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# Transforming Academic Emotions and Critical Thinking Through Augmented Reality in PBL: A Rasch Stacking-Racking Analysis

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**Abstract:** This study aims to evaluate the effectiveness of the Augmented Reality (AR)-integrated Problem-Based Learning (PBL) model on students' academic emotions and critical thinking skills in the topic of Matter and Its Changes. The primary background for this intervention was the low level of student engagement and the difficulty of visualizing abstract science concepts at SMP Negeri 2 Gorontalo. The research employed a quasi-experimental method with a pretest-posttest control group design involving 124 seventh-grade students divided into experimental (n=62) and control (n=62) groups. Data were collected through academic emotion questionnaires (30 Likert-scale items) and two-tier critical thinking tests (16 items), which were then analyzed using the Rasch Model via stacking and racking techniques to ensure data linearity in logit units. The analysis results indicate that integrating AR into PBL significantly increased students' positive academic emotions, with 70.97% of experimental students showing significant improvement, and accelerated critical thinking ability by 1.28 logits compared to 0.44 logits in the control class (Mann-Whitney U, $p < 0.001$). These findings confirm that AR's immersive visualization functions as cognitive scaffolding that simultaneously strengthens students' affective engagement and analytical thinking, consistent with the Control-Value Theory framework. This study concludes that AR-PBL is an effective intervention for simultaneously transforming affective and cognitive dimensions in junior high school science learning. The findings underscore the importance of integrating immersive technology into the science curriculum to support deeper conceptual understanding of abstract material.

**Keywords:** Augmented reality; Critical thinking; Learning emotions; Problem-based learning; Rasch model

## Introduction

Academic emotions are multidimensional constructs encompassing academic emotions ranging from enjoyment to boredom (Pekrun, 2024), which integrally influence student engagement and cognitive success (Hariono & Yoenanto, 2024). According to Muslim (2026), emotional stability serves as a vital foundation for developing critical thinking skills, particularly when confronting complex subject matter.

Conditions at SMP Negeri 2 Gorontalo in June 2025 revealed a significant gap. The average Science learning outcomes were only 65, with a minimum mastery rate of just 25%. Observations indicated that one-way learning triggered negative emotions and low participation. This gap highlights students' weak critical thinking abilities in analyzing scientific phenomena, which is further exacerbated by the lack of supporting media to visualize abstract concepts.

Problem-Based Learning (PBL) was selected for its ability to provide scaffolding in the investigation of real-world problems (Siswanto et al., 2025). The integration of Augmented Reality (AR) via Assembler Edu provides an innovative solution by visualizing molecular

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structures in 3D (Ramadhani et al., 2024; Sari et al., 2026). Referring to Control-Value Theory, the synergy between PBL and AR can enhance students' active control, which theoretically triggers positive emotions and strengthens critical thinking (Pekrun, 2024; Rujiani et al., 2025).

Despite the great potential of AR-PBL, precise evaluations of latent emotional and cognitive changes remain limited. This study utilizes the Rasch Model to overcome the weaknesses of conventional statistics by converting ordinal data into interval data (logits) (Cahyaningsih, 2025; Riskawati et al., 2025). This psychometric approach allows for a more objective and accurate mapping of students' emotional profiles and critical thinking.

This study aims to implement AR-integrated PBL to comprehensively evaluate the academic emotion profiles and critical thinking skills of students at SMP Negeri 2 Gorontalo through the lens of Rasch modeling.

## Method

*Time and Location*

The research was conducted during the odd semester of the 2025/2026 academic year at SMP Negeri 2 Gorontalo, specifically focusing on seventh-grade students. The research location was determined using a purposive method (Sugiyono, 2018; Mukhlis et al., 2019; Mukhlis et al., 2024; Asgaf et al., 2025), deliberately chosen the location was based on its relevance to the research context, namely the low levels of critical thinking skills and emotional engagement among students in Science learning particularly regarding the topic of "Matter and Its Changes" as identified through preliminary observations at the school.

*Research Design*

The research design employed is a quasi-experimental approach using a pretest-posttest control group design (Anantasia & Rindrayani, 2025; Hutapea et al., 2025). The quasi-experimental design was selected because it allows for a comparison between the experimental group, which received AR-integrated PBL instruction, and the control group, which received standard PBL instruction. Subject selection was conducted using the cluster random sampling technique to ensure that every member of the population had an equal probability of being included in the sample, thereby minimizing bias and enhancing the validity of the research findings. Schematically, the research design is illustrated as follows:

**Table 1**. Research Design

| Group | Pretest | Treatment | Posttest |
|---|---|---|---|
| Experiment | $O_1$ | $X_1$ | $O_2$ |
| Control | $O_3$ | $X_2$ | $O_4$ |

Information
$O_1$ = Pretest Experiment Class
$O_2$ = Posttest Experimen Class
$O_3$ = Pretest Control Class
$O_4$ = Posttest Control Class
$X_1$ = Treatment in the experimental class (AR-integrated PBL)
$X_2$ = Treatment in the control class (conventional PBL)

The population of this study consists of all seventh-grade students at SMP Negeri 2 Gorontalo during the even semester of the 2025/2026 academic year. This population was selected because seventh-grade students are at the early stage of formal operational cognitive development, which theoretically enables them to engage in higher-order thinking activities. The research sample was drawn using a cluster random sampling technique. From the eight available classes, four were randomly selected to serve as the experimental and control groups, involving a total of 124 students. The distribution of the research sample is presented in the following table.

**Table 2**. Research Distribution Sample

| Group | Class | Number of Student | Treatment |
|---|---|---|---|
| Experiment | VII 2 | 31 Student | PBL Integrated AR |
| Experiment | VII 4 | 31 Student | PBL Integrated AR |
| Control | VII 1 | 32 Student | PBL Conventional |
| Control | VII 3 | 30 Student | PBL Conventional |
| Total Number of Student: 124 Student | | | |

Source: Primery Data, 2026

Based on the table above, the total research sample was 124 students divided into two groups. The experimental group consisted of 62 students (VII-2 and VII-4) who received treatment in the form of learning with the PBL model integrated with Augmented Reality through the Assembler Edu platform. The control group consisted of 62 students (VII-1 and VII-3) who received treatment in the form of conventional PBL model learning. Both groups were given a pretest before the intervention and a posttest after the intervention was completed to measure differences and changes in academic emotions (Y1) and critical thinking skills (Y2).

*Research Procedures*

Preparation Phase: The researcher developed learning tools, including a PBL-based teaching module integrated with AR and the research instruments. The instruments consisted of a academic emotion questionnaire (30 Likert-scale items) and a critical thinking test (16 two-tier multiple-choice items). Both instruments were validated through a pilot study involving 62 students (a sample outside the research subjects) and analyzed using the Rasch Model to ensure psychometric quality (item validity and person reliability) before being applied in the main study.

Implementation Phase: The intervention was conducted over six meetings (2×40 minutes per meeting), covering topics such as the States of Matter, Changes in Matter, and Separation of Mixtures. In the experimental class, AR-integrated PBL syntax was implemented via the Assembler Edu platform through five phases: (1) AR-based problem orientation, (2) guided conceptual exploration, (3) collaborative investigation, (4) solution development and feedback, and (5) learning reflection. The use of AR media focused on visualizing abstract molecular structures to facilitate students' cognitive scaffolding.

Measurement Phase: Measurements were conducted through pretests and posttests in both groups to measure changes in academic emotion variables and critical thinking skills. Raw data were converted into logit units using the Rasch Model with stacking techniques (to analyze changes over time) and racking techniques (to objectively compare between variables) via Winsteps software. This technique ensures that comparisons between the control and experimental classes are performed on an equivalent interval scale.

*Data Analysis*

Data analysis was performed using the Rasch Model to calibrate item difficulty levels and student abilities onto the same linear scale (Ahmad et al., 2025; Riyadi et al., 2024). Since the data from the academic emotion instrument (Likert scale) and the critical thinking test (two-tier) generated polytomous responses, this study applied the Rating Scale Model (RSM) as an extension of the dichotomous model. All parameter estimations were converted into logit units (log odds units) using Winsteps software version 3.73.

The evaluation of data and instrument quality was based on three Item Fit criteria: (1) Outfit Mean Square (MNSQ) within the range of 0.5–1.5; (2) Z-Standard (ZSTD) within the range of -2.0 to +2.0; and (3) Point Measure Correlation (Pt-Mea Corr) within the range of 0.4–0.85. Fulfillment of these criteria ensures that the instruments possess high logical validity and reliability in measuring students' emotional constructs and critical thinking. To comprehensively address the research objectives, the data were analyzed using two specific techniques:

Stacking Technique: Used to combine response data from the experimental and control groups into a single analysis matrix, enabling an objective between-group comparison of posttest person measures on an equivalent logit scale (Laliyo, 2021). The person measure output from this technique was then tested using the Mann-Whitney U test to determine the significance of differences between the experimental and control classes.

Racking Technique: Used to place each student's pretest and posttest responses side by side within a single Rasch analysis, enabling individual-level tracking of change magnitude and direction over time (Laliyo, 2021). This technique enables the researcher to map changes in individual response patterns in depth as an impact of the AR-PBL intervention.

*Normality Test and Hypothesis Testing*

Prior to hypothesis testing, a Shapiro-Wilk normality test was conducted using SPSS 29 to determine the appropriate statistical method. The results are presented in Table 3.

**Table 3**. Shapiro-Wilk Normality Test Results

| Variable | Group | Statistic | Sig. |
|---|---|---|---|
| Academic Emotions | Control Class | 0.976 | 0.279 |
| Academic Emotions | Experiment Class | 0.957 | 0.030 |
| Critical Thinking Skills | Control Class | 0.975 | 0.244 |
| Critical Thinking Skills | Experiment Class | 0.932 | 0.002 |

Source: Primary Data After Processing, 2026

The normality test results indicate that the posttest data for the experimental group did not meet the normality assumption for both academic emotions ($p = 0.030$) and critical thinking skills ($p = 0.002$), as both values are below $\alpha = 0.05$. Although the control group data were normally distributed ($p > 0.05$), the violation of normality in one group is sufficient to warrant the use of a non-parametric test (Field, 2018). Therefore, hypothesis testing was conducted using the Mann-Whitney U test, which does not require the assumption of normally distributed data and is appropriate for comparing two independent groups.

## Result and Discussion

The results of the Mann-Whitney U statistical test in Table 4 below provide a clear comparative picture of the impact of the treatment on the two dependent variables. The striking difference in Mean Rank and the highly significant p-value ($p < 0.001$) for both variables are not merely statistical findings, but strong empirical evidence that leads to the rejection of the null hypothesis. The results of testing the two research hypotheses are presented comparatively in Table 4.

Table 4 clarifies that for the variables of academic emotions and critical thinking skills, the Mean Rank of the experimental group was consistently much higher (78.72 and 80.76) than that of the control group (46.28 and 44.24). The p-value for both tests was 0.000 ($p<0.001$), indicating very strong statistical evidence.

**Table 4**. Mann-Whitney U Test Results for the Emotional Academic and Critical Thinking Skills Variables

| Dependent Variable | Class | Person | Mean Rank | U | Z | p-value |
|---|---|---|---|---|---|---|
| Emotional academic | Experiment (PBL+AR | 62 | 78.72 | 916.500 | -5.029 | <0.001 |
| | Control | 62 | 46.28 | | | |
| Critical Thinking Skills | Experiment (PBL+AR) | 62 | 80.76 | 790.000 | -5.677 | <0.001 |
| | Control (PBL) | 62 | 44.24 | | | |

Source: Primary Data After Processing, 2026

Based on the statistical analysis results, both research hypotheses are accepted. The implementation of the Augmented Reality (AR)-integrated PBL model is proven to be significantly more effective than conventional PBL, which aligns with the findings of Rahmanda (2025). The improvement achieved by the experimental group demonstrates that the use of interactive visual technology is capable of helping students understand concepts, develop analytical skills, and enhance their ability to draw logical conclusions regarding both academic emotions and critical thinking skills among seventh-grade students on the topic of "Matter and Its Changes."

Changes in student academic emotion levels and critical thinking skills were analyzed by calculating the difference between the posttest and pretest person measure scores, which had been calibrated using the Rasch Model. A positive difference indicates an increase, while a negative difference indicates a decrease. To interpret the magnitude of change more meaningfully, these differences were categorized based on the standard deviation (SD) of the change distribution in each group. Cohen (1988), in Statistical Power Analysis for the Behavioral Sciences, suggests that using SD based effect size to assess the magnitude of change where a change is considered practically significant if it exceeds half to one SD is a robust approach.

*Changes in Students' Emotional academic Levels*

To facilitate interpretation, the results of the categorization of changes in emotional academic are presented in Table 5.

**Table 5.** Categorization of Changes in Students' Emotional Academic Levels in the Experimental and Control Classes

| Categoryy Change | Experiment Class (n=62) | Control Class (n=62) |
|---|---|---|
| Significant Increase | 44 Student (70.97%) | 32 Student (51.61%) |
| Normal Change | 12 Student (19.35%) | 16 Student (25.81%) |
| No Change | 1 Student (1.61%) | 0 Student (0.00%) |
| Decrease | 5 Student (8.06%) | 14 Student (22.58%) |
| Total | 62 Student | 62 Student |

Source: Primary Data After Processing, 2026

From Table 5, it is evident that the experimental class had a far larger percentage of students who experienced an increase in emotional academic (70.97%) than the control class (51.61%). On the other hand, a greater proportion of students in the control class (22.58%) than in the experimental class (8.06%) reported a decline in emotional academic. This suggests that using the AR-integrated PBL paradigm is superior to traditional PBL in terms of enhancing students' emotional academic. According to Kurniati et al. (2025), the use of PBL boosts students' interest in learning based on emotive and participative elements.

*Changes in Students' Critical Thinking Skills*

To facilitate interpretation, the results of the categorization of changes in critical thinking skills are presented in Table 6.

**Table 6**. Categorization of Changes in Students' Critical Thinking Skills in the Experimental and Control Classes

| Categoryy Change | Experiment Class (n=62) | Control Class (n=62) |
|---|---|---|
| Significant Increase | 40 Student (64.52%) | 26 Student (41.94%) |
| Normal Change | 16 Student (25.81%) | 16 Student (25.81%) |
| No Change | 0 Student (0.00%) | 6 Student (9.68%) |
| Decrease | 6 Student (9.68%) | 14 Student (22.58%) |
| Total | 62 Student | 62 Student |

Source: Primary Data After Processing, 2026

The two groups may be clearly distinguished from one another in the table. Critical thinking abilities significantly improved for 64.52% of students in the experimental class, which means that their score improvement was greater than the group standard deviation (0.99 logits). Only 41.94% of students in the control group, on the other hand, met the criteria for significant improvement. Additionally, more than twice as many students in the control class (22.58%) as in the experimental class (9.68%) reported a loss in critical thinking abilities. Furthermore, no students in the experimental class fell into this category, while six individuals (9.68%) in the control class exhibited no change at all (difference = 0).

The average gain in critical thinking scores in the experimental class (1.28 logits) was also substantially higher than in the control class (0.44 logits). These findings consistently demonstrate that the implementation of the AR-integrated PBL model is not only more effective in enhancing students' overall critical thinking skills (Saputra, 2024) but also succeeds in fostering meaningful (significant) improvements for the majority of students. This aligns with the characteristics of PBL, which trains analysis, synthesis, and evaluation, complemented by AR visualization via Assembler Edu. This technology assists students in understanding the abstract concepts of "Matter and Its Changes," thereby optimizing the critical thinking process.

The findings of this study are consistent with Rihayati et al. (2023), proving that the integration of Augmented Reality (AR) into the Problem-Based Learning (PBL) model empirically enhances both students' academic emotions and critical thinking skills simultaneously. This success lies in combining the problem-solving structure of PBL with the interactive visual experience of AR, creating a dual impact across affective and cognitive dimensions (Idham & Rauf, 2025).

The effectiveness of AR-PBL can be explained through the lens of Control-Value Theory (Pekrun, 2024), which posits that academic emotions are generated by two core cognitive appraisals: control appraisal (the degree to which students feel they can influence learning outcomes) and value appraisal (the perceived importance and relevance of the learning activity). In this study, AR visualization through Assembler Edu directly addresses control appraisal by transforming previously incomprehensible microscopic phenomena — such as particle movement and phase transitions in Matter and Its Changes — into interactive 3D representations that students can manipulate and observe in real time. This shift from passive reception to active exploration enhances students' sense of mastery and reduces anxiety. Simultaneously, the authentic real-world problem contexts embedded in PBL strengthen value appraisal by demonstrating the relevance of scientific concepts to everyday phenomena. The convergence of these two appraisal pathways — control through AR and value through PBL — creates a synergistic effect that simultaneously reduces negative emotions such as boredom and anxiety while amplifying positive emotions including enjoyment, pride, and engagement (Pekrun & Goetz, 2023; Riffert et al., 2021). This dual-pathway mechanism explains why AR-PBL produced stronger affective outcomes than conventional PBL alone, where only the value appraisal pathway is actively supported.

The increase in critical thinking in the experimental class (1.28 logits) reaching three times that of the control class (0.44 logits) confirms that AR visualization functions as a cognitive scaffolding. Within the PBL framework, students are required to perform analysis and inference (Shofiyah & Wulandari, 2018). The presence of AR allows students to interactively observe microscopic scientific phenomena, ensuring that conceptual understanding is firmly established before the discussion phase. This prevents cognitive overload and allows evaluative thinking processes to occur more optimally.

The use of the Rasch Model with stacking and racking techniques provides a sharper analytical dimension compared to classical statistics. The stacking technique ensures that pretest-posttest comparisons are on an equivalent linear scale (logits), providing high objective validity for the Mann-Whitney U test. Meanwhile, the racking technique offers novelty by mapping individual change profiles, addressing the "how" of personal transformation (Laliyo, 2021). This study provides an answer to the findings of Riffert et al. (2021), who stated that academic emotions tend to be stable and difficult to change in the short term. These findings prove that immersive technology (AR) integration is a form of "extensive intervention" capable of accelerating positive emotional shifts. By simultaneously strengthening control and value appraisals, AR-PBL enables meaningful emotional transformation even within a limited intervention duration.

## Conclusion

Thei implementationi ofi thei AR-integratedi PBLi modeli isi proveni toi significantly transform students' academic emotion profiles, making them more positive compared to the conventional model. Analysis using the racking technique reveals thati thei majorityi ofi studentsi ini thei experimentali classi achievedi consistenti emotionali improvement. This confirms that the use of immersive AR media is effective in reducing negative emotions and strengthening students' affective engagement throughout the problem-solving process. Furthermore, the integration of AR within PBL provides a stronger acceleration of students' critical thinking skills. The improvement in thei experimentali classi substantiallyi surpassedi thati ofi thei controli classi acrossi alli categories.i Ai cruciali findingi ini thisi studyi isi thei absencei ofi studentsi experiencingi ai declinei ini criticali thinking skills within the experimental class. This indicates that AR visualization functions as a stable cognitive scaffolding instrument, facilitating students' analytical and evaluative processes effectively.

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**Conflicts of Interest**

The author declare no conflict of interest.

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