SCIENTIFIC CULTURE

www.sci-cult.com

SCIENTIFIC CULTURE, Vol. 12, No. 2.1, (2026), pp. 10683-10693
Open Access. Online & Print

DOI: 10.5281/zenodo.20068026

JOY AS PEDAGOGICAL ENERGY: SCRATCH-ASSISTED PROJECT-BASED LEARNING AND COGNITIVE STYLE IN FOSTERING JUNIOR HIGH SCHOOL STUDENTS' MATHEMATICAL SELF-EFFICACY

Audra Pramitha Muslim[1], Tatang Herman[2*], Al Jupri[3], Jarnawi Afgani Dahlan[4], Nurul Farida[5], Hendra Lesmana[6]

[1]Department of Mathematics Education, Universitas Pendidikan Indonesia, Bandung, Indonesia
audrapramitha@upi.edu
[2]Department of Mathematics Education, Universitas Pendidikan Indonesia, Bandung, Indonesia
tatangherman@upi.edu
[3]Department of Mathematics Education, Universitas Pendidikan Indonesia, Bandung, Indonesia
aljupri@upi.edu
[4]Department of Mathematics Education, Universitas Pendidikan Indonesia, Bandung, Indonesia
jarnawi@upi.edu
[5]Department of Mathematics Education, Universitas Pendidikan Indonesia, Bandung, Indonesia
nurulfaridamath@upi.edu
[6]Department of Mathematics Education, Universitas Pendidikan Indonesia, Bandung, Indonesia
Department of Mathematics Education, Universitas Sriwijaya, South Sumatera, Indonesia
Hl302@upi.edu , hl302@fkip.unsri.ac.id

Received: 06/04/2026
Accepted: 29/04/2026

Corresponding Author: Tatang Herman
(tatangherman@upi.edu)

ABSTRACT

This study addresses a critical gap in mathematics education research by examining the effects of Scratch-assisted Project-Based Learning (PjBL) on junior high school students' mathematical self-efficacy while explicitly integrating cognitive style (field independent [FI] and field dependent [FD]) as a moderating variable. Although prior studies have explored PjBL or Scratch separately, limited evidence exists regarding their combined influence on multidimensional self-efficacy development. Using a quasi-experimental non-equivalent control group design, 92 students were assigned to three groups: Scratch-assisted PjBL (n = 32), PjBL without Scratch (n = 29), and conventional instruction (n = 31). Mathematical self-efficacy was measured through a validated instrument assessing magnitude, generality, and strength of belief and analyzed using normalized gain and two-way ANOVA. The results indicate greater descriptive improvements in the Scratch-assisted PjBL group compared to the other approaches. At the dimensional level, FI students showed stronger gains in magnitude and strength, whereas FD students demonstrated relatively greater improvement in generality within project-based settings. These findings extend social cognitive theory into technology-supported project settings and provide empirical evidence that aligning digital PjBL with learners' cognitive style offers a more nuanced pathway for strengthening mathematical self-efficacy.

KEYWORDS: Mathematical Self-Efficacy, Project-Based Learning, Scratch, Cognitive Style, Field Independent, Field Dependent.

1. INTRODUCTION

Mathematics instruction at the junior high school level extends beyond mastering procedural skills and conceptual comprehension; it also encompasses the cultivation of students' affective orientations toward the subject. One of the most influential affective constructs in this domain is mathematical self-efficacy, which significantly determines how students engage with learning activities, sustain effort, and respond to complex or demanding mathematical problems. Self-efficacy is defined as individuals' judgments about their capacity to plan and carry out the actions necessary to achieve specific performance goals (Bandura, 1997). Within mathematics education, students who possess higher levels of self-efficacy tend to adopt more strategic approaches to problem solving, demonstrate greater resilience when encountering obstacles, and ultimately attain stronger academic achievement (Schunk & DiBenedetto, 2020).

However, empirical evidence from classroom practices indicates that many junior high school students perceive mathematics as an intimidating subject. Observations in schools reveal that students often hesitate to participate actively, show anxiety when facing non-routine problems, and rely heavily on teacher guidance. These conditions suggest that students' mathematical self-efficacy remains underdeveloped, particularly when learning environments emphasize correctness and speed rather than exploration, reflection, and meaningful engagement. Recent studies have confirmed that traditional, teacher-centered instruction tends to provide limited opportunities for mastery experiences, which are the most influential source of self-efficacy development (OECD, 2021).

To address this issue, contemporary mathematics education has increasingly emphasized student-centered instructional models, one of which is Project-Based Learning (PjBL). PjBL engages students in solving authentic problems through extended projects, encouraging collaboration, inquiry, and reflective thinking. Research has shown that PjBL can positively influence students' motivation, engagement, and affective outcomes by providing meaningful contexts and opportunities for success (Hernandez-Ramos & De La Paz, 2021). Through sustained engagement in projects, students are more likely to experience mastery and develop confidence in their mathematical abilities.

Nevertheless, the effectiveness of PjBL largely depends on the learning tools and environments that support students during the project process. In recent years, digital technologies, particularly visual programming environments, have been integrated into mathematics learning to enhance students' understanding and engagement. Scratch, a block-based programming platform, allows students to represent mathematical ideas visually, test solutions iteratively, and receive immediate feedback. These affordances align well with principles of constructivist learning and computational thinking, making scratch a promising tool for supporting project-based mathematics learning (Falloon, 2020).

Several studies have reported that Scratch-supported learning environments can foster positive emotional experiences, creativity, and problem-solving confidence among students (Resnick et al., 2022). However, most existing research has focused primarily on cognitive outcomes, such as conceptual understanding or computational thinking skills. Studies that explicitly examine mathematical self-efficacy as a multidimensional construct within Scratch-assisted PjBL contexts remain limited, particularly at the junior high school level.

Students do not react in the same way to particular teaching strategies because learning is shaped by individual characteristics, including cognitive style. One prominent dimension of cognitive style is the distinction between field independent (FI) and field dependent (FD) learners, which affects how information is interpreted, organized, and utilized during the learning process. Learners categorized as field independent generally demonstrate analytical thinking, autonomy, and a preference for working individually. In contrast, field-dependent learners are typically more responsive to social contexts, structured guidance, and instructional support from teachers or peers (Tinajero & Paramo, 2020). Failure to take these cognitive variations into account may conceal meaningful differences in the way instructional interventions impact students' affective outcomes, including their development of self-efficacy.

Recent literature indicates that technology-enhanced learning environments may reduce disparities between cognitive styles by offering flexible representations and multiple learning pathways (Altun & Erden, 2021). However, empirical evidence regarding the interaction between learning models, cognitive style, and mathematical self-efficacy remains inconclusive. Many studies examine self-efficacy globally without analyzing its underlying dimensions: task difficulty (magnitude), generality, and strength of belief, which may respond differently to instructional interventions.

Based on these considerations, a clear research gap emerges. Although PjBL, Scratch, and self-efficacy have each been widely studied, few studies integrate these three elements simultaneously while explicitly considering students' cognitive styles and the dimensional structure of mathematical self-efficacy. Furthermore, existing studies often rely solely on statistical outcomes, providing limited insight into how classroom processes and learning experiences contribute to students' affective development.

Accordingly, this study seeks to respond to the identified gaps by examining the effectiveness of Scratch-assisted project-based learning in enhancing junior high school students' mathematical self-efficacy through the perspective of cognitive style (field independent and field dependent). The distinctive contribution of this research lies in its integrative analytical design, which simultaneously (1) compares three instructional approaches, Scratch-assisted PjBL, PjBL without Scratch, and conventional styles; and (3) investigates mathematical self-efficacy at the dimensional level (task difficulty, generality, and strength of belief), supported by evidence from classroom implementation. Through this comprehensive framework, the study advances the theoretical discourse on self-efficacy within technology-enhanced mathematics learning and offers practical implications for designing inclusive pedagogical strategies that are responsive to diverse cognitive characteristics.

Based on this rationale, the study is guided by the following research questions:

RQ 1. Are there significant differences in the improvement of mathematical self-efficacy among students exposed to Scratch-assisted PjBL, PjBL without Scratch, and conventional learning?

RQ 2. Does an interaction exist between learning model and cognitive style (FI and FD) in influencing students' mathematical self-efficacy?

RQ 3. How do the dimensions of mathematical self-efficacy (task difficulty, generality, and strength) vary across learning models when analyzed according to students' cognitive styles?

2. LITERATURE REVIEW

2.1. *Mathematical Self-Efficacy*

The notion of self-efficacy is grounded in Bandura's social cognitive theory. Bandura (1997) conceptualizes self-efficacy as "people's belief in their capabilities to organize and execute the courses of action required to produce given attainments." This perspective underscores that self-efficacy is concerned not simply with actual competence, but with individuals' judgments about what they are capable of accomplishing in particular contexts. Within mathematics education, these judgments play a critical role in shaping how learners interpret task demands, cope with complexity, and regulate their persistence when encountering difficulties.

Bandura (1997) further proposes that self-efficacy comprises three interrelated dimensions, noting that "efficacy beliefs vary in level, generality, and strength." The level (or magnitude) dimension refers to the perceived difficulty of tasks that individuals believe they can successfully perform. Generality addresses the degree to which efficacy beliefs extend across different situations or domains. Strength reflects the firmness and durability of those beliefs when confronted with challenges or setbacks. In mathematics classrooms, these dimensions manifest in students' differing confidence when dealing with routine exercises, complex problem-solving tasks, or unfamiliar mathematical contexts.

Contemporary scholarship continues to affirm the close association between mathematical self-efficacy and learning outcomes. Schunk and DiBenedetto (2020) emphasize that "self-efficacy influences choice of activities, effort, persistence, and resilience," indicating that students with stronger efficacy beliefs are more inclined to engage in demanding tasks, sustain effort, and remain persistent during problem-solving. Conversely, lower self-efficacy often leads to task avoidance and reduces perseverance.

In addition, Usher and Pajares (2008) identify four principal sources of self-efficacy: mastery experiences, vicarious experiences, social persuasion, and physiological states. Among these, mastery experiences are regarded as the most powerful contributor. This highlights the importance of instructional approaches that provide meaningful, successful learning experiences, as such experiences are fundamental in reinforcing students' mathematical self-efficacy.

2.2. *Project-Based Learning*

Project-Based Learning (PjBL) is rooted in constructivist theory and positions authentic projects at the center of the learning process. Thomas (2000) defines PjBL as a "model that organizes learning around projects." In this approach, projects are not supplementary activities but serve as the primary vehicle for knowledge construction.

Krajcik and Blumenfeld (2006) describe key characteristics of PjBL, including "driving question, inquiry, collaboration, and the creation of tangible products." Students are engaged in investigating essential questions, conducting inquiry-based exploration, collaborating with peers, and producing meaningful artifacts. This process encourages active participation and deep conceptual understanding.

From an affective perspective, PjBL provides opportunities for students to experience incremental success through project completion. Hernandez-Ramos and De La Paz (2021) report that project-based learning enhances students' motivation and engagement because it increases the relevance and authenticity of learning experiences. When students complete meaningful mathematical projects, they gain mastery experiences that contribute to stronger self-efficacy beliefs.

However, the effectiveness of PjBL depends heavily on instructional scaffolding, project structure, and the learning tools employed. Without adequate support, projects may become cognitively overwhelming and potentially reduce students' confidence.

2.3. Scratch in Mathematics Learning

Scratch is a visual, block-based programming platform created by the MIT Media Lab with the primary aim of fostering creative and interactive learning experiences. Resnick et al. (2009) explain that Scratch was designed to enable learners to "imagine, program, and share their creations." This platform encourages exploration, experimentation, and creative problem-solving.

In mathematics education, Scratch functions as a visual representation tool that helps students concretize abstract concepts. Falloon (2020) highlights that Scratch "supports iterative experimentation and immediate feedback," allowing students to test ideas, observe outcomes instantly, and revise their solutions without fear of failure. Such an environment is conducive to building confidence, as errors are framed as part of the learning process rather than as indicators of incompetence.

Furthermore, Scratch supports the development of computational thinking abilities, such as breaking problems into manageable components (decomposition), identifying patterns, abstracting essential information, and constructing systematic algorithmic solutions. These skills align closely with mathematical problem-solving processes. When students successfully construct and debug programs, they experience tangible mastery, which strengthens their self-efficacy.

Despite these advantages, most research integrating Scratch into mathematics education focuses primarily on cognitive outcomes rather than affective constructs such as self-efficacy. Studies examining the integration of scratch-assisted PjBL and its impact on the multidimensional structure of mathematical self-efficacy remain limited.

2.3. Cognitive Style

Cognitive style refers to relatively stable individual differences in the way people perceive, process, and organize information. Witkin et al. (1977) categorize cognitive style into two major orientations: field independent (FI) and field dependent (FD). They explain that "field-independent individuals are more likely to impose structure on ambiguous information, whereas field-dependent individuals rely more on external frames of reference." This distinction highlights how learners differ in their reliance on internal versus external cues when interpreting and responding to learning tasks.

Field-independent students tend to be analytical, capable of isolating details from contextual backgrounds, and comfortable working independently. In contrast, field-dependent students are more socially oriented and often benefit from structured guidance and collaborative interaction. These differences influence how students respond to specific instructional models.

Tinajero and Paramo (2020) indicate that cognitive style is associated with learning strategies and academic achievement. In technology-enhanced environments, Altun and Erden (2021) find that flexible digital tools can reduce performance disparities between FI and FD learners by offering multiple pathways for engagement.

However, research exploring how cognitive style interacts with Scratch-assisted project-based learning in shaping mathematical self-efficacy remains scarce. Given that Scratch offers both independent exploration and collaborative project opportunities, it may accommodate diverse cognitive characteristics in unique ways.

3. METHODS

3.1. Research Design

This research adopted a quasi-experimental approach employing a non-equivalent control group design, a methodology frequently utilized in educational studies when random assignment of participants cannot be implemented (Creswell, 2018). The design involved three intact groups: (1). An experimental group receiving Scratch-assisted Project-Based Learning (PjBL) (2). A comparison group receiving PjBL without Scratch and (3). A control group receiving conventional mathematics instruction.

This design enabled the researchers to compare the gains in the students' mathematical self-efficacy among the different instructional approaches and to investigate whether an interaction emerged between the type of learning model and students' cognitive styles.

3.2. Population and Sample

The population of this study consisted of junior high school students enrolled in an urban public school. A purposive sampling technique was used to select the sample, considering the equivalence of academic level, curriculum implementation, and school facilities across classes. Three intact classes were selected and assigned as the experimental, comparison, and control groups.

Purposive sampling is considered appropriate in quasi-experimental studies where intact classrooms are used and random assignment is not possible, while still maintaining internal validity through careful group selection (Fraenkel, Wallen, & Hyun, 2019).

3.3. Research Instruments

Three instruments were employed in this study:

1. Mathematical Self-Efficacy Questionnaire

The questionnaire was developed based on Bandura's (1997) self-efficacy theory and consisted of three dimensions: magnitude (task difficulty), generality, and strength of belief. Items were constructed using a Likert scale and adapted to the context of junior high school mathematics learning. Instrument validation involved:

1. Content validity, assessed by experts in mathematics education and educational psychology
2. Construct validity, examined through factor analysis
3. Reliability testing, conducted using Cronbach's alpha, which indicated satisfactory internal consistency (□ > 0.70), consistent with recommendations by Taber (2018).

2. Cognitive Style Test

Students' cognitive styles were determined through a standardized field dependence-independence assessment adapted from the Group Embedded Figures Test (GEFT). Based on the obtained scores, participants were categorized as either Field Independent (FI) or Field Dependent (FD). According to cognitive style theory, FI learners generally demonstrate an analytical approach to information processing, while FD learners are more inclined to depend on contextual references and social cues when interpreting information (Witkin et al., 1977).

3. Observation Sheet.

An observation sheet was used to monitor the fidelity of PjBL implementation, including student engagement, collaboration, teacher scaffolding, and adherence to project-based learning phases. This instrument ensured that instructional treatments were implemented consistently across groups.

Research Implementation Procedure

The study was conducted over six weeks (12 instructional meetings) and followed several systematic stages:

1. **Preparation Stage.**

Lesson plans, learning materials, Scratch project modules, and research instruments were developed and validated prior to implementation.

2. **Pretest Stage.**

All groups completed a mathematical self-efficacy pretest to establish baseline equivalence.

3. **Cognitive Style Classification.**

Students completed the cognitive style and were categorized as FI or FD for subsequent analysis.

4. **Treatment Stage.**

- The experimental group learned through scratch-assisted PjBL, integrating hands-on activities with computational thinking and visual programming.
- The comparison group engaged in PjBL without Scratch, focusing on collaborative projects without digital programming support.
- The control group received conventional instruction characterized by teacher-centered explanations and individual exercises.

5. **Posttest Stage.**

After the intervention, all students completed the mathematical self-efficacy posttest.

Data Analysis Techniques

Data analysis was conducted using both descriptive and inferential statistics. Prerequisite tests (normality and homogeneity) were performed prior to hypothesis testing. Improvement in mathematical self-efficacy was measured using N-gain scores. A two-way ANOVA was employed to examine the following:

1. Differences in self-efficacy improvement across learning models,
2. Interaction effects between learning models and cognitive styles.
3. Post hoc analyses were conducted where appropriate to further explore group differences.

4. FINDINGS

4.1. Differences in the Improvement of Mathematical Self-Efficacy across Learning Models

The enhancement of students' mathematical self-efficacy was analyzed using normalized gain (N-gain) scores across three instructional conditions: Scratch-assisted Project-Based Learning (PjBL), PjBL without Scratch, and conventional instruction. Preliminary normality tests showed that the N-gain data were not fully normally distributed across the groups; consequently, the nonparametric Kruskal-Wallis test was employed for further analysis.

Importantly, the descriptive trends showing higher mean N-gain in the Scratch-assisted PjBL group suggest the presence of practical or educational significance, even in the absence of statistical significance. This distinction highlights the need to consider both statistical and practical perspectives when evaluating instructional effectiveness in educational research.

Table 1 summarizes the statistical results. The Kruskal-Wallis analysis indicated no statistically significant difference in the improvement of mathematical self-efficacy among the three instructional models (H = 0.601, p = 0.741). This finding suggests that, from a quantitative standpoint, students across all groups demonstrated relatively similar levels of improvement in mathematical self-efficacy.

Table 1: Kruskal-Wallis Test on N-Gain of Mathematical Self-Efficacy by Learning Model.

Test Statistics[a,b]	
	NGainSE
Kruskal-Wallis H	.601
df	2
Asymp. Sig.	.741
a. Kruskal Wallis Test	
b. Grouping Variable: Kelas	

Although the statistical analysis did not reveal significant differences among the three instructional models, this finding should be interpreted cautiously. The absence of statistical significance may be influenced by several methodological factors, particularly the relatively short duration of the intervention (six weeks) and the limited sample size across groups. Given that mathematical self-efficacy is a complex and gradually developing affective construct, short-term instructional exposure may not be sufficient to produce measurable statistical changes.

Furthermore, the relatively small number of participants in each group may have reduced the statistical power of the analysis, thereby limiting the ability to detect subtle differences among instructional approaches. Therefore, while the quantitative results indicate similarity across groups, they do not necessarily imply the absence of meaningful pedagogical effects.

4.2. Interaction between Learning Models and Cognitive Style

To examine whether the impact of the instructional models varied according to students' cognitive style, a two-way analysis of variance (ANOVA) was performed on the posttest self-efficacy scores, with learning model and cognitive style (field independent and field dependent) treated as independent factors.

As presented in Table 2, the findings revealed no statistically significant interaction effect between learning models and cognitive style on students' mathematical self-efficacy (F = 0.181, p = 0.835). Furthermore, neither the main effect of learning models nor the main effect of cognitive style demonstrated statistical significance. These results indicate that the posttest levels of mathematical self-efficacy were not significantly influenced by differences levels of mathematical self-efficacy were not significantly influenced by differences in instructional approach or cognitive style classification.

Table 2. Two-Way ANOVA Results on Mathematical Self-Efficacy.

Tests of Between-Subjects Effects					
Dependent Variable: SkorSE					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1329578.842[a]	5	265915.768	.678	.641
Intercept	1958920830.346	1	1958920830.346	4993.247	<.001
Kelas	627615.495	2	313807.748	.800	.453
GayaKognitif	522807.708	1	522807.708	1.333	.252
Kelas * GayaKognitif	142188.775	2	71094.387	.181	.835
Error	33739007.016	86	392314.035		
Total	2246860919.000	92			
Corrected Total	35068585.859	91			
a. R-squared = .038 (Adjusted R-squared = -.018)					

These findings indicate that, at the global level of mathematical self-efficacy, the three learning models functioned similarly for both field-independent and field-dependent students.

4.3. Self-Efficacy Dimensions Viewed from Cognitive Style

Further analysis was conducted on the dimensions of mathematical self-efficacy: task difficulty (magnitude), generality, and strength of belief to obtain a more detailed picture of students' affective development. Across learning models, field-independent student demonstrated higher self-efficacy in the task difficulty and strength dimensions, whereas field-dependent students showed relatively higher scores in the generality dimension, particularly in project-based learning environments.

4.4. Discussion

RQ 1. Differences in the Improvement of Mathematical Self-Efficacy across Learning Models

The findings indicating no statistically significant differences in the improvement of mathematical self-efficacy across instructional models should not be interpreted as evidence of ineffectiveness. Instead, this result reflects the complex and gradual nature of self-efficacy development. As suggested by social cognitive theory, self-efficacy evolves through repeated mastery experiences over time rather than through short-term instructional interventions.

In this study, the intervention lasted only six weeks, which may not have provided sufficient time for students to internalize and stabilize changes in their self-beliefs. Additionally, the relatively small sample size may have limited the statistical sensitivity required to detect differences among groups. These factors likely contributed to the absence of statistically significant findings.

Nevertheless, the descriptive improvements observed in the Scratch-assisted PjBL group indicate a meaningful pedagogical tendency. This suggests that while the effect was not strong enough to reach statistical significance, the instructional approach may still offer practical benefits in supporting students' self-efficacy development. Therefore, future studies with longer duration and larger samples are necessary to validate these preliminary trends.

RQ 2. Interaction Effects between Learning Models and Cognitive Styles

The absence of a significant interaction effect between learning models and cognitive styles suggests that three instructional approaches implemented in this study were relatively inclusive for both field-independent and field-dependent learners. This finding aligns with Tinajero and Paramo (2020), who argued that well-designed learning environments can reduce affective outcome disparities associated with cognitive style differences.

Therefore, the lack of interaction effects should not be interpreted as evidence that cognitive styles are irrelevant. Rather, it indicates that the instructional approaches provided adequate support for diverse learner characteristics, allowing students with different cognitive styles to benefit in comparable ways.

RQ 3. Differences in Self-Efficacy Dimensions Viewed from Cognitive Styles

Dimensional analysis provides a more nuanced understanding of students' mathematical self-efficacy development. Field independent students demonstrated advantages in the magnitude and strength dimensions, reflecting greater confidence in handling challenging tasks and stronger beliefs in their mathematical capabilities. During Scratch-assisted PjBL activities, FI students were observed working independently to design algorithms, test solutions, and correct errors. These activities represent mastery experiences, which constitute the most influential source of self-efficacy development (Bandura, 1997).

Figure 1. Authentic Learning Activities in Scratch-Assited Project-Based Learning: Measurement, Data Collection, and Digital Processing

The combined images illustrate students' active engagement in authentic project activities during Scratch-assisted project-based learning. Students are shown collaboratively conducting real-world measurement tasks, collecting and organizing data, and subsequently processing the data using the Scratch programming environment. These hands-on and digital activities reflect a learning process that integrates physical exploration with computational representation, enabling students to connect mathematical concepts with tangible experiences. Such involvement provides repeated mastery experiences, immediate feedback, and opportunities for collaboration, which collectively contribute to a joyful learning atmosphere and support the development of students' mathematical self-efficacy.

In contrast, field-depedent students exhibited a relatively higher level of self-efficacy in the generality dimension, particularly in project-based learning contexts. This pattern was evident in their engagement in collaborative measurement activities, group discussions, and project presentations.

Figure 2. Teacher Scaffolding and Collaborative Problem Solving in Scratch-Assisted Project-Based Learning

The images depict the teacher's active role in providing scaffolding and guidance during Scratch-assisted project-based learning, alongside students' collaborative problem-solving activities. The teacher is seen facilitating group discussions, clarifying task requirements, and supporting students as they translate project ideas into Scratch-based representations. Simultaneously, students engage in peer collaboration while working with digital tools, which promotes shared understanding and sustained engagement. This instructional interaction fosters a supportive learning environment where social persuasion, guided feedback, and collaborative learning contribute to strengthening students' mathematical self-efficacy and confidence in completing complex tasks.

These findings are consistent with Altun and Erden (2021), who reported that FD students benefit from social interaction, scaffolding, and verbal support in generalizing their confidence across learning situations. The teacher's role as a facilitator was also found to be critical in supporting FD students' self-efficacy development. Direct guidance and feedback during project implementation contributed to social persuasion and emotional support, as described by Schunk and DiBenedetto (2020).

Overall, the discrepancy between statistical and descriptive findings in this study underscores an important issue in educational research. Statistical non-significance does not necessarily equate to pedagogical irrelevance. In classroom contexts, even small improvements can have meaningful implications for students' learning experiences, particularly in affective domains such as self-efficacy. Therefore, both statistical evidence and descriptive patterns should be considered complementarily to provide a more comprehensive understanding of instructional impact.

5. CONCLUSION

This study investigated the effectiveness of Scratch-assisted Project-Based Learning (PjBL) in strengthening junior high school students' mathematical self-efficacy, taking into account students' cognitive styles (field independent and field dependent) as well as the multidimensional nature of self-efficacy (magnitude, generality, and strength). The statistical findings indicated that there were no significant differences in overall self-efficacy gains among the three instructional models. Additionally, no significant interaction effect was identified between learning model and cognitive style. These results suggest that, at the aggregate level, variations in instructional approach and cognitive orientation did not produce statistically distinct improvements in students' mathematical self-efficacy. These findings confirm that self-efficacy, as an affective construct, develops gradually and may not demonstrate statistically significant change within short-term instructional interventions.

Nevertheless, descriptive and dimensional analyses revealed pedagogically meaningful patterns. Scratch-assisted PjBL showed relatively higher improvement trends and supported differentiated self-efficacy development according to students' cognitive characteristics. Field-independent students demonstrated stronger gains in the magnitude and strength dimensions, whereas field-dependent students exhibited relatively stronger tendencies in the generality dimension within collaborative project contexts. The integration of authentic projects, visual programming through scratch, iterative feedback, and structured teacher scaffolding created a joyful and supportive learning environment that functioned as pedagogical energy in fostering students' mathematical confidence. Thus, although global statistical differences were not significant, Scratch-assisted PjBL demonstrates substantial potential in facilitating the development of mathematical self-efficacy in cognitively diverse classrooms.

These findings should be interpreted with caution, as the lack of statistical significance may be influenced by methodological constraints, particularly the short intervention duration and limited sample size. Therefore, the conclusions drawn from this study represent initial insights rather than definitive evidence.

5.1. Limitations

This study has several limitations that should be considered when interpreting the findings. First, the intervention was conducted over a relatively short period (six weeks), which may not have been sufficient to produce statistically significant changes in mathematical self-efficacy. As an affective construct rooted in students' belief systems, self-efficacy typically develops gradually through sustained mastery experiences and consistent instructional reinforcement. A longer intervention may reveal stronger and more measurable effects.

Second, the study employed a quasi-experimental design using intact classes from a single school, which may limit the generalizability of the results. Variations in institutional context, teacher expertise, technological access, and student characteristics could influence the implementation and effectiveness of Scratch-assisted project-based learning. Broader samples across multiple schools or regions would enhance external validity.

Third, the primary data source for measuring mathematical self-efficacy was a self-report questionnaire. Although theoretically grounded and validated, self-report instruments may be subject to response bias and may not fully capture the complexity of students' affective development. The inclusion of richer qualitative data could provide deeper insight into students' evolving confidence and learning experiences.

Additionally, the statistical power of the study may have been limited due to the relatively small group sizes, which could affect the detection of significant differences.

5.2. Suggestions for future research

Future research should therefore consider longitudinal design to examine the long-term development of mathematical self-efficacy in technology-enhanced project-based environments. Expanding the scope to include multiple schools and diverse educational settings would provide a more comprehensive understanding of contextual influences. Additionally, mixed-method approaches incorporating interview, reflective journals, or classroom discourse analysis are recommended to capture the nuanced processes underlying self-efficacy formation. Further, investigations may also explore additional moderating variables: such as prior achievement, computational thinking skills, gender, or digital literacy, to develop a more integrative model of affective development in mathematics learning.

Acknowledgments: This work was supported and funded by the Indonesian Education Scholarship, Centre for Higher Education Funding and Assessment, and Indonesian Endowment Fund for Education, whose assistance and funding we greatly appreciate. The author would like to express his gratitude for the use of AI tools, which were only used to refine the language and improve grammar during the writing process. No scientific content, research analysis, or academic interpretation was created by AI.

Author Bio: Audra Pramitha Muslim was born in Padang August 25, 1988. Lecturer in the Mathematics Education Study Program, Faculty of Science and Technology, UPGRISBA. She completed her undergraduate degree in mathematics education at Padang State University in 2010 and her master's degree in mathematics education at Indonesia University of Education, Bandung, in 2013. She is currently pursuing her doctoral degree in mathematics education at Indonesia University of Education, Bandung, class of 2022. The book "Discrete Mathematics for Education" is his work and that of his team, which has been published and holds copyright. Additionally, he serves as a speaker and presenter at national and international seminars in the field of education.

Tatang Herman was born in Garut on October 11, 1962. He is a lecturer in the Department of Mathematics Education at FPMIPA UPI. He completed his bachelor's degree in Mathematics Education at IKIP Bandung in 1989, his master's degree in Mathematics Education at Deakin University Melbourne, Australia, in 1996, and his doctorate in Mathematics Education at the Indonesia University of Education in 2006.

Al Jupri was born in Serang on May 10, 1982. He is a lecturer in the Department of Mathematics Education at FPMIPA UPI. He studied mathematics education at the Indonesia University of Education in 2004, mathematics education at Utrecht University, the Netherlands, in 2008; and mathematics and algebra education at Utrecht University, the Netherlands, in 2015.

Jarnawi Afgani Dahlan earned his Bachelor’s degree in Mathematics Education from IKIP Bandung in 1987 and his Master’s degree in Mathematics Education from IKIP Malang in 1994. He obtained his Ph.D in Mathematics Education from Universitas Pendidikan Indonesia. He is currently a Doctoral Lecturer in the Department of Mathematics Education.

Nurul Farida is a doctoral student in the Mathematics Education Study Program at the Universitas Pendidikan Indonesia, Bandung, class of 2024. She completed her undergraduate education (S1) at the Mathematics Education Study Program of the University of Lampung in 2010, and continued his master's education (S2) at the Mathematics Education Study Program at Sebelas Maret University, Surakarta, and graduated in 2013. Her fields of study include mathematics education, problem solving, and didactic design. She is active in research activities and has participated in various national and international seminars in the field of education. In addition, he is also involved as a reviewer and/or editor in several SINTA-indexed scientific journals in the field of mathematics education.

Hendra Lesmana completed his bachelor's and master's degrees in mathematics education at Sriwijaya University in 2011 and 2013, respectively. Currently, he is a doctoral student in mathematics education at the Faculty of Mathematics and Natural Sciences, Universitas Pendidikan Indonesia. He is interested in conducting research in the fields of LMS-assisted digital learning environments, PIAAC, problem-solving, mathematical reasoning, and several other 21st-century skills.

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