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Self-Regulated Learning Through The Ethno-Flipped Classroom Model: A Study of Stacking Analysis in Rasch Measurement

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ABSTRACT

Purpose: This study aims to evaluate the effectiveness of the ethno-flipped classroom model, which integrates Nias cultural artifacts, in enhancing students' self-regulated learning (SRL) in statistics. **Methods:** This study employed a quantitative approach with a longitudinal design. Data were collected from 152 students at the Senior High School residing on Nias Island, Indonesia via SRL questionnaires administered at the pre- and post-intervention stages. Data analysis utilized stacking analysis within the Rasch Model framework to measure growth in ability on a consistent logit scale, supplemented by in-depth interviews to clarify inconsistent response patterns. **Findings:** The results showed a significant increase in students' self-regulated learning, with the percentage of students at the "High" level surging dramatically from 17.76% at the pre-intervention stage to 76.35% at the post-intervention stage. All students demonstrated positive logit score growth, reflecting a paradigm shift in learning from individualistic to collaborative approaches. However, it was found that students with low initial mathematics ability still require additional support during the self-monitoring phase. **Research Implications:** These findings provide practical contributions for educators in designing instructional approaches that integrate modern technology with local wisdom to strengthen student autonomy and engagement. However, this study is limited by students' adaptation difficulties, self-monitoring gaps among low and moderate ability students, and the Nias cultural context restricting generalizability. **Originality:** The novelty of this research lies in the unique integration of Nias-specific ethno-mathematics artifacts into a flipped classroom model, validated using the psychometric Rasch Model approach to ensure the objectivity of student ability growth measurements.

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INTRODUCTION

Educational developments in the current digital era demand a paradigm shift in learning that is oriented toward student independence and autonomy. Self-regulated learning (SRL) has been a primary focus in educational research over the past decade due to its crucial role in enhancing student performance and learning outcomes (Palos et al., 2019; Tao et al., 2023; Theobald, 2021). The concept of SRL encompasses processes such as self-evaluation, self-observation, and self-reflection, which enable students to manage their learning processes independently (Zimmerman & Moylan, 2009; Zimmerman & Schunk, 2008). In the context of modern learning, self-regulation skills are becoming increasingly important as students are expected to manage their own time and learning strategies, particularly in asynchronous environments (Rasheed et al., 2020; Wong et al., 2019). This need for learning autonomy demands instructional models capable of facilitating student flexibility without compromising instructional effectiveness.

One learning model considered effective in accommodating these self-regulated learning needs is the flipped classroom. This model inverts the traditional classroom by moving lecture content out of the classroom and bringing active engagement back into the classroom (Reidsema et al., 2017). As part of a blended learning strategy, the flipped classroom provides students with the flexibility to learn anywhere and anytime, which directly encourages them to become more independent and autonomous (Galindo-Domínguez & Bezanilla, 2025; Rasheed et al., 2020). Research indicates that students with high levels of self-regulation are more successful in this environment compared to those with low self-regulation (Al Mulhim, 2021). However, the effectiveness of this model depends not only on technology but also on how relevant the presented material is to students' real-life experiences.

The relevance of this material can be strengthened through the integration of local cultural contexts into the formal curriculum, a practice known as ethnomathematics. The use of culture within a mathematical context facilitates students' ability to model concepts based on ideas, methods, and techniques developed by the communities around them (D'Ambrosio, 2017; Rosa & Orey, 2016b). Ethnomathematics is not merely about presenting informal problems but involves learning that actualizes cultural values in classroom activities to create meaningful learning (Risdiyanti & Prahmana, 2020). Investigating data derived from real-life phenomena has been shown to help develop statistical reasoning skills (Ramadhani et al., 2023b)as well as student creativity (Faiziyah et al., 2020). It is this synergy between the flexibility of technology in the flipped classroom and the richness of the local cultural context that gave rise to the innovative Ethno-Flipped Classroom model.

The author developed the Ethno-Flipped Classroom model as a collaborative pedagogical solution that combines digital efficiency with sociocultural relevance. This model is designed to foster meaningful learning by integrating cultural elements, values, and characteristics embedded in students' experiences into two learning phases: out-of-class and in-class (Ramadhani et al., 2021, 2023a). The implementation of this model has proven to be valid and practical through six syntactic stages: Flexibility, Culture Experience, Cooperative, Elaboration, Collaboration, and Evaluation. Preliminary research conducted by the author showed a very positive student response, with a satisfaction rate reaching 83% in the small-group stage and increasing to 85% in the field test (Ramadhani et al., 2023b). In another study, the ethno-flipped classroom model using the local cultural context of Nias was shown to effectively optimize the improvement of students' statistical reasoning skills, reaching Level 5 (integrated reasoning) (Ramadhani et al., 2025). Ardana et al. (2024) also implemented the ethno-flipped classroom model by integrating the Tri Mandala concept into Balinese culture, achieving an 87.54% success rate in the learning process. Meyllinda et al. (2023)also found in their study that students' mathematical creative thinking skills improved, with 25.81% achieving the "very high" category after implementing the ethno-flipped classroom model. Based on the results of the studies conducted, further research is needed to comprehensively demonstrate the effectiveness of this model on other competencies, such as self-regulated learning; therefore, a measurement instrument with high precision and objectivity is required.

The Rasch model is a psychometric tool capable of objectively measuring individual ability and item difficulty beyond classical statistics (Laliyo et al., 2023). Its application in educational research enables researchers to enhance assessment quality, calibrate tests, and track student progress over time using a measurement scale that is generally (Laliyo et al., 2022). This model is consistently used in the development of instruments that accurately measure students' abilities, attitudes, and character (Sumintono, 2018; Sumintono & Widhiarso, 2015). Nevertheless, to obtain a more dynamic picture of the patterns of students' SRL development, conventional Rasch analysis needs to be expanded with more detailed analytical techniques.

This analysis is extended through stacking analysis, which enables the longitudinal evaluation of students' growth and skill development. Stacking analysis is a comprehensive measurement methodology that combines the predictive distributions of an ensemble of models to predict the rate of progress more accurately than using a single model (Kaplan et al., 2025; Ramadhani, Saragih, et al., 2022; Wright, 1996). In the context of educational research, this approach is highly relevant for building optimal growth models to monitor students' competency development toward specific learning targets (Kadyrov et al., 2026; Uzun & Öğretmen, 2021). This study contributes to the literature by being among the first to integrate the Ethno-Flipped Classroom model with Rasch-based stacking analysis to longitudinally map the development of students' self-regulated learning. By applying stacking analysis through Rasch measurement, this study aims to precisely map changes in students' self-regulated learning through the implementation of the Ethno-Flipped Classroom model, thereby providing a deeper understanding of student learning dynamics. To assist in conducting the analysis to achieve the objectives of this study, the following research questions are used:

RQ1: Is there a change in students' self-regulated learning after the ethno-flipped classroom model intervention, as viewed from the individual student level?

RQ2: Are there changes in students' self-regulated learning levels between the initial condition (Time 1) and the final condition (Time 2)?

RQ3: Is there a significant difference in students' self-regulated learning between the pre-intervention (Time 1) and post-intervention (Time 2) conditions of the ethno-flipped classroom model?

METHOD

Research Design

This study employs a quantitative approach using a one-group pre-post test design. In this design, a series of observations were conducted before and after the intervention to evaluate the impact of implementing the ethno-flipped classroom model on students' self-regulated learning abilities. Measurements were conducted using an SRL questionnaire that had undergone validation in a previous research phase (Ramadhani et al., 2024), where the raw data obtained was subsequently converted into interval data through Rasch model psychometric modeling. The primary analysis technique applied in this study is Stacking Analysis within the Rasch model framework. The use of the stacking technique aims to monitor the development and changes in students' individual self-regulation ability levels following exposure to a learning process that integrates cultural context and technological flexibility. In the stacking analysis procedure, pre-test (Time 1) and post-test (Time 2) data are combined or stacked into a single data matrix for joint calibration. This allows students' abilities at both time points to be on the same logit scale, enabling an objective comparison of ability growth.

Participants

The subjects of this study were senior high school students residing on Nias Island, Indonesia. From an initial population of 235 students across six high schools, 180 participants were selected using simple random sampling through a computer-generated random number procedure. Of these, 152 students (56% female, 44% male; aged 17–18 years) completed all 14 weeks of learning activities and both assessment phases and were included in the stacking analysis, while 28 students were excluded due to incomplete data or withdrawal. Prior to data collection, ethical clearance was obtained from the relevant institutional review board, and written informed consent was secured from all participants and their parents or legal guardians, with confidentiality and the right to withdraw guaranteed.

The sample participated in a 14-week learning process using the Ethno-Flipped Classroom model, comprising six out-of-class phases, six in-class phases, an initial assessment (Time 1), and a final assessment (Time 2). This study employed a one-group pretest–posttest design without a control group, as the objective was to longitudinally map within-subject changes in self-regulated learning rather than compare groups; although this limits causal inference, the Rasch-based stacking analysis enables precise measurement of individual growth trajectories, providing a robust basis for evaluating developmental patterns within participants.

Research Instruments

The instrument used was a self-regulated learning questionnaire developed based on Zimmerman's (2002) self-regulation cycle framework, which emphasizes aspects of student motivation and learning strategies. This instrument is organized into three main phases: the forethought phase, the performance phase, and the self-direction phase (see the Appendix). Furthermore, this questionnaire includes six comprehensive measurement subscales: planning, self-monitoring, self-evaluation, self-satisfaction, self-efforts, and self-efficacy. The self-regulated learning questionnaire used in this study has undergone content and construct validation, and all items in the questionnaire meet the criteria for validity and reliability (Ramadhani et al., 2024). Table 1 presents the description of the items used in the SRL questionnaire.

Table 1. Description of the Self-Regulated Learning Questionnaire (Ramadhani et al., 2024)

SRL Phase	Description	Sub-Scale
Forethought Phase	This phase relates to how students prepare for the learning process. They analyze tasks, set goals, and plan how to achieve them. Additionally, this phase also includes motivational beliefs that drive the desire to learn and influence the use of learning strategies provided by the teacher.	Planning and Self-Efficacy
Performance Phase	In this phase, students work on the task while monitoring their learning progress. They use self-regulation strategies to stay focused, engaged, and motivated in completing the task.	Self-Monitoring and Self-Efforts
Self-Reflection Phase	This phase involves evaluation after the task is completed. Students assess their level of satisfaction and analyze the causes of success or failure in the learning process.	Self-Evaluation and Self-Satisfaction

Research Procedure

This research was conducted during the last three months of 2022, beginning with an initial assessment (questionnaire) to evaluate students' self-regulated learning on Nias Island. The ethno-flipped classroom intervention was implemented over 12 weeks through three learning cycles. Activities began with an out-of-class phase involving independent exploration and discussions on the Learning Management System, specifically the Collaborative Cloud Classroom (LMS-3CR) (Ramadhani et al., 2022; Ramadhani et al., 2023), followed by an in-class phase where students were presented with sociocultural problems using the context of Nias cultural ethnomathematics in learning groups organized based on students' initial ability levels. This collaboration continues seamlessly between classroom interactions and expanded discussions on LMS-3CR, which are then validated through a tiered confirmation process among low-, medium-, and high-ability groups until a consensus is reached and validated by the teacher. The entire learning sequence concludes with the administration of a final questionnaire, where the measurement results from both time points are analyzed using stacking analysis to monitor changes, growth, and the development of self-regulated learning for each student longitudinally on a consistent logit scale.

Data Analysis

The research data were analyzed using WINSTEPS software version 5.9.0 by applying the Joint Maximum Likelihood Estimation approach within the framework of stacking analysis. Through this procedure, the raw scores from the SRL questionnaire were transformed into a logit scale, which is an interval-scaled variable, allowing for an objective comparison of students' self-regulation abilities beyond classical statistics. The evaluation of the Rasch Model in this study included testing the unidimensionality assumption to ensure that the instrument measures only a single dimension, namely SRL, as well as testing local independence to ensure that students' responses to one item are not influenced by responses to other items. Additionally, person and item reliability assessments were conducted to ensure the consistency of measurement results among the high school student sample on Nias Island.

Data visualization was performed using a Wright Map to confirm the alignment between the distribution of participants' SRL ability levels and the difficulty levels of the developed instrument items. To maintain measurement fairness, Differential Item Functioning (DIF) analysis was applied to identify potential item bias based on participant demographics, particularly the gender variable, which consisted of 56% females and 44% males. A more in-depth analysis was conducted by automatically grouping person and item logit values using the COUNTIF function in Microsoft Excel, based on the mean and standard deviation of the logit values. This automated categorization approach aimed to improve the accuracy of classifying students' SRL ability and item difficulty levels in a sample of 152 participants, while minimizing the risk of subjective errors resulting from manual grouping. With the application of stacking analysis, every change in students' SRL profiles over time can be accurately mapped on a single measurement scale.

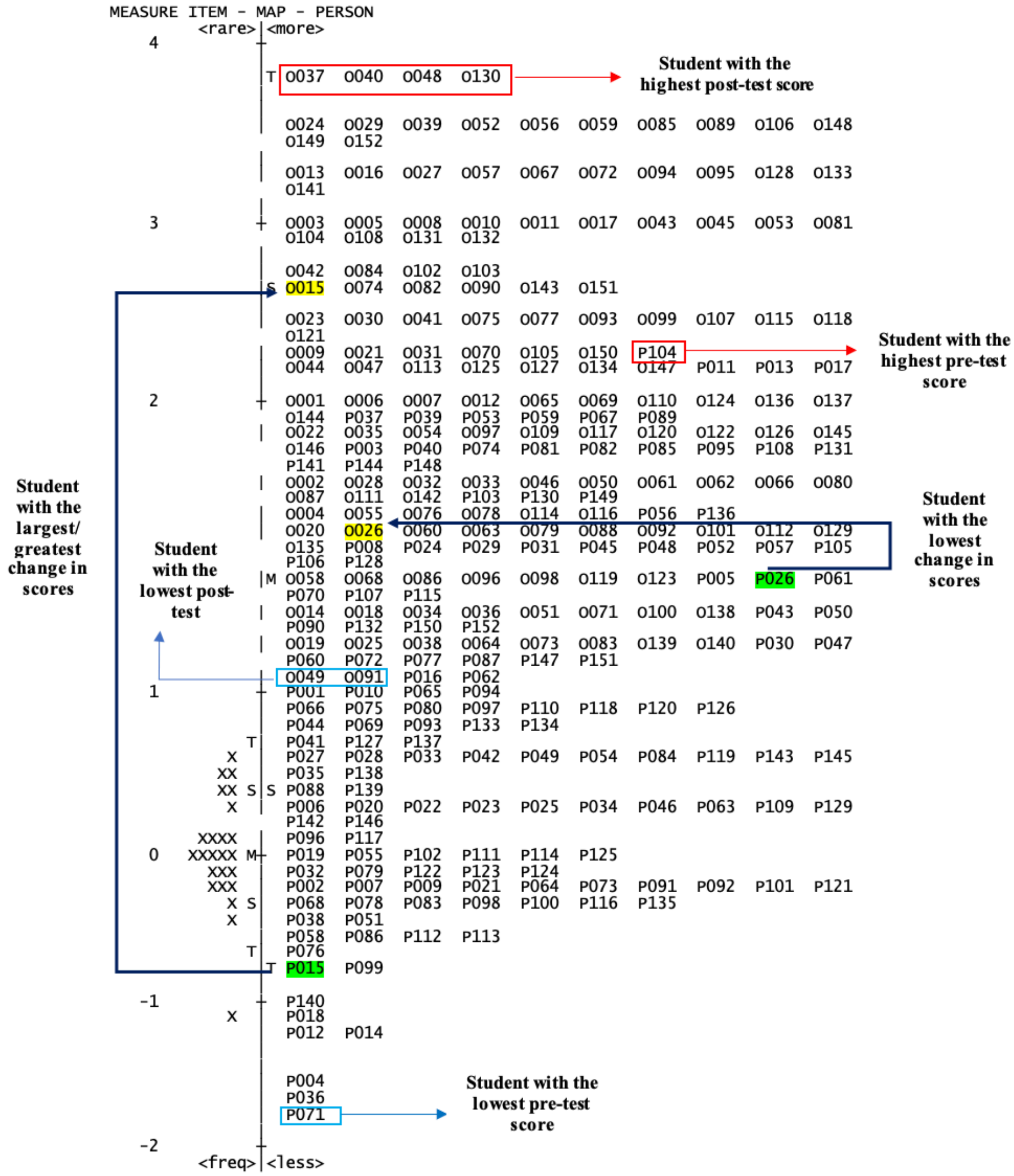
Furthermore, a significance test for the increase in self-regulated learning across the two time conditions was also conducted using inferential statistical analysis. If the classical assumptions (normally distributed and homogeneous data) were met, a paired sample t-test was performed; however, if the data did not meet one or both of the classical assumptions, the analysis was conducted using non-parametric statistical methods, specifically the Wilcoxon Signed-Rank test.

RESULTS

RQ1: Changes in Students' Self-Regulated Learning After the Ethno-Flipped Classroom Model Intervention Examined at the Individual Student Level

Changes in students' self-regulated learning were analyzed based on the initial questionnaire (Time-1) and the final questionnaire (Time-2). The results of the questionnaire analysis at both time points were subsequently analyzed using stacking techniques assisted by the Winstep application. The analysis revealed that the average logit score on the student self-regulated learning questionnaire at the initial condition (Time-1) was 0.70 logit. After the Ethno-Flipped Classroom model intervention, the average logit score for student self-regulated learning at the final condition (Time-2) increased to 2.27 logit. These results indicate a significant increase in logit scores following the ethno-flipped classroom intervention, with an average change in logit scores of 1.57. A total of 152 paired students were plotted across the two time frames (Time-1 and Time-2), allowing for the observation of individual changes in students' self-regulated learning in Figure 1 below.

Based on Figure 1 above, it is evident that all students experienced positive changes in self-regulated learning. There was a positive average change in logit scores from the initial condition (Time 1) to the final condition following the ethno-flipped classroom model intervention (Time 2). Student questionnaire scores at the final condition (Time 2) also yielded a positive average logit score. The magnitude of the positive change in logit values indicates that all students were able to improve their self-regulated learning effectively and positively through the implementation of the ethno-flipped classroom model.



Notes:
Green colour = indicates the pretest condition (Time 1)
Yellow colour = indicates the posttest condition (Time 2)

Figure 1. Wright Map of Changes in Self-Regulated Learning: Initial Condition (Time 1) and Final Condition (Time 2), Viewed at the Individual Student Level

Referring to Figure 1, it was found that the student with code 026 had the smallest change in logit value compared to the other students, namely 0.11. The student with code 026 in the initial condition (code P026) had a positive logit value of 1.45, but this increased to a positive logit value in the final condition (code O026), namely 1.56. In contrast, student code 015 exhibited the largest change in logit value, at 3.46. Figure 1 also indicates that the student with code 071 had the lowest initial questionnaire score code P071 (logit value -1.80) but by the final condition, the student with code 071 (code O071) was no longer the one with the lowest logit value. The student with code 049 (code O049) and the student with code 091 (code O091) have the lowest logit scores at the final condition or Time-2 (both with a logit score of 1.14).

Furthermore, Figure 1 also shows that the student with code 104 is the student with the highest initial questionnaire score (code P104). A different pattern is evident in the final questionnaire scores, where students with code 037 (O037), student 040 (O040), student 048 (O048), and student 130 (O130) constitute the group with the highest final questionnaire scores. These findings provide evidence that although students were provided with the ethno-flipped classroom intervention and demonstrated positive changes, they have not yet achieved optimal improvement. The impact of the ethno-flipped classroom intervention has not been fully effective in helping students enhance their self-regulated learning, particularly for student code 026.

RQ2: Changes in Students' Self-Regulated Learning Levels Before and After the Ethno-Flipped Classroom Model Intervention, Examined by Phase, Subscale, and Students' Initial Mathematics Ability

Based on the findings addressing RQ 1, it appears that the results of the individual student level stacking analysis indicate changes in self-regulated learning in both the initial condition (Time 1) and the final condition (Time 2). Further analysis regarding students' self-regulated learning levels at both the initial (Time 1) and final (Time 2) conditions, based on students' initial mathematics ability (KAM) demographics and examined in terms of phases and sub-scales within self-regulated learning, is presented in Figures 2 and 3 below.

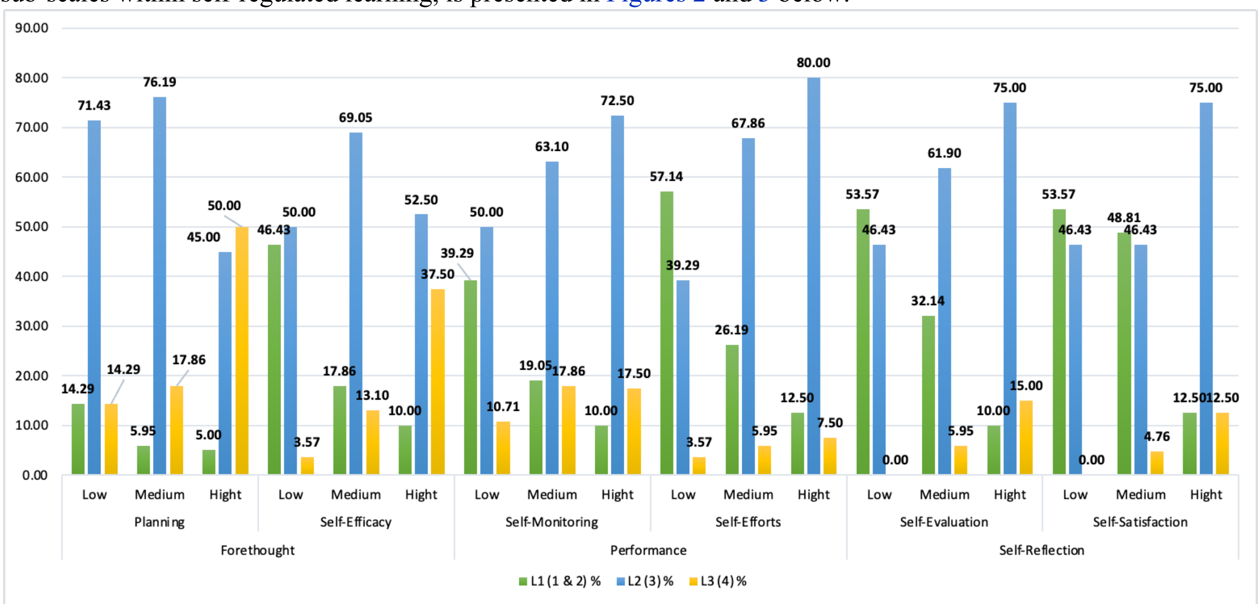


Figure 2. Students' Self-Regulated Learning Levels Based on KAM and Examined by Phase and Sub-Scale at the Initial Condition (Time 1)

Referring to Figure 2, it appears that the group of students with low KAM had difficulties in the Performance Phase, specifically in the Self-Efforts subscale, where students predominantly only achieved Level 1 of Self-Regulated Learning (57.14% or 16 out of 28 students). In addition to the Performance Phase, the group of students with low KAM also predominantly reached Level 1 of Self-Regulated Learning (53.57% or 15 out of 28 students) in the Self-Reflection Phase, specifically on the Self-Evaluation and Self-Satisfaction sub-scales (53.57% or 15 out of 28 students). Students in the low KAM group were not yet able to reach Level 3, but were able to reach Level 2 of Self-Regulated Learning at the Initial condition (Time-1). Based on this analysis, the low KAM student group still requires support in developing self-regulated learning during the performance phase and the self-reflection phase at the Final condition (Time-2) thereafter.

Not much different from students in the low KAM group, students in the moderate KAM group were also only able to reach Level 2 of Self-Regulated Learning at the Initial condition (Time-1). However, students in the moderate KAM group also still face challenges in the Self-Reflection Phase, specifically in the Self-Satisfaction sub-scale, where 48.81% of students (41 out of 84 students) were only able to reach Level 1 of Self-Regulated Learning. Based on this analysis, the moderate KAM student group still requires support in developing self-regulated learning during the self-reflection phase in the subsequent Final (Time-2) condition.

The highest level (Level 3) of Self-Regulated Learning has been achieved by the high KAM student group in the planning sub-scale of the thinking phase. The high KAM student group has been able to plan the learning programs they will undertake, and this helps them in building the self-directed learning autonomy they possess. The high KAM student group is predominantly at Level 2 of Self-Regulated Learning in the other phases and sub-scales. Based on this analysis, the high KAM student group still requires support in developing self-regulated learning in the thinking and performance phases during the subsequent final phase (Time-2) to reach the highest level. Further analysis regarding students' self-regulated learning levels at the post-test (Time-2) based on student KAM demographics and examined across each phase and subscale of self-regulated learning is presented in Figure 3 below.

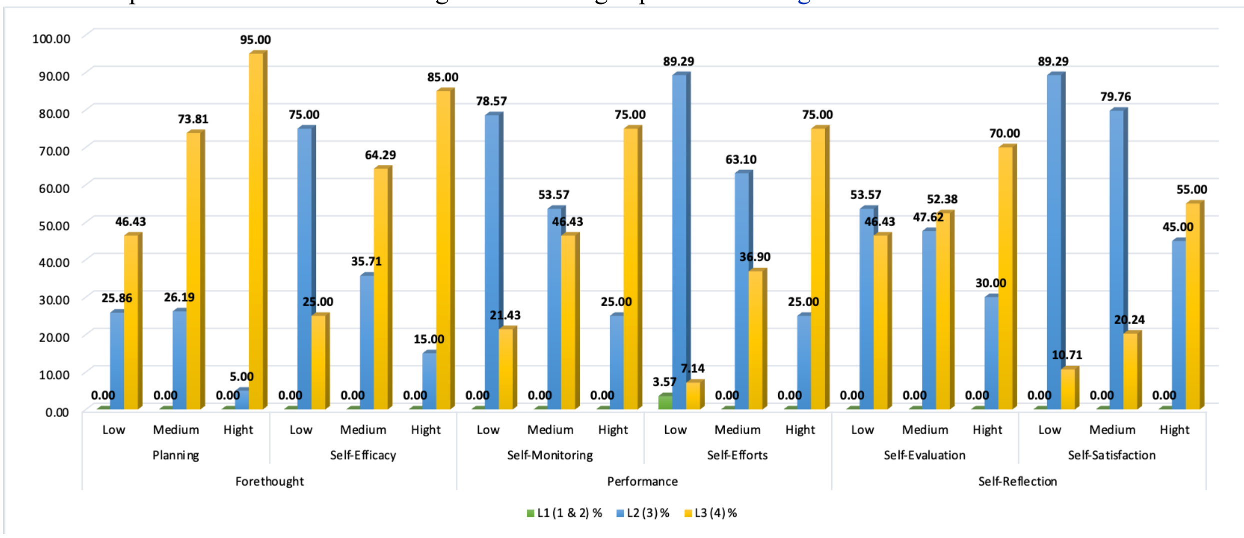


Figure 3. Students' Levels of Self-Regulated Learning Based on KAM and Examined by Phase and Subscale at the Final Measurement (Time 2)

Referring to Figure 3, it appears that the group of students with low KAM has experienced an increase in level in the performance phase (sub-scale: self-efforts) and the self-reflection phase (sub-scales: self-evaluation and self-satisfaction). The results in Figure 2, it can indicate that 25 out of 28 students (89.29%) in the low KAM group had advanced from Level 1 of self-regulated learning at the Initial Condition (Time-1) to Level 2 of self-regulated learning at the Final Condition (Time-2) in the performance phase (sub-scale: self-efforts). Furthermore, the results in Figure 3 also indicate that 15 out of 28 students (53.57%) in the low KAM group were able to reach Level 2 of self-regulated learning in the self-reflection phase, sub-scale: self-evaluation.

The same trend was observed on the sub-scale: self-satisfaction, which at the Initial Condition (Time-1) only reached Level 1; however, 25 out of 28 students (89.29%) advanced to Level 2. The low KAM group achieved the highest level (Level 3) of self-regulated learning in the planning phase, specifically on the planning subscale (13 out of 28 students, or 46.43%). However, students in the low KAM group still require maximum support in the performance phase, specifically the sub-scale: self-efforts, where 1 out of 28 students (3.57%) remained at Level 1 of self-regulated learning.

Different findings were observed in the moderate KAM student group, where there were 2 sub-scales in the performance phase that did not show a dominant increase in level among students. The self- -monitoring sub-scale only reached Level 2 of self-regulated learning at 53.57% (45 out of 84 students), and the self-efforts sub-scale also only reached Level 2 at 63.10% (53 out of 84 students). Nevertheless, students in the intermediate KAM group were already able to predominantly reach Level 3 (the highest level) of self-regulated learning in the performance phase (sub-scale: planning), at 46.43% (13 out of 28 students); the performance phase (subscale: self-efficacy) at 64.29% (54 out of 84 students); and the self-reflection phase (subscale: self-evaluation) at 52.38% (44 out of 84 students). Based on these findings, students in the KAM group still require reinforcement and support in developing self-regulated learning, particularly in the sub-scales of self-monitoring, self-effort, and self-satisfaction.

Students in the high KAM group achieved high scores, with all sub-scales across the three phases of self-regulated learning reaching the highest level (Level 3). The highest response was observed in the planning phase (sub-scale: planning), where 95% (38 out of 40 students) reached Level 3. Students in the high KAM group still require support in developing their self-regulated learning, particularly in the self-reflection phase with the self-satisfaction subscale. This is because, on that subscale, the percentage of high KAM students did not exceed 55% of the total number of students in the high KAM group.

RQ3: Significant Differences in Students' Self-Regulated Learning Between the Pre-Intervention (Time 1) and Post-Intervention (Time 2) Conditions of the Ethno-Flipped Classroom Model

A further analysis was conducted to determine whether there was a significant increase in students' self-regulated learning after receiving instruction through the Ethno-Flipped Classroom model intervention. Previous analyses had shown that students' self-regulated learning had undergone positive changes, both at the individual student level and in terms of the difficulty level of the questionnaire items completed by the students. The results of the analysis regarding these positive changes require further inferential analysis to confirm that the positive changes observed in students have a subsequent impact, namely an increase in self-regulated learning. The research hypothesis to be tested for significance is:

H_0 : There is no difference in students' self-regulated learning between the initial condition (Time-1), before the ethno-flipped classroom model intervention, and the final condition (Time-2) after the ethno-flipped classroom model intervention.

H_1 : There is difference in students' self-regulated learning between the initial condition (Time-1), before the ethno-flipped classroom model intervention, and the final condition (Time-2) after the ethno-flipped classroom model intervention.

The analysis of the increase in self-regulated learning utilized the total scores for each phase and subscale of self-regulated learning obtained at both the initial (Time-1) and final (Time-2) conditions. This was done to justify that the analysis of changes across all phases and subscales could be used to assess the overall improvement in students' self-regulated learning. Before conducting the improvement analysis, the researcher needed to perform prerequisite tests, namely data normality and data homogeneity tests. The data used in the normality and homogeneity tests were the logit scores for self-regulated learning at the initial and final conditions.

The normality test for self-regulated learning data used the Lilliefors test, while the homogeneity test used the Levene test. The results of the normality and homogeneity tests for self-regulated learning data indicated that the initial questionnaire data and the final questionnaire data were homogeneous but not normally distributed. Based on these results, the analysis of the improvement in self-regulated learning was continued using a non-parametric statistical test, namely the Wilcoxon signed-rank test. The results of the Wilcoxon signed-rank test on the students' self-regulated learning data can be seen in Table 2 below.

Table 2. Results of the Wilcoxon Signed-Rank Test Analysis on Logit Data for Self-Regulated Learning

Ranks				
		N	**Mean Rank**	**Sum of Ranks**
Final_SRL_Logit - Initial_SRL_Logit	Negative Ranks	0[a]	0,00	0,00
	Positive Ranks	152[b]	76,50	11628,00
	Ties	0[c]		
	Total	152		
a. Final_SRL_Logit < Initial_SRL_Logit				
b. Final_SRL_Logit > Initial_SRL_Logit				
c. Final_SRL_Logit = Initial_SRL_Logit				

Test Statistics[a]	
	Final_ISR_Logit - Initial_ISR_Logit
Z	$-10{,}695$[b]
Asympt. Sig. (2-tailed)	0,000
a. Wilcoxon Signed Ranks Test	
b. Based on negative ranks.	

Based on the "Test Statistics" output, it is found that Asymp.Sig (2-tailed) is $0{,}000$, and this value is smaller than $0{,}05$ $(0{,}000 < 0{,}05)$. The results indicate that "H0 is accepted" (H_a is accepted,H_0 is rejected), meaning there is a difference between the initial and final questionnaire scores for self-regulated learning. These results also indicate that there was an increase in students' self-regulated learning following instruction using the ethno-flipped classroom model. This improvement in self-regulated learning was solely due to the positive accompanying effects provided by the ethno-flipped classroom model during the learning process.

DISCUSSION

The findings of this study indicate a significant increase in students' self-regulated learning through the implementation of the Ethno-Flipped Classroom model, evidenced by the rise in students at the "High" level from 17.76% (Time-1) to 76.35% (Time-2). This transformation confirms that the flipped classroom structure, which grants autonomy outside the classroom, effectively triggers students' self-regulation mechanisms (Martín et al., 2020), while fostering personal responsibility for academic progress (Setiyawan et al., 2024). The integration of technology and the ethnomathematics context further enhances self-efficacy and intrinsic motivation by contextualizing mathematical problems within students' social reality, making learning more meaningful and culturally affirming (Elhilal, 2025).

Despite these positive outcomes, the inconsistent response patterns observed in some items, such as the shift in PLAN3 (analyzing problems independently) from "Strongly Agree" to "Somewhat Disagree," reveal an important pedagogical transition. Rather than indicating a decline, this pattern reflects a shift from Self-Regulated Learning toward Co-Regulated Learning or Socially Shared Regulation of Learning, in which students increasingly rely on group regulation and social interaction during collaborative phases (Ahola et al., 2024; Quackenbush & Bol, 2020). This finding suggests that the model's collaborative components may inadvertently reshape students' perceptions of independent learning, an aspect that warrants further investigation in future research (Naidoo, 2021; Rosa & Orey, 2016a).

The relationship between initial mathematical ability (IMA) and SRL achievement further reveals that students with low and moderate IMA require more targeted scaffolding, particularly during the self-monitoring phase. While the high-IMA group reached Level 3 in nearly all phases, the other groups remained at Level 2, suggesting that initial cognitive ability significantly mediates the effectiveness of self-directed strategies (Villalobos et al., 2022). This supports the view that self-regulation is not a singular skill but a complex process requiring structured, tiered guidance for students with diverse academic backgrounds (Rincón et al., 2025; Setiyawan et al., 2024).

Methodologically, the use of Rasch-based logit scores provides objective validity for tracking SRL growth, as it yields ability estimates independent of item difficulty and ensures that observed changes reflect genuine intervention effects rather than measurement artifacts (Combrinck et al., 2017; Uzun & Öğretmen, 2021). Nevertheless, several limitations should be critically acknowledged. First, the absence of a control group restricts causal claims regarding the model's effectiveness, as observed gains may be partly attributable to maturation, repeated testing, or external instructional influences. Second, students' difficulties in adapting to the new model produced inconsistent response patterns, which may have introduced measurement noise during the early implementation phase. Third, the persistent gap in self-monitoring among low- and moderate-IMA students suggests that the current model's scaffolding mechanisms are not yet sufficiently differentiated to accommodate diverse cognitive starting points. Finally, the focus on the Nias cultural context, while central to the model's novelty, limits the generalizability of the findings to other cultural and educational settings. Future research should therefore employ quasi-experimental designs with control groups, extend the implementation across multiple cultural contexts, and develop adaptive scaffolding strategies for the self-monitoring phase to strengthen both the internal and external validity of the model.

CONCLUSION

This study concludes that the implementation of the ethno-flipped classroom model significantly enhances students' self-regulated learning, as evidenced by a surge in the percentage of students at the "High" level on the from 17.76% to 76.35%. The integration of Nias cultural artifacts into the flipped learning framework has proven capable of creating a more meaningful learning environment and shifting students' paradigm from individual to collaborative learning. Analysis results show positive logit growth across all students, confirming that this intervention is effective in strengthening self-directed learning responsibility and mathematical concept understanding through relevant local wisdom contexts. However, this study has limitations regarding students' challenges in adapting to the new model, which led to inconsistent response patterns, as well as gaps in the self-monitoring phase for students with low and moderate initial mathematical ability. Additionally, the focus on the specific cultural context of the Nias ethnic group limits the broad generalization of the findings. Therefore, further research is recommended to develop more personalized scaffolding tools to support groups of students with diverse abilities. It is also important to conduct cross-cultural comparative studies and in-depth explorations of the dynamics of socially shared regulation through a longitudinal approach to ensure the long-term sustainability of improvements in students' learning autonomy.

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AUTHOR CONTRIBUTION STATEMENT

RR conceptualized the study, designed the research framework, conduct data analysis, drafted the manuscript, critical revisions, and final editing of manuscript. SA contributed to data collection, validation, literature review, and interpretation of findings. HAN assisted in methodology development, data analysis, contributed to theoretical framework development. All authors read and approved the final version of the manuscript.

AI DISCLOSURE STATEMENT

The authors declare that this research was prepared, researched, written, and edited without the aid of artificial intelligence (AI) techniques.

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Appendix
The Self-Regulated Learning Questionnaire

Phase	Sub-Scale	Code	Statements
Forethought Phase	Planning	PLAN1	I determine learning goals or targets before I begin studying a topic or subject matter.
		PLAN3	I re-examine the problem and try again to solve it, if I encounter difficulty or confusion in problem-solving.
		PLAN4	I attempt to analyze the credibility of information sources and other references before using them in problem-solving.
		PLAN5	I make plans for solutions to given mathematical problems.
		PLAN7	I visualize which part of the mathematical problem I need to solve first.
		PLAN9	I plan a practice schedule, particularly for difficult mathematics tasks.
	Self-Efficacy	SE4	If I experience difficulty in understanding a given mathematical problem, I can usually think of something as an initial solution to overcome the difficulty I am experiencing.
		SE5	I remain calm when I encounter difficulty in understanding mathematical problems, because I know how to overcome the difficulty.
		SE7	It is easy for me to concentrate on achieving my goals in learning mathematics.
		SE8	I can solve most mathematical problems if I invest the necessary effort.
Performance Phase	Self-Monitoring	SM2	I check my work as soon as possible after I finish completing it.
		SM3	While doing a given task, I ask myself how well I am performing the task.
		SM6	I check my accuracy in completing given mathematics tasks.
	Self-Efforts	SF3	I strive to develop alternative strategies in problem-solving.
		SF4	I strive to identify sources of information in problem-solving.
		SF7	I strive to understand a topic or subject matter and to understand a problem more thoroughly.
		SF8	I do not give up even if the given mathematics task is a difficult one.
		SF10	I strive to complete tasks even if it must be done outside of learning hours.
Self-Reflection Phase	Self-Evaluation	SV5	I review the tasks I have completed until they are finished.
		SV6	I revisit mathematical problems I have already solved to verify whether my answers make sense or not.
		SV7	I reconsider the problem-solving steps I have taken on the tasks I have worked on.
	Self-Satisfaction	SS2	I am aware that I have weaknesses in mastering certain subject matter and in problem-solving.
		SS3	I will open myself to learning in keeping up with developments in science and technology.
		SS5	I try to think about how I can do things better in mathematics learning activities in the future.
		SS6	I reward myself after I have successfully solved a problem on a given task.