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Augmented Reality-based Rebuttal Texts (ARaRaT) on Momentum-Impulse: Rasch Analysis on Students' Conceptual Change

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ABSTRACT: This study aimed to implement Augmented Reality-based Rebuttal Texts (ARaRaT) on momentum-impulse in the Predict Discuss Explain Observe Discuss Explain (PDEODE) strategy to identify students' conceptual change. The design used in this study was an embedded mixed method. The research instrument used was 10 diagnostic test questions in a multi-tier format on momentum and impulse. The respondents in the study were 31 students (9 males and 22 females) of grade XI at one of the state high schools in Central Java, Indonesia. Data analysis was carried out with three categories of conceptual change, namely Acceptable Change (AC), Unacceptable Change (UC), and No Change (NC). Rasch analysis was used to map the comparison between the quality of respondents to the instruments used. The results showed that there was a change in conception in the AC category (32%), NC (44%), and UC (25%). Meanwhile, the highest change in misconceptions occurred in the AC category in question T5 (26%) and the lowest in questions T4 and T10 (10%). These results are supported by Rasch analysis which shows that in general there is a change from pretest to posttest. However, the probability of a change in conception can also be seen from the results of the analysis of Andrich Thresholds. Likewise, for the confidence level, students become more confident than before in answering questions. But this probability only shows the possibility that can occur when there is a category change. Furthermore, these results can be recommendations for other researchers in developing and implementing AR in physics learning.

Keywords: ARaRaT, momentum-impulse, PDEODE strategy, Rasch analysis, conceptual change

I. INTRODUCTION

Some concepts have a high level of abstraction including momentum and impulse. This causes difficulties in conveying the concept to students. These difficulties have implications for students' low mastery of physics concepts [1]. Therefore, it is not enough if the learning delivered in class only uses the lecture method. Several learning strategies or models can be used to help students understand concepts. However, in this research we use a cyclical learning strategy, namely Predict Discuss Explain Observe Discuss Explain (PDEODE). The PDEODE learning strategy can create a conducive learning climate and its steps are in accordance with science process skills [2-4]. According to [5] states that PDEODE learning can be used as a means to explore students' understanding of a concept. The PDEODE learning model is a learning model based on constructivism theory [6]. Previous researchers stated that the strategy that can reduce misconceptions in students is the PDEODE learning strategy. In addition, several researchers have also implemented the PDEODE strategy to reduce misconceptions, including [3] about “Correcting grade 11 students' misconceptions of the concept of force through the conceptual change model (CCM) with PDEODE*E tasks”, [6] about “Improving students conceptions on fluid dynamics through peer teaching model with PDEODE (PTM-PDEODE)”, [7] about “Effect of PDEODE teaching strategy on Turkish students' conceptual understanding: Particulate nature of matter”, [8] about “Unveiling students' misconceptions through computer simulation-based PDEODE learning strategy on dynamic electricity”. However, in abstract concepts, the application of the PDEODE strategy alone is not enough to help students understand concepts such as momentum and impulse.

Direct observation of concepts such as momentum and impulse can influence students' conceptual understanding. According to [9] that abstract concepts require visualization to help students understand the concept. In addition, by doing practical work in physics learning, it can make it easier for students to understand physics concepts. With the existence of practicum in physics learning, namely on momentum and impulse materials, students can make direct observations and can also visualize the material to make it easier for students to understand the concept of momentum and impulse. In addition, the use of technology is also popular as a practicum medium to visualize various concepts in physics.

The use of technology in the form of simulations and visualizations is a learning tool to obtain more real information from abstract information [10-12]. One of the popular contributions of digital technology that can be used in education is the Augmented Reality (AR) application [13, 14]. Augmented Reality (AR) is a technology that inserts virtual objects into real life, this technology provides new ideas to users that AR can unite virtual objects with real life in the same space. AR has also been recognized as a technology that can help students complete real-world tasks such as practicums with support from digital systems [15-17]. Therefore, the application based on Augmented Reality-based Rebuttal Texts (ARaRaT) on momentum-impulse is designed to make it easier for students to understand the concept of momentum and impulse. The ARaRaT application on momentum-impulse is designed with new innovations that have never existed before, the differences include AR which is designed based on the results of the practicum carried out and processed using a tracker and in the ARaRaT application. There is a collision practicum on free-falling objects while in the virtual laboratory on the internet, no one has created a practicum with this technology, and the ARaRaT application on momentum-impulse is specifically designed to change students' conceptions. This is because ARaRaT on momentum-impulse can be accessed flexibly and is equipped with rebuttal texts. Rebuttal texts are texts that refute the initial alternative conceptions held by students. Several studies have shown that rebuttal texts help students understand a concept and even change their conceptions.

Conceptual change is a process of change in understanding experienced by students after a cognitive conflict occurs or after being given a treatment (intentionally or not) so that a conceptual construction occurs that is in accordance with the scientific conception [18-21]. It is known that before entering the class, students already have an understanding of the concepts to be learned, either from previous experiences or other sources. Thus, before learning in class, students' understanding will be prone to misconceptions [22-24]. However, these changes are not only focused on wrong understanding or misconceptions, because some researchers even provide categories of conception based on the diagnosis made [23, 25, 26]. Meanwhile, misconceptions are students' understanding of wrong concepts, but they believe in these wrong concepts [27, 28]. This is based on several diagnostic instruments, such as students who answer incorrectly on concept questions and are sure their answers are categorized in the misconception category. Meanwhile, misconceptions often occur in physics concepts.

Misconceptions in physics are closely related to understanding gained from experience, both at and outside school. Some sources of misconceptions include legends, books, classroom learning, interactions at school, daily experiences, or even articles on the web [29, 30]. Misconceptions in physics can also occur in several concepts, for example in the kinematics concept [31, 32]. In the concept of kinematics, misconceptions occur such as the difference between speed and velocity. In addition, misconceptions occur in the understanding of cases when two objects make the same displacement at the same time, then both have the same speed [31]. In the concept of dynamics such as in the concept of Newton's Law. Some researchers say that in Newton's Law there are still misconceptions such as Newton's First Law causing all moving objects to slow down, because it applies to objects that are still [33]. Likewise, in the concept of momentum, there are misconceptions such as that the momentum of an object is influenced by the size of the object, even though the speed variable must also be taken into account [34]. This is what educators anticipate when implementing classroom learning. Before entering the classroom, educators should give tests to identify student concessions through diagnostic tests. After educators have an overview of students' initial understanding, learning can be carried out that is expected to change conceptions that were initially not in accordance with scientific conceptions to be better. It is known that the process of conceptual change not only involves adding new information, but also requires students to revise their conceptions if they are not in accordance with scientific conceptions. Thus, conceptual change is important because understanding the concept is the basis for learning advanced concepts from the material being studied, and should be free from misconceptions. Usually in the process of changing this conception, cognitive conflict often occurs, but this is good because it requires students to think critically about their initial understanding. In addition, Rasch analysis is used to provide an overview of the findings obtained.

Rasch analysis is an Item Response Theory (IRT) model developed by Georg Rasch in 1960 and used to measure data from a test instrument [22, 23]. Rasch analysis measures how well the instrument used measures what it is intended to measure and assumes that the person's ability (potential) is very important in answering the given items [35]. This is because each Person and Item are measured simultaneously in Rasch analysis. The possibility of a Person answering an Item correctly is largely determined by their ability. Therefore, the measurement must be measured with a measuring instrument that has the same interval for each category created. In this case, Rasch analysis provides a solution for conducting objective measurements. Rasch analysis has also been widely used in educational research in various aspects, such as surveys [36], measurement of misconceptions [22], development research [37], and other research related to the application of treatment. The implementation of Rasch analysis in this study is to ensure the quality of the instrument in measuring student conceptions. Thus, this study aims to implement Augmented Reality-based Rebuttal Texts (ARaRaT) on momentum-impulse in the Predict Discuss Explain Observe Discuss Explain (PDEODE) strategy to identify students' conceptual change. Based on these aims, the description of the research questions is as follows:

1) How Students’ Conception Category in Pretest and Posttest?
2) How Students’ Conceptual Changes?

II. LITERATURE REVIEW

1. ARaRaT, ON MOMENTUM-IMPULSE

Augmented Reality-based Rebuttal Texts (ARaRaT) on momentum-impulse is a rebuttal texts based on Augmented Reality (AR) momentum and impulse. This media is used as teaching material in the learning process on the PDEODE strategy. The difference between ARaRaT on momentum-impulse using AR to build a new learning atmosphere and the latest platform to support the learning process [38]. ARaRaT on momentum-impulse is designed by packaging abstract physics concepts and phenomena into a 3D animated display on a smartphone screen so that it can support the learning process of students and make it easier to understand and relate the concepts received. The development of worksheets using AR technology is very suitable for use as a learning tool in physics practicum activities [39]. ARaRaT on momentum-impulse is compiled based on PDEODE learning stages and assisted by AR applications. ARaRaT on momentum-impulse can also be used as a fairly good alternative in the learning process.

Augmented Reality media that has been developed and validated by experts can be used as media in the learning process with appropriate and effective results. In previous research [40] states that physics learning media with Augmented Reality technology in optics material is feasible to be applied in the learning process because it affects the way students think. Based on the results of previous research on the use of Augmented Reality technology, it can be stated that AR can be used in the learning process to help students understand the material because with AR, abstract physics material can be visualized.

2. PREDICT DISCUSS EXPLAIN OBSERVE DISCUSS EXPLAIN (PDEODE)

The Predict Discuss Explain Observe Discuss Explain (PDEODE) learning strategy was first proposed by [41]. PDEODE learning strategy is a learning strategy that approaches by linking the daily life experiences of students with the material being taught. Based on the constructivist perspective and the conception of behaviorists, learning is not purely the result of stimulus and response phenomena, but learning is a process that requires self-regulation and the construction of conceptual structures through reflection and abstraction [42]. The PDEODE learning can be used as a means to explore students' understanding of a scientific concept [5].

In addition, PDEODE is a development of the POE learning strategy. The difference between POE and PDEODE is the addition of “Discussion (D)” to POE. In [6] explains that the addition of Discussion (D)” to POE provides space for students to create a learning atmosphere that supports diverse views from discussion sessions. PDEODE consists of six stages, namely the prediction stage (Prediction), discussion stage I (Discuss I), explanation stage I (Explain I), observation stage (Observe), discussion stage II (Discuss II), and explanation stage II (Explain II) [6]. The syntax of PDEODE learning stages is shown in Table 1.

Table 1. Syntax of PDEODE.

Syntax	Learning Activities
Prediction	Provide conceptual phenomena to students and ask students to write down predictions of what will happen in order to validate students' initial thoughts.
Discuss I	Direct students to discuss and share their thoughts in their respective groups.
Explain I	Direct students from each group to temporarily conclude (hypothesis) about the phenomenon being investigated to be understood.
Observe	Provide demonstrations or simulations to create cognitive conflict.
Discuss II	Direct students to discuss and reconcile observation results with previously made predictions.
Explain II	Ask students to explain and write down the final conclusions between observation data and initial predictions.

3. PDEODE WITH ARaRaT, ON MOMENTUM-IMPULSE

In implementing the PDEODE learning strategy, it must be able to adapt to current educational challenges, namely learning in the era of revolution 4.0 with the use of sophisticated technology in the world of education and online learning due to the COVID-19 pandemic. Because the learning process is carried out online, the PDEODE learning strategy requires adaptation. This is one of the reasons for using Augmented Reality-based LKPD as a learning medium to help implement PDEODE learning. In addition, LKPD and the Augmented Reality Momentum and Impulse applications can be accessed easily and flexibly on smartphones. The steps for learning PDEODE with ARaRaT, on Momentum-Impulse are shown in Table 2.

Table 2. Syntax PDEODE with ARaRaT, on Momentum-Impulse

Syntax	ARaRaT on Momentum-Impulse
Prediction	Students are given problems that occur in everyday life phenomena, predict, and answer on ARaRaT.
Discuss I	Students are given problems from the case in prediction I but with different circumstances, then students are asked to discuss and share thoughts with group members to answer the problem questions.
Explain I	Each group temporarily concludes (hypothesis) the results of the group discussion about the phenomenon being investigated to be understood.
Observe	Students conduct observations by conducting experiments using the ARaRaT application, on Momentum-Impulse and filling in the experimental results table found in the rebuttal texts.
Discuss II	Reconcile the observation results with the predictions made in the previous step.
Explain II	Explain and write the final conclusion between the observation data and the initial predictions.

4. RASCH ANALYSIS

Rasch analysis was first developed in the 1960s by comparing the quality of items and persons [23, 43, 44]. This analysis is Item Response Theory (IRT) which was originally designed in the field of psychology, but its development to date has been very diverse, such as in the fields of education and health [45-47]. This model can change ordinal data into interval data, to achieve a more meaningful interpretation. The implementation of this section is very helpful for researchers in using the type of data from the instrument used, but the data analyzed can be automatically measured with interval data. For example, many researchers use the Likert scale as an instrument, but the raw data is sometimes directly processed as a percentage and categorized. Meanwhile, data from the Likert scale is ordinal data [48,49]. Thus, with Rasch analysis, the score can be changed into a logit value to be interpreted based on the criteria of Rasch analysis. In addition, many outputs can be used to test the instruments used (validity, reliability, level of difficulty, discrimination, gender bias), and the probability of determining the shift between one possibility to another in choosing an option. While in education, the Rasch model is often used to measure students' conceptions and changes in conceptions, especially in science learning [50-52].

5. CONCEPTION AND MISCONCEPTION

Conception is a student's understanding of a concept, such as being able to explain a concept in their style of language. Conception must be by scientific conception [53-55]. If the conception does not correspond to the scientific conception, and one is certain about the conception, then the understanding falls into the category of misconception [22-24]. Misconceptions can occur in all subjects and all concepts, such as in physics concepts. Misconceptions in physics often occur in students with understanding obtained before learning in class. This understanding must be handled by educators or teachers in the classroom. Misconceptions must be addressed immediately because they are the basis for learning advanced concepts in physics. For example, in the concept of momentum, students must correctly understand the concept of momentum which is influenced by two quantities, namely mass and velocity [34]. If students only view momentum in terms of the size of an object, without considering its speed, it will have an impact on students' understanding of the next concept, such as the concept of impulse and others. However, the basic thing must also be considered whether students correctly understand the concept of force in Newton's law or still have misconceptions, because these are still related to each other. This means that in understanding a concept, students must have a complete conception, and must be ensured to avoid misconceptions. If students still have misconceptions and are not identified, then continue to study other concepts that are still related, then this misconception will spread to other concepts and it will be difficult to eliminate it. Identification such as diagnostic tests can help in identifying misconceptions [33, 44, 56]. Early identification is very important because it can provide an initial picture of the category of student conceptions, and can think about the follow-up actions to be taken. Several efforts can be made to reduce misconceptions, including creating cognitive conflicts [57], presenting scientific concepts in an interesting way (such as using simulation media) [58], Augmented Reality (AR) or Virtual Reality (VR) [59]), demonstration of tools, or development of models or strategies that trigger cognitive conflict or changes in student conceptions. This effort has been proven by several researchers and in this research, we provide an alternative solution using AR media equipped with rebuttal-text.

6. CONCEPTUAL CHANGE

Changing the concept is done to change the students' understanding of a phenomenon to be better. The initial concept that students have about phenomena in everyday life can be built by changing their concept [3, 60]. Conceptual change involves changes in the conception of students and the conception of scientists, so that in the end they obtain a higher status. Conceptual change is considered as a change in the mindset of students from one level of understanding to another (for example from alternative conception to partial understanding) [61]. Based on several statements, then the change of conception can be said as a process of changing conception from the initial state before learning to the final state after learning. The general interpretation for changes in conception, namely: 1) Acceptable Change (AC) is marked with a (+) sign if the change occurs from a low level of conception to a high level of conception; 2) Not Acceptable (NA) is marked with a (-) sign if the change occurs from a high level of conception to a low level of conception, and; 3) No Change (NCh) is marked with the number zero (0) if there is no change in conception [62]. There are at least three conditions of prior knowledge that students have, namely, students do not have prior knowledge, students have incomplete knowledge, and students have conceptions that conflict with the concepts that must be learned [63]. Based on this, learning can be in the form of adding new knowledge for condition one, gap filling for condition two, while for the third condition learning will be in the form of a change. Thus, it can be concluded that learning will be in the form of a conceptual change if the initial conception of the student is contrary to the scientific conception, while for other conditions learning is only to enrich their knowledge.

III. MATERIAL AND METHOD

1. RESEARCH DESIGN

The design used in this study is embedded mixed method. This research design involves two types of data collection, namely quantitative data and qualitative data which are combined using different designs involving assumptions and theoretical frameworks [64]. Figure 1 shows the embedded mixed methods design used in this study.

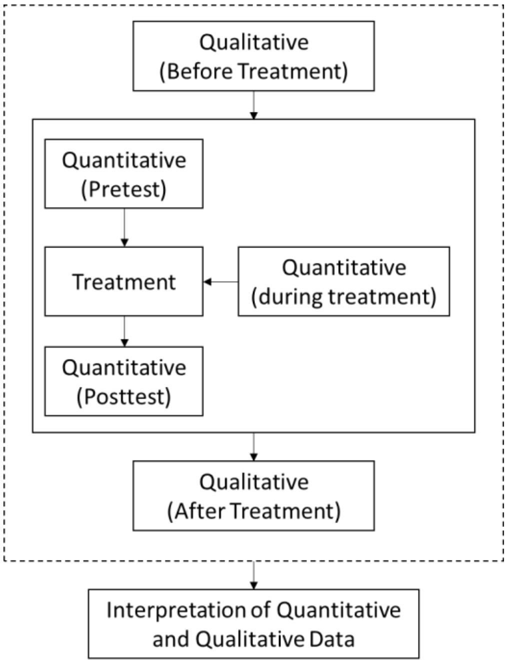

FIGURE 1. Embedded mixed methods design.

Figure 1 shows the design used in this research because it combines qualitative and quantitative data. Both of these data complement each other. Qualitative data before and after treatment are taken from pretest and posttest data. The difference with quantitative data is that qualitative data uses coding to analyze student conception categories, while quantitative data is the score obtained during the pretest and posttest. Both will complement each other in determining the position of the student's conception category whether it is in the conception or misconception category or others (Table 3). Thus, during the interpretation we use both data which strengthen each other.

2. RESPONDENTS

The respondents in this study were 31 students (9 males and 22 females) of grade XI at a public high school in Central Java, Indonesia. The purposive sampling technique was used to find respondents for this study. The purposive sampling technique takes research samples that are deliberately selected based on certain criteria. In this study, the criteria used include sampling based on classes that have not studied momentum and impulse material, chosen classes based on the results of discussions with the school, where the selected classes have varying qualities, and finally because the curriculum in Indonesia makes momentum and impulse material studied in grade XI. This is a consideration, thus the sample that became respondents in this study was 31 students in one class in grade XI.

3. DATA COLLECTION

Data collection was done by giving pretests and posttests to students (Figure 1). Meanwhile, the instrument used was 10 diagnostic test questions in a multi-tier format on the concept of momentum and impulse. The diagnostic test instrument in a four-tier format was able to identify misconceptions experienced by students well and accurately [65]. Based on this, we use a four-tier diagnostic test to diagnose students' conceptions of momentum and impulse. The first tier contains questions about the concept of momentum and impulse, then the second tier contains beliefs about the answers filled in by students in the first tier. The third tier contains questions about the reasons based on the answers in the first tier, and the fourth tier contains beliefs about the answers filled in by students in the third tier. Meanwhile, an example of the instrument used in this research can be seen in Figure 2.

Number 1

1.1. Please pay attention to the table below!

Car Type	Mass (kg)	Speed (km/h)
Sedan	1.200	60
Pick up	1.500	
Van	2.000	
School Bus	6.000	
Sand truck	8.000	

The five cars are moving at the same speed with different masses. Among the five cars, car … is the most difficult to stop.

a. Sand truck
b. School bus
c. Van
d. Pick up
e. Sedan

1.2. Level of confidence in the answer 1.1.

a. Sure
b. Not sure

1.3. The reasons for the answer to 1.1.

a. Because the momentum value has nothing to do with stopping the motion of an object
b. Because the momentum value is not affected by mass and velocity
c. Because the momentum value of the five cars is the same
d. Because the momentum value is the smallest
e. Because the momentum value is the largest

1.4. Level of confidence in the answer 1.3.

a. Sure
b. Not sure

FIGURE 2. Example of a diagnostic test with a multi-tier format.

Figure 2 shows a multi-tier format, where when students answer questions 1.1 and 1.3 correctly, then their confidence level is at the sure level (1.2 and 1.4), then the students are included in the Sound Understanding (SU) category. Conversely, if the answers 1.1 and 1.3 are wrong, and sure on 1.2 and 1.4, then they are included in the misconception category. In detail, all the possibilities can be seen in Table 4. Meanwhile, this instrument has been validated using Rasch analysis on the dimensionality test (raw variance explained by measures value) of 34.3% (appropriate category). The quality of each question item can be seen in the item fit order from the MNSQ, ZSTD, and PT Measure Corr outfi values. The respective criteria for MNSQ ($0.5 < x < 1.5$), ZSTD ($-2 < x < +2$) and PT Measure Corr $0.4 < x < 0.85$. If all three categories are met, then it is included in the "Very Appropriate" category. If only 2 categories are met, then it is in the “Appropriate” category. If only 1 category is met, then it is in the “Less Appropriate” category, and if all three are not met then it is in the “Not Appropriate” category. The results for each item can be seen in Table 3.

Table 3. Instrument validity.

Question Number	MNSQ	ZSTD	PT Measure Corr	Interpretasi
Q1	0.86	-0.08	0.62	Very appropriate
Q2	1,96	1,35	0.51	Appropriate
Q3	0.81	-0.24	0.38	Appropriate
Q4	0,57	-1,85	0.65	Very appropriate
Q5	1,48	1,23	0.27	Appropriate
Q6	0,90	0.34	0.56	Very appropriate
Q7	1.26	0.83	0.29	Appropriate
Q8	0,57	-1,85	0.65	Very appropriate
Q9	0.84	-0.09	0.31	Appropriate
Q10	0,90	0.34	0.56	Very appropriate

4. DATA ANALYSIS

Previously, students' conceptions were categorized based on conception categories. This was done for initial identification before analyzing changes in conception. Table 4 shows the conception categories used in this study [23].

Table 4. Conception scores and categories.

Tier	Kategori																
	SU		PP						PN					NU		MC	NC
	(0)		(1)						(2)					(3)		(4)	(5)
	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	13	17
1	C	C	C	C	C	C	C	C	I	I	I	I	I	I	I	I	IA
2	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	NS	S	
3	C	C	C	C	I	I	I	I	C	C	C	C	I	I	I	I	
4	S	S	NS	NS	S	S	NS	NS	S	S	NS	NS	NS	S	NS	S	

Note: SU (Sound Understanding); C (Correct); PP (Partial Positive); I (Incorrect); PN (Partial Negative); MC (Misconception); NU (No Understanding); IA (Incomplete Answer); NC (No Coding); S (Sure), dan; NS (Not sure)

Scoring for each conceptual category (0, 1, 2, 3, 4, and 5) is done only for coding (ordinal data). Then, the sequence from 0 to 5 is the direction from positive to negative. We give the highest negative code to identify conceptions that are not in accordance with scientific conceptions. In addition, the use of ordinal data can be analyzed by Rasch analysis, such as on the Likert scale because it is converted to interval data [66-68]. Thus, the distance between categories will be the same even though the raw data used is ordinal data. While the categories for the confidence level are in Table 5.

Table 5. Confidence level scores and categories.

Tier	C (3)	PC (2)		U (1)	NC (0)
	1	2	3	4	5
2	√	√	x	x	IA
4	√	X	√	x	

Note: C (Confident); PC (Partial Confident); U (Unconfident); NC (No Coding); √ (Sure); x (Not sure), dan; IA (Incomplete Answer)

Table 5 shows that the confidence level category is only in tiers 2 and 4 of the 4-tier instruments. Thus, categorization is done by sorting as in Table 2 and producing 4 confidence level categories with 5 possibilities that will occur. This categorization will also be analyzed using Rasch analysis, where the initial stage of this analysis is done with the percentage for each category of conception using Equation 1.

$$\% = \frac{\text{Number of students at a certain conception level}}{\text{Number of students}} \times 100\% \quad (1)$$

Further analysis was carried out with three categories of conceptual change, namely Acceptable Change (AC), Unacceptable Change (UC), and No Change (NC), which can be seen in Table 6 [3].

Table 6. Categories of conceptual changes and changes in confidence levels.

No	Conception Category		Confidence Level Category		Conceptual Changes Category
	Pretest	Posttest	Pretest	Posttest	
1	PP	SU	PC	C	Acceptable Change (AC)
2	PN	SU	U	C	
3	PN	PP	NC	C	
4	NU	SU	U	PC	
5	NU	PP	NC	PC	

6	NU	PN	-	-	
7	MC	SU	-	-	
8	MC	PP	-	-	
9	MC	PN	-	-	
10	NC	SU	-	-	
11	NC	PP	-	-	
12	NC	PN	-	-	
13	SU	SU	C	C	No Change (NC)
14	PP	PP	PC	PC	
15	PN	PN	U	U	
16	MC	MC	NC	NC	
17	NU	NU	-	-	
18	NC	NC	-	-	
19	SU	PP	C	PC	Unacceptable Change (UC)
20	SU	PN	C	U	
21	SU	NU	C	NC	
22	SU	MC	PC	U	
23	SU	NC	PC	NC	
24	PP	PN	U	NC	
25	PP	NU	NC	U	
26	PP	MC	-	-	
27	PP	NC	-	-	
28	PN	NU	-	-	
29	PN	MC	-	-	
30	PN	NC	-	-	
31	NU	MC	-	-	
32	NU	NC	-	-	
33	MC	NU	-	-	
34	MC	NC	-	-	
35	NC	NU	-	-	
36	NC	MC	-	-	

Table 6 shows all the possibilities that can occur based on students' answers during the pretest and posttest for the Conception Category and Confidence Level Category. Generally, changes for the Acceptable Change (AC) category move in a better direction. For example, in the conception category, whatever the conception category is at the time of the pretest if it is in the sound understanding (SU) category at the posttest, it is good and falls into the AC category. Meanwhile, an example for the Confidence Level Category where at the time of the pretest it is in any category, and at the time of the posttest it is in the Confident (C) category, it is an acceptable change (AC). For the No Change (NC) category, it means there is no change during the pretest or posttest. Then changes for the Unacceptable Change (UC) category indicate changes that are getting worse and unacceptable.

Meanwhile, the Rasch is used to map the comparison between the quality of respondents to the instruments used, as well as the level of trust and comparison to changes in conception. The software used is MINISTEP 5.7.4.0. Meanwhile, the output used is WrightMap R Statistics (identification of changes in conception and confidence level).

IV. RESULTS AND DISCUSSION

1. HOW STUDENTS' CONCEPTION CATEGORY IN PRETEST AND POSTTEST?

This conception level profile was obtained from the results of the pretest and posttest using the Four-tier instrument. The pretest answers of students that had been obtained were mapped based on the conception level category and processed in the form of a percentage of the student conception level profile on the Momentum and Impulse material. The profile of the student conception level from the pretest results was obtained before the implementation of learning as shown in Table 7.

Table 7. Conception Category Pretest-Posttest Results

No	Pretest (%)						Posttest (%)					
	SU	PP	PN	NU	MC	NC	SU	PP	PN	NU	MC	NC
S1	32.4	0	48.4	0	19.4	0	61.3	0	22.6	3.2	12.9	0
S2	29	3.2	9.7	6.5	48.4	3.2	32.3	0	22.6	3.2	41.9	0
S3	3.2	3.2	22.6	12.9	58.1	0	9.7	3.2	35.5	9.7	41.9	0
S4	12.9	0	32.3	22.6	32.3	0	9.7	0	41.9	9.7	38.7	0
S5	3.2	0	32.3	25.8	38.7	0	16.1	0	38.7	9.7	35.5	0
S6	12.9	12.9	32.3	9.7	32.3	0	16.1	3.2	51.6	6.5	22.6	0
S7	3.2	0	19.4	9.7	61.3	6.5	6.5	0	35.5	12.9	45.2	0
S8	16.1	0	38.7	6.5	35.5	3.2	22.6	0	38.7	9.7	29	0
S9	9.7	6.5	35.5	19.4	29	0	22.6	6.5	25.8	6.5	38.7	0
S10	9.7	0	32.3	35.5	22.6	0	22.6	9.7	19.4	19.4	29	0
Average	13.2	2.6	30.3	14.8	37.7	1.3	21.9	2.3	33.2	9	33.5	0

Based on Table 7, information is obtained on the percentage of students' conception levels for each number and the overall average for the number. Table 6 for pretest data obtained the percentage for the Sound Understanding (SU) category of 13.2%, the Partial Positive (PP) category of 2.6%, the Partial Negative (PN) category of 30.3%, the Not Understanding (NU) category of 14.8%, the Misconception (MC) category has a percentage of 37.7%, and the No Coding (NC) category of 1.3%. The conception level category that has the highest average percentage is 37.7% in the Misconception (MC) category or misconception. Misconception is a wrong understanding of the concept of a phenomenon [69-71]. The highest average percentage shows that misconceptions are a conceptual problem that occurs among students.

Meanwhile, the percentage of students' conception levels at the time of the posttest for each conception level obtained the Sound Understanding (SU) category of 21.9%, the Partial Positive (PP) category of 2.3%, the Partial Negative (PN) category of 33.2%, the Not Understanding (NU) category of 9%, the Misconception (MC) category has a percentage of 33.5%, and the No Coding (NC) category of 0%. Different from the pretest results, in the posttest because the NC value is 0%, it means that all students filled in all the questions, there were no questions that were not filled in or were unclear. The conception level category that has the highest average percentage is still in the Misconception (MC) or misconception category, which is 33.5%. However, even so, the misconception value of the posttest results is smaller than the pretest results, this shows that there is a decrease in students' misconceptions in the momentum and impulse material. Meanwhile, the average values for all categories during the pretest and posttest can be seen in Figure 3.

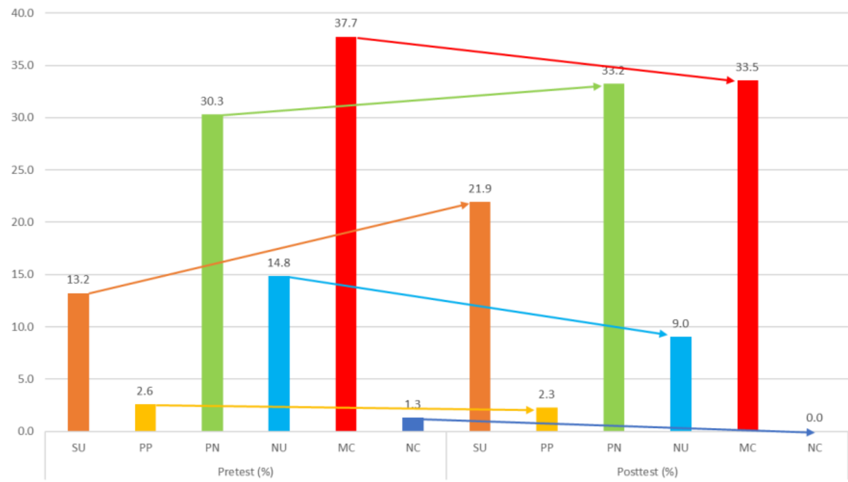

FIGURE 3. Average of conception category.

2. HOW STUDENTS' CONCEPTUAL CHANGES?

This result is a follow-up to the results shown in Figure 3. Where are the changes that occurred from pretest to posttest? Student conceptual change based on student responses to LKPD Concept Changes after implementing PDEODE learning assisted by LKPD based on Augmented Reality on momentum and impulse. The results of the percentage value of the types of student concept changes are shown in Figure 4.

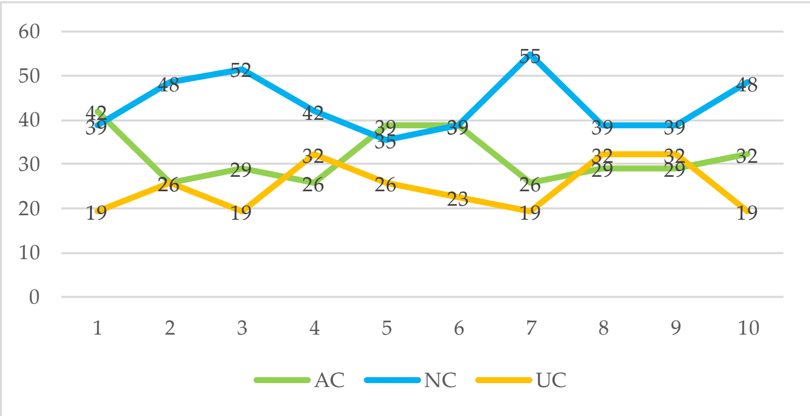

FIGURE 4. Student's conceptual changes.

Figure 4 shows that the highest average pattern is in the NC pattern (blue line). Meanwhile, the lowest is in the UC pattern (orange line). After being identified based on the average calculation for each category of conceptual change, namely AC (32%), NC (44%), and UC (25%). In these results, the AC category has not occupied the highest ranking in conceptual change. This is because several factors cannot be controlled in this research, such as the equalization of facilities used by students. For example, in the use of smartphones, not all group members use their smartphones in the experiment. Meanwhile, ideally each group member uses their own smartphone. So that during the implementation, we gave leeway to the group with the provision that at least 1 group has 1 smartphone. Of course, this was not previously controlled in the research because we only focused on the impact of its implementation on changes in student conceptions. In addition, it is indeed not easy to change student conceptions, especially if identified more deeply against abstract concepts. Meanwhile, as a case study, we discuss students' answers to question number 1, where changes in conception can be identified as seen in Figure 5.

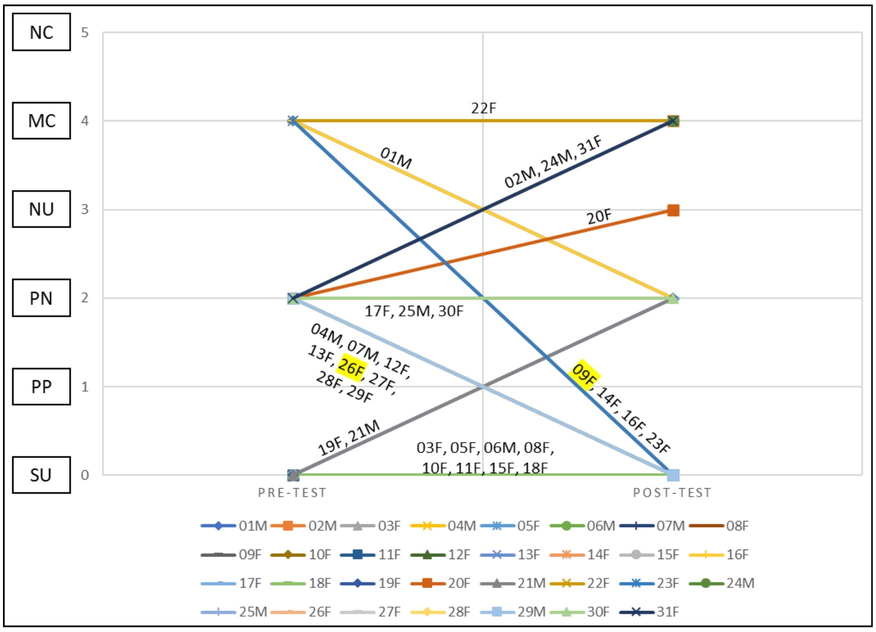

FIGURE 5. Changes in concept of question T1.

Students with code 26F experienced a better change in conception, namely from the conception level with the category "PN" changing to "SU". In addition, students with code 09F experienced a better change in conception from "MC" to "SU". In the pretest, 09F answered with a certain level of confidence that at the same speed a car with a smaller mass is more difficult to stop than a car with a larger mass on the grounds that the momentum value has nothing to do with stopping the motion of an object. In the posttest, 09F was found to answer with confidence that at the same speed a car with a larger mass is more difficult to stop than a car with a smaller mass on the grounds that at the same speed a car with a larger mass has a greater momentum value. This is based on 09F's answer to the ARaRaT on Momentum and Impulse (Table 8).

Table 8. Sample Answer from 09F

Syntax	**Answer from 09F**

Prediction

Predict

1. Which would be harder to stop a school bus or a car if both are traveling at the same speed? Explain!

   The school bus because its mass is large

09F has made the prediction correctly, but the reasoning is still not quite right.

Discuss I

In another situation, if a car with the same mass has different speeds, such as car 1 moving at a speed of $2\vec{v}$, and car 2 moving at a speed of $\vec{v}$ as shown in the picture on the side.

Discuss I

2. Which one will be more difficult to stop between car 1 and 2 if both have the same speed? Explain!

   Car 1 because it has greater speed $2\vec{v}$

09F discussed with group members to answer the question. 09F had given the correct answer, but the reason was still not quite right.

Explain I

Explain I

3. After answering the above questions, explain the definition of momentum? What quantities affect momentum? How are these quantities related?

   Momentum is a quantity related to the mass of an object. There are 2 quantities that affect it, namely mass and velocity. The relationship between velocity and mass is inversely proportional, meaning that the greater the load of an object, the smaller the speed of the object, and vice versa.

09F and his group made a temporary conclusion about the phenomenon being investigated and then answered the question. 09F's explanation did not answer completely correctly. This can be seen from 09F's answer which was correct in answering that momentum can be influenced by mass and speed, but the understanding or definition of momentum is still not quite right.

Observe

Observe

Experiment 1: Different masses with the same velocity $\vec{v}_1 = \vec{v}_2$
Independent variable: m_2
Dependent variables : m_1, $\vec{v}_1$, dan $\vec{v}_2$

No.	m_1 (kg)	$\vec{v}_1$ (m/s)	$\vec{v}_1'$ (m/s)	$\vec{p}_1 = m_1\vec{v}_1$ $(kg\ m/s)$	$\vec{p}_1' = m_1\vec{v}_1'$ $(kg\ m/s)$	$\lvert\Delta\vec{p}_1\rvert = \vec{p}_1' - \vec{p}_1$ $(kg\ m/s)$	m_2 (kg)	$\vec{v}_2$ (m/s)	$\vec{v}_2'$ (m/s)	$\vec{p}_2 = m_2\vec{v}_2$ $(kg\ m/s)$	$\vec{p}_2' = m_2\vec{v}_2'$ $(kg\ m/s)$	$\lvert\Delta\vec{p}_2\rvert = \vec{p}_2' - \vec{p}_2$ $(kg\ m/s)$
1.	1,8	2,0	-1,06	3,60	-1,91	5,51	1,4	-2,0	1,94	-2,8	2,71	5,51
2.			-1,50	3,60	-2,70	6,30	1,8		1,50	-3,6	2,70	6,30
3.			-1,85	3,60	-3,33	6,93	2,2		1,15	-4,4	2,53	6,93

09F fill in the experimental results data table using the ARaRaT application

ARaRaT Application Example (two ball collision menu and falling object collision menu)

Discuss II

Discuss II

1. Is the effect of mass and velocity on momentum based on experimental data 1 in accordance with the previous hypothesis? Explain the relationship with mass, velocity, and momentum!

   Momentum (p) directly proportional to mass (m) and velocity (v). The greater the velocity of an object, the greater its momentum.

2. Did the experimental data 1 for the blue and red balls change after the collision? Does it match the previous hypothesis?

   Yes, I predicted it because the blue ball has less mass than the red ball.

2. Based on experimental data 1 with different masses when the mass of the blue ball is greater than the mass of the red ball $(m_1 > m_2)$ at the same velocity, which of the blue and red balls has a greater velocity after the collision?

   ☐ blue ball

   ☑ red ball

09F answer questions based on research data by discussing with group members

Explain II

Explain II

Give a final conclusion from the prediction results and experimental results regarding momentum!

Momentum is a measure of the difficulty of stopping an object. The quantities that affect momentum are mass and velocity. Momentum is the result of mass multiplied by velocity. The relationship is, if the mass is greater, then the momentum is also greater. Likewise, the greater the velocity, the greater the momentum.

09F can answer according to the correct concept that momentum is a measure of the difficulty of stopping an object and what influences momentum is mass and speed.

Table 8 shows that 09F can reconstruct initial understanding into new understanding through learning experiences with the PDEODE stage. In addition, among the 3 categories, namely Accepted Change (AC), Not

Change (NC), and Unacceptable Change (UC), the percentage value in the Not Change (NC) category is the largest, namely 44%. This shows that students have difficulty accepting new concepts that are in accordance with scientific explanations [72]. For the analysis of misconception categories, changes occurred as shown in Figure 6.

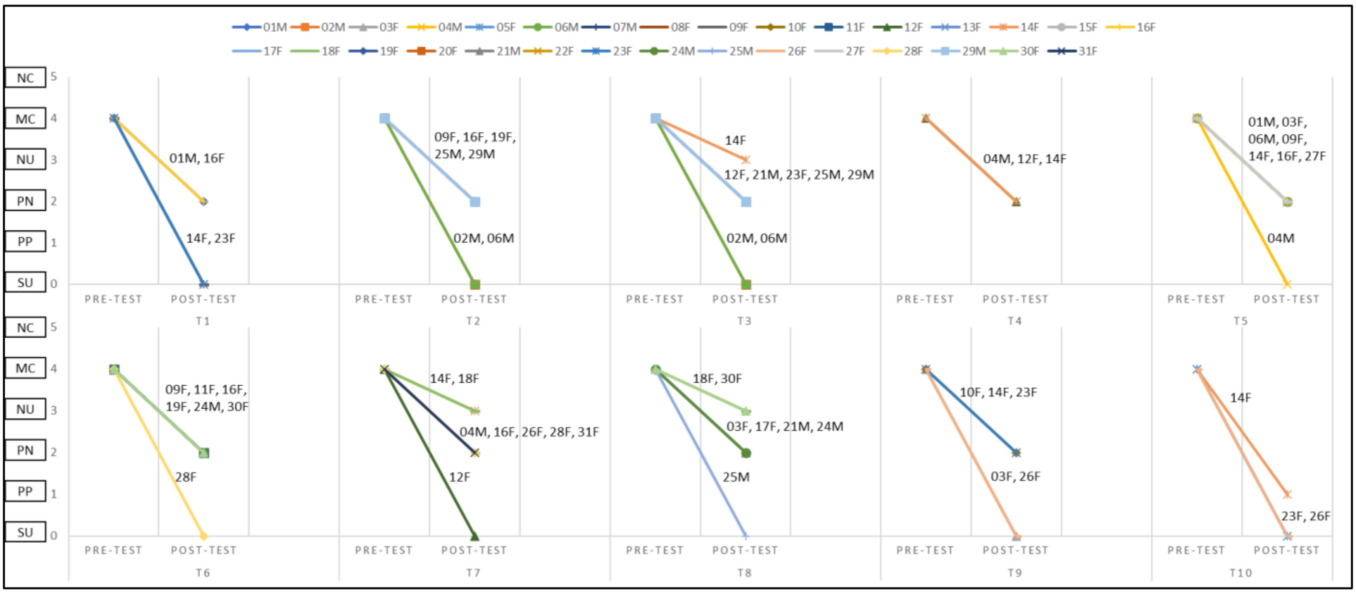

FIGURE 6. Conceptual changes from misconception categories.

Every misconception change occurred in all question numbers. The highest misconception change was in questions T3 (26%), T5 (26%), and T7 (26%). It's just that in T3, T7, and T8 there was a change from MC to Nu, and this is included in UC (which is not expected). Apart from that, the misconception change that occurred was AC (which is expected). Meanwhile, the highest misconception change for the AC category was in question T5 (26%) and the lowest was in questions T4 and T10 (10%). The results of the Rasch analysis show that the results of identifying changes in conception can be seen in Figure 7.

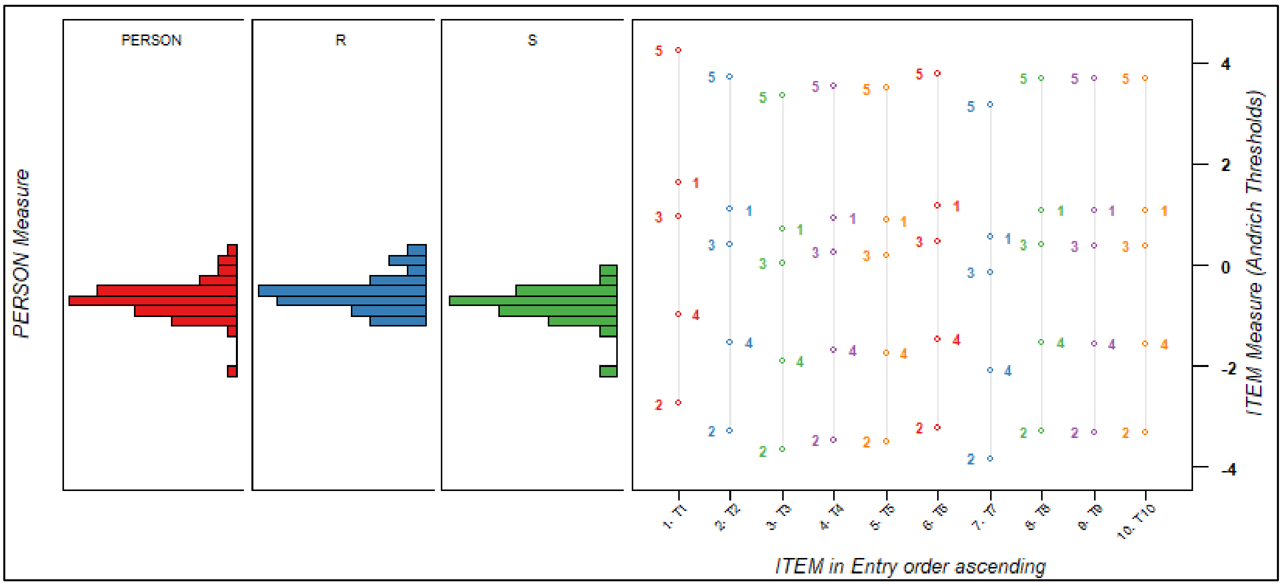

FIGURE 7. Rasch analysis for conceptual change.

The left side of Figure 7 shows the changes in conception during the pretest (code R) and posttest (code S) through WrightMap R Statistics. The red histogram is the overall distribution of PERSON Measure (combined codes R and S). The vertical axis (positive y) shows the direction of students' understanding towards

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misconceptions, while the negative y axis shows students' understanding towards conceptions according to scientific conceptions. The length of each bar (horizontal direction) for all colors shows the number of students at a certain level. Thus, the reading for the bar graph is the higher the position of the bar for all colors indicates that students' understanding is increasingly misconception, and the lower the position of the bar for all colors indicates that students' understanding is increasingly in accordance with their scientific conceptions.

SUMMARY OF CATEGORY STRUCTURE. Model="R"

CATEGORY LABEL	SCORE	OBSERVED COUNT	%	OBSVD AVRGE	SAMPLE EXPECT	INFIT MNSQ	OUTFIT MNSQ	ANDRICH THRESHOLD	CATEGORY MEASURE	
0	0	109	18	-1.08	-1.06	.98	1.03	NONE	(-2.29)	0
1	1	15	2	-.82	-.87	1.04	.92	1.02	-1.49	1
2	2	197	32	-.73	-.72	1.03	1.00	-3.37	-.95	2
3	3	74	12	-.53	-.59	.44	.39	.33	-.39	3
4	4	221	36	-.46	-.45	1.06	1.03	-1.61	1.30	4
5	5	4	1	-.46	-.31	1.22	1.06	3.64	(4.74)	5

OBSERVED AVERAGE is mean of measures in category. It is not a parameter estimate.

FIGURE 8. Andrich thresholds analysis of conception categories.

The right side of Figure 7 is Code T1 to T10 which shows the code for questions number 1 to 10. Meanwhile, ITEM Measure (Andrich Thresholds) shows the location of the response probability changes between response categories. The colored numbers on the ITEM Measure (Andrich Thresholds) of each vertical line on T1 to T10 show the threshold position for each category in each item. However, the numbers on the vertical lines contain only numbers 1 to 5, while the existing categories (based on the conceptual score in Table 4) consist of 0 to 5. A score of 0 in the Andrich Thresholds analysis is considered category 0 but does not appear in the Figure 6 display. This is because the logit value of the probability is not identified, which is shown in detail by Figure 8.

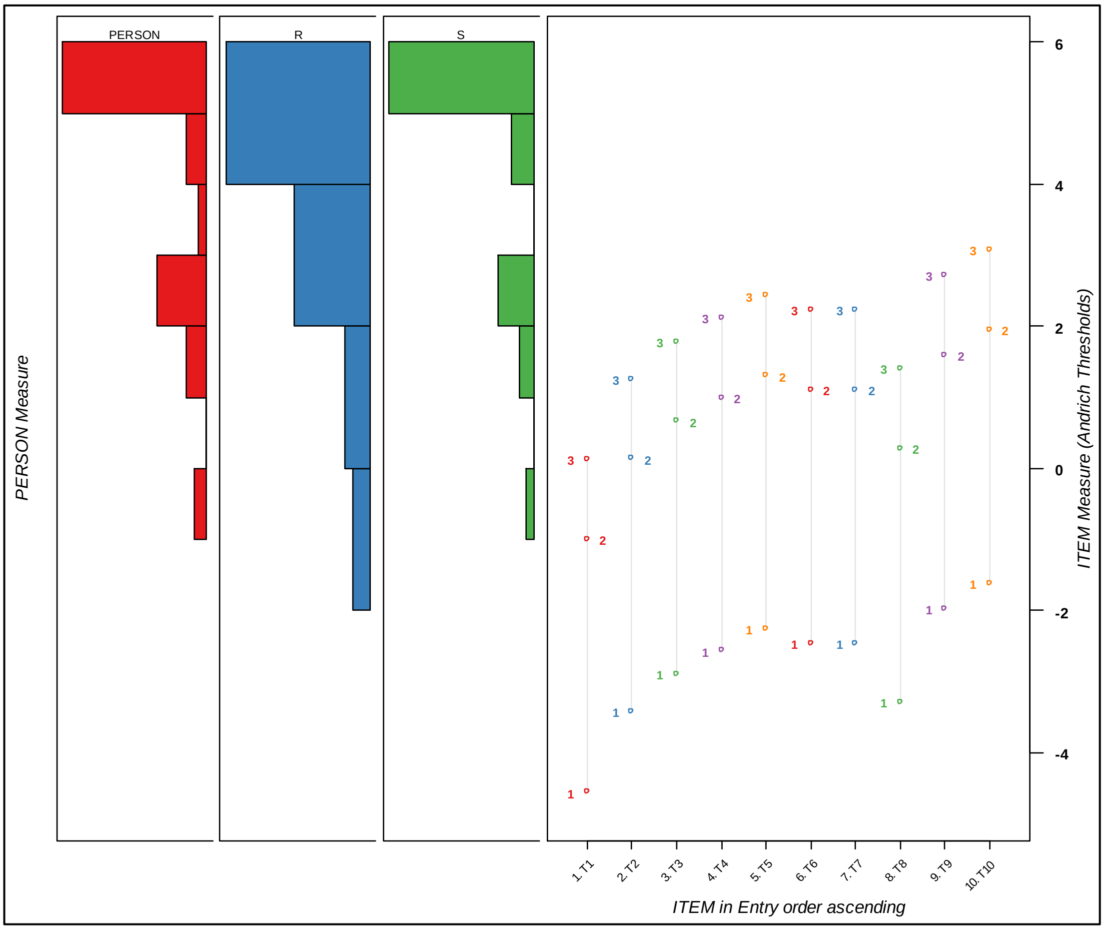

FIGURE 9. Rasch analysis for confidence level.

Figure 8 shows that the results of the Andrich Thresholds analysis (red box) category 0 (SU) do not have a logit marked with the description (None). Meanwhile, the order of the Andrich Thresholds (red box) is not sequential because from category 0 to category 5 the logit values are not sequential. The order in the red box will match the order of the Andrich Thresholds in Figure 5, where the order from top to bottom is 5 (logit 3.64), 1 (logit 1.02), 3 (logit 0.33), 4 (logit -1.61), and 2 (logit -3.37). Actually, the use of Andrich Thresholds is usually used for the closest category transfer. However, in this analysis we will identify the probability of possible category transfer based on possible conceptual changes (Table 6). The Andrich Thresholds threshold used is 1.4 to 5 [73]. If Andrich Thresholds <1.4, then the probability distance of the thresholds is too close and indicates that respondents cannot distinguish between the two adjacent categories. Meanwhile, if Andrich Thresholds >5, it can eliminate the accuracy of measurement between the two adjacent categories. In addition, Figure 5 also provides information that there is a change in students' general conception during the pretest (code R) and posttest (code S) because the position of the bar during the posttest is lower vertically than during the pretest. This means that in general, students' understanding after the implementation of ARaRaT on momentum impulse has changed for the better. This analysis was also carried out to identify the students' confidence level which can be seen in Figure 9.

Figure 9 shows that the higher the position of the bar, the more confident and vice versa. The histogram of the pretest (Code R) and posttest (Code S) shows a change, where the position of the posttest (Code S) is higher overall than the pretest. This means that the level of student confidence has increased after treatment. The position of Andrich Thresholds for all questions (T1 to T10) is also more regular, where the lowest to highest categories are 1, 2, and 3. Meanwhile, only Code 0 is not shown in this analysis because it has a logit value (none) which is completely shown in Figure 10.

SUMMARY OF CATEGORY STRUCTURE. Model="R"

CATEGORY LABEL	SCORE	OBSERVED COUNT	%	OBSVD AVRGE	SAMPLE EXPECT	INFIT MNSQ	OUTFIT MNSQ	ANDRICH THRESHOLD	CATEGORY MEASURE	
0	0	4	1	1.38	-.86	3.16	2.09	NONE	(-3.87)	0
1	1	48	8	.13*	.47	.73	.66	-2.75	-1.02	1
2	2	74	12	2.01	1.94	.86	1.52	.81	1.39	2
3	3	494	80	3.33	3.32	.96	.95	1.94	(3.23)	3

OBSERVED AVERAGE is mean of measures in category. It is not a parameter estimate.

FIGURE 10. Andrich thresholds analysis of confidence levels.

Figure 10 shows that the logit values for Andrich Thresholds are sequential. These results provide an overview of the changes in students' general confidence levels after treatment. Thus, it can be said that after receiving treatment, students are more confident in answering questions. These results are supported by research [60] that confidence after learning can be achieved because of the positive and innovative learning experience in AR technology. In addition, [74] explains that a person's self-confidence is based on self-efficacy, while AR has a positive effect on self-efficacy. Thus, the indicate that changes in the confidence level in this research are due to the use of AR in the learning process.

V. CONCLUSION

Augmented Reality-based Rebuttal Texts (ARaRaT) on momentum-impulse has been implemented in learning using the Predict Discuss Explain Observe Discuss Explain (PDEODE) strategy to change students' conceptions. In general, the results show that there is a change in conception in the AC category (32%), NC (44%), and UC (25%). Meanwhile, the highest change in misconceptions occurs in the AC category (found in question T5 (26%)) and the lowest in questions T4 and T10 (10%). These results are supported by the Rasch analysis which shows that in general there is a change from pretest to posttest. However, the probability of a change in conception can also be seen from the results of the analysis of Andrich Thresholds. Likewise, for the confidence level, students become more confident than before in answering questions. But this probability only shows the possibility that can occur when there is a category change. Meanwhile, external factors are not calculated in this research such as the distribution of facilities used. In this case, not all group members use their smartphones in the experiment. Meanwhile, ideally each group member uses their respective smartphones. Of course, this is not controlled in the research because we only focus on the impact of its implementation. Thus, it can be seen that the change in the AC category has not been the highest of the categories of conceptual changes that have occurred. However, these results can be a recommendation for other researchers in developing and implementing AR in physics learning. Likewise, the use of learning strategies or models can also be varied to review the success of using AR in changing students' conceptions for the better. The suggestions for further research, it is expected to ensure that in this implementation all students must be able to use their respective smartphones. Then make sure the sequence of strategies used can be implemented optimally. We hope that this research can provide implications for teachers or educators in the field in using AR as a learning medium included in the learning strategy.

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Authors Contribution

All the authors made equal contributions to the development and planning of the study.

Conflict Of Interest

The authors have no potential conflicts of interest.

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