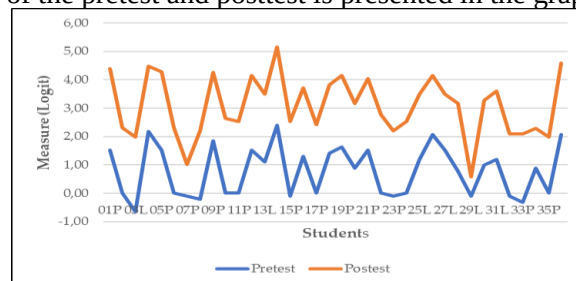


Figure 10 Comparison chart of pretest and posttest learning motivation

Thus, if the pretest-posttest data is analyzed using the Rasch model stacking technique, AR-based interactive e-modules can increase students' learning motivation in the medium category. A thorough analysis showed that all students experienced increased positive learning motivation. This indicates that using AR-based interactive e-modules positively impacts students' motivation to learn physics, especially on Global Warming material. This is also in line with the results of [Chiang et al. \(2014\)](#), who found that students who learn with augmented reality-based mobile learning approaches show much higher motivation in attention, confidence, and relevance than those who learn with conventional inquiry-based mobile learning approaches. Additionally, recent studies by [Widia et al. \(2023\)](#) and [Sabrina et al. \(2023\)](#) further support the positive impact of AR technology on student motivation and learning outcomes.

Behind the increase in learning motivation, researchers face several challenges in implementing Interactive AR-based e-modules on Global Warming. First, accessing AR requires a stable internet connection. This can be a significant barrier to effective use in areas with poor or unreliable internet infrastructure. In addition, AR applications often

require mobile devices with large storage capacities and high processing power to run smoothly. This can be a problem for students who do not have access to the latest technology or who may share devices with family members.

CONCLUSION

The validity and reliability analysis results showed that most of the items in the learning motivation questionnaire were in the category of very suitable or appropriate, with some items not matching and one item not suitable. Overall, this instrument is valid and reliable for measuring students' learning motivation. The results of this study also show that the use of Augmented Reality (AR)-based interactive e-modules in physics learning significantly increases students' learning motivation. Analysis using the Rasch model and stacking techniques showed increased learning motivation in the very high, high, medium, and low categories. These results support using AR technology as an effective learning medium for increasing student motivation and learning outcomes. Based on these results, it is recommended that AR technology be further maximized in the learning process and that challenges related to the use of AR technology be overcome, which can only be accessed using the internet and requires a large storage space to run an application. In addition, the assessment instruments used in this study need to be continuously improved and adjusted to ensure their validity and reliability. For inappropriate and inappropriate question items, it is necessary to revise and adapt them so that they can be more effective in measuring student learning motivation.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS STATEMENT

AR played a leading role as the author of the article, as well as being responsible for developing AR-based e-modules and collecting data for this study. AS and K made significant contributions to the development and implementation of the AR e-module. AWG is responsible for analyzing the data collected during the study. LA and IMS supervised the research project, providing valuable guidance and critical feedback throughout the study.

ACKNOWLEDGMENTS

The authors would like to express their heartfelt gratitude to all the Physics Education Department faculty members at Universitas Pendidikan Indonesia for their invaluable support and guidance throughout this research.

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