Critical thinking disposition and learning approach as predictors of mathematics performance

Kyla Mae Agustin Salviejo[1], Edwin Daniega Ibañez[2], Jupeth Toriano Pentang[1]
[1]Department of Science Education, College of Education, Central Luzon State University, Science City of Muñoz, Philippines
[2]Department of Mathematics and Physics, College of Science, Central Luzon State University, Science City of Muñoz, Philippines

Article Info

Article history:

Received Oct 21, 2023
Revised Mar 1, 2024
Accepted Mar 20, 2024

Keywords:

Intrinsic motivation
Mathematics education
Prospective teachers
Reflective thinking
Thinking skills

ABSTRACT

In the Philippines, improving pre-service math teachers' critical thinking is receiving increasing attention, emphasizing the importance of tailoring instructional methods to students' learning approaches for a more equitable environment and enhanced mathematics performance. Thus, this study aimed to determine if the critical thinking disposition (CTD) subscales (reflective, attentiveness, open-mindedness, organization, perseverance, and intrinsic motivation) and learning approach (deep approach and surface approach) predict the mathematics performance of pre-service math teachers. This study employed a descriptive-correlational research design to randomly selected 125 pre-service math teachers from Central Luzon, Philippines. The survey instruments are administered through the student-educator negotiated CTDs scale, the revised two-factor study process questionnaire, and the 40-item validated test. Using descriptive analysis, findings revealed that pre-service mathematics teachers have moderate levels of CTD, most of which use a deep approach and have average mathematics performance. Regression analysis showed that CTD and the deep approach were predictors. Therefore, pre-service mathematics teachers with a higher CTD and a deep approach are likelier to perform better in mathematics. These findings provide valuable insights into enhancing mathematics teacher education.

This is an open access article under the CC BY-SA license.

Corresponding Author:

Jupeth Toriano Pentang
Department of Science Education, College of Education, Central Luzon State University
Science City of Muñoz, Nueva Ecija, Philippines
Email: jupeth.pentang@clsu2.edu.ph

1. INTRODUCTION

Mathematics education holds importance in fostering intellectual growth and professional success among pre-service mathematics teachers. Pre-service mathematics teachers' crucial responsibility in achieving these goals is vital, especially considering their role in enhancing mathematical competence in mathematics education. The importance of tackling mathematics performance among pre-service teachers is being emphasized, echoing concerns regarding the mathematical knowledge of in-service teachers [1]. Pre-service teachers' poor mathematics performance is connected to their willingness and habit of learning mathematics concepts [2]. The lack of necessary academic credentials for pre-service mathematics teachers will cause a lack of knowledge to impart, limiting the students' performance in mathematics [3]. With this, investigating factors to improve attitude and habits in learning mathematics, such as critical thinking disposition (CTD) [4], [5] and learning approach [6] among pre-service teachers, are essential to remove contributors like poor habits in learning mathematics resulting in low subject performance.

Critical thinking is a fundamental goal of the modern education system [7]. It molds individuals to make intelligent decisions in solving complex problems in mathematics [8]. American Philosophical Association's Delphi Report by Facione [9] states that one of the components of critical thinking is the CTD. CTD is a behavioral inclination considered a consistent internal motivation to make decisions using critical thinking [10]. It is an essential tool for using critical thinking effectively. Moreover, a person with a high CTD possesses the willingness and effort to persevere at challenging tasks, necessitating openness to new ideas, which most students struggle with because of fear of failing when trying new things. In other words, pre-service teachers with high CTD tend to use higher-order thinking [11]. Also, CTD helps to motivate others to think [12] and improves self-efficacy [13] in individuals. Thus, utilizing CTD in learning mathematics encourages future math educators to approach the subject with a deeper understanding, adaptability, and a commitment to continuous improvement to enhance the students' overall mathematics performance and learning experience.

On the other hand, the learning approach used by pre-service teachers in learning mathematics is essential for achieving success because it provides perspectives on the characteristics of good learners [14]. An individual can take one of two learning approaches [15], deep or surface. Deep learners tend to understand the lessons and connect new ideas to existing ones, and surface learners tend to memorize and only focus on what is required to pass the subject [16]. The learning approach reflects their dedication to acquiring valuable knowledge and skills [17] necessary to prepare pre-service teachers to become competitive and competent human resources that enrich the breadth of expertise in higher education learning. Also, the learning approach can directly impact the teaching methods of pre-service teachers [18], proving that tailoring instruction to match the preferred learning approach of the student will open opportunities for pre-service teachers to become influential facilitators of mathematical learning by allowing the students to nurture critical thinking, and cater to diverse learning needs.

Exploring CTD and learning approaches among pre-service teachers is necessary to become future math educators. By nurturing the CTD and aligning teaching methods with the learning approach, pre-service teachers can create an equitable and engaging environment that will enhance the students' mathematics performance and overall learning experience. This would enable pre-service teachers to offer prospective students the opportunity to grasp mathematical concepts and substantiate their learning [19]. This study was grounded in self-regulatory theory, which underscores the dynamic involvement of learners in adopting cognitive processes, emotions, and conduct [20]. Studies showed that students who exhibit robust self-regulation in learning, including reflection, motivation, self-evaluation, and procedural understanding, tend to perform better in mathematics [21], [22]. These qualities are linked to CTD and the learning approach since these two interconnected variables play a significant role in the engagement and process of information during learning.

Several studies have investigated CTD and learning approaches with different variables and respondents. For instance, a positive association of CTD with numeracy problems and problem-based learning was shown in previous studies [23], [24]. A high level of CTD is also believed to positively affect learning proficiency among Chinese high school students [25]. Study among South African students in mathematics performance shows a correlation between their learning approach [26]. Likewise, self-assessment and learning methods positively affect students' academic achievements [27], [28]. However, CTD and learning approaches have not yet been fully explored in mathematics education. It is noticeable that CTD research is less than studies about critical thinking skills. This implies that there is insufficient research to guide teachers in encouraging CTD. Also, it will be interesting to find out whether the learning approach used by the pre-service mathematics teachers has a connection with their mathematics performance level. In this regard, exploring CTD and learning approaches is still necessary, but this time, it is correlated with the pre-service math teacher's mathematics performance. The findings of this study will serve as a foundation and point of reference for future research endeavors in the field of education, notably the three variables examined in the study.

2. METHOD

A quantitative research design employing descriptive-correlational was utilized to attain the study objectives. The descriptive method was used to provide comprehensive insights into the respondent's CTD, learning approach, and overall level of mathematics performance. The correlational design was employed to delve deeper into the relationships between specific variables, focusing on understanding how CTD and learning approaches are related to the mathematics performance of pre-service mathematics teachers. One hundred twenty-five individuals whose characteristics align with the research's specific purpose were chosen. The respondents for this research were first-year to fourth-year students enrolled in the Bachelor of Secondary Education majoring in mathematics at Central Luzon, Philippines, school year 2022-2023.

In gathering data, a three-part questionnaire instrument was used. The student-educator negotiated critical thinking dispositions scale (SENCTDS) developed by Quinn *et al.* [29] was used to evaluate the CTDs of respondents. This survey questionnaire consisted of six scales (reflection, attentiveness, open-mindedness, organization, perseverance, and intrinsic goal motivation) allocated with 21 questions. One hundred one items spanning 13 dispositions were analyzed using exploratory and confirmatory factor analysis across two independent samples. Results confirmed a six-factor SENCTDS measure, with good reliability for the total scale ($\alpha = 0.773$) and sub-scales ($\alpha = 0.594 - 0.823$). The revised two-factor study process questionnaire (R-SPQ-2F) adopted by Zakariya *et al.* [30] in Biggs *et al.* study [15] was used to identify the learning approach of pre-service mathematics teachers. This survey consists of two subscales (deep approach and surface approach) allocated with 19 questions. Analysts' results confirmed good reliability for ($\alpha = 0.81$, and $\alpha = 0.72$) in each approach.

The last part of the questionnaire comprises items from four branches of mathematics (arithmetic, algebra, trigonometry, and geometry) commonly encountered by junior and senior high school students. This ensured that all respondents possessed a background in the subject matter. To determine the reliability and validity of the questionnaire, the items were evaluated for appropriateness among the pre-service mathematics teachers. The instruments underwent mathematics experts review, and researchers made necessary revisions and edits based on comments and suggestions; then, after the validation process, the final mathematics test consisted of 40 items. The instrument underwent a pilot test involving 53 non-participants. Cronbach's alpha coefficient was calculated, with a 0.791 value indicating acceptable consistency and reliability to determine its reliability. The final sample for the main study comprised 125 participants, and Cronbach's alpha coefficient was estimated to be 0.817, demonstrating the instrument's acceptable consistency and reliability.

In data gathering, a letter of request was sent to the relevant authorities, seeking approval for conducting the research. The study also passes through the approval of the research protocol by the Ethics Review Committee at Central Luzon State University, located at Science City of Muñoz, Nueva Ecija, Philippines [ERC Code: 2023-498]. When it comes to utilizing the adopted questionnaires, responsible action was taken by emailing the original authors of the instruments and requesting permission to use them before integrating them into the study. The respondents are then asked to answer the SENCTDS, R-SPQ-2F, and mathematics tests. Adequate time, ranging from 10 to 20 minutes, was allotted for the first two parts and an additional 1 hour for the last part. Regarding data analysis, descriptive statistics were utilized to determine the level and frequency of the variables. At the same time, multiple and simple regression was used to identify the relationship between CTD and learning approach in the mathematics performance of pre-service mathematics teachers.

3. RESULTS AND DISCUSSION

3.1. Respondents' critical thinking disposition

The CTD is a fundamental aspect of critical thinking that influences academic achievement, especially in mathematics education ($\bar{x}$ = 4.85, SD = 1.28). Using the descriptive analysis, Table 1 shows limited CTD among the pre-service mathematics teachers. The reflective parameter displayed ($\bar{x}$ = 5.01, SD = 1.05) indicates that respondents exhibited little inclination to engage in reflective thinking. At the same time, the attentiveness parameter yielded ($\bar{x}$ = 4.98, SD = 1.14), implying that respondents demonstrated a relatively limited level of attentiveness during their mathematics learning journey. Moving on to the open-mindedness parameter, the data reveal that respondents showcased a fair degree of openness to different points of view in learning math ($\bar{x}$ = 4.50, SD = 1.48). Additionally, the organization parameter obtained ($\bar{x}$ = 4.84, SD = 1.69) suggests respondents' moderate inclination towards being orderly, systematic, and diligent when working on their mathematics tasks. Moreover, in the perseverance parameter, respondents achieved ($\bar{x}$ = 4.97, SD = 1.61), indicating that respondents tended to be resilient when confronted with complex tasks in mathematics without easily giving up. Respondents obtained ($\bar{x}$ = 4.85, SD = 0.71) regarding the intrinsic goal motivation parameter signifies a moderately positive and enthusiastic attitude among pre-service mathematics teachers toward their mathematics tasks and acquiring new knowledge.

The overall CTD aligned with the verbal description "somewhat agree" level, the same as all verbal descriptions of parameters. This suggests a collective inclination towards limited engagement in critical thinking during mathematics study. In connection with these results, earlier investigations reported students demonstrating a fair level of CTD [31]. However, the CTD of pre-service teachers in other majors is slightly higher than the average [32], [33]. This finding is notably a high level of CTD compared to the limited application observed in pre-service mathematics teachers in the study. This may be due to the lack of a teaching guide on enhancing CTD when teaching mathematics among pre-service mathematics teachers. Additionally, since CTD is the habit of thinking critically [9], the mathematics task or objectives given in the pre-service mathematics teachers in mathematics courses is also a reason why the level of CTD shown in the study was quite limited. It is essential to consider introducing new teaching materials in mathematics education that can improve the attitudes to think critically for potential enhancement of mathematics performance among math educators. This is because the complex nature of mathematics courses demands high CTD to understand effectively.

Table 1. Respondents' overall CTD

Parameter	$\bar{x}$	SD	Description
Reflection	5.01	1.05	Somewhat agree
Attentiveness	4.98	1.14	Somewhat agree
Open-mindedness	4.50	1.48	Somewhat agree
Organization	4.84	1.69	Somewhat agree
Perseverance	4.97	1.61	Somewhat agree
Intrinsic goal motivation	4.82	0.71	Somewhat agree
Weighted mean	4.85	1.28	Somewhat agree

Note: strongly disagree (1.00 to 1.82), disagree (1.83 to 2.69), somewhat disagree (2.70 to 3.56), neither disagree nor agree (3.57 to 4.43), somewhat agree (4.44 to 5.30), agree (5.31 to 6.17), strongly agree (6.18 to 7.00)

3.2. Respondents learning approach

The respondents were effectively categorized into their employed learning approaches during their mathematics learning endeavors as shown in Table 2. The result shows that most pre-service mathematics teachers, accounting for 60% of the total sample, utilized a deep learning approach. This indicates that they engaged in a learning style that prioritized higher-order cognitive skills by exercising critical thinking abilities and interacting dynamically with the material being studied. On the other hand, a significant portion, encompassing 40% of respondents, employed a surface approach to learning. This finding implies that the respondents opted for a more passive learning style, focusing primarily on acquiring the necessary information without delving deeper into the subject matter.

A deep or surface approach among pre-service mathematics teachers serves as their characteristics as learners. Learners who taught with an integrated curriculum exhibited a deep approach more frequently than the surface approach [34], indicating the influence of curriculum design on learning approaches. While the surface approach is often utilized depending on the objective of the course study [35], if the purposes of the mathematics course focus on lower thinking skills, then learners tend to use the surface approach to achieve it sufficiently. Thus, most pre-service mathematics teachers who use deep approaches in the study are greatly affected by the educators' learning objectives, teaching methods, and assessment tasks in mathematics education. Although the majority of respondents in the study employed a deep approach, which is encouraging, a notable portion of pre-service teachers utilized a surface approach, which is concerning since mathematics concepts typically demand a deep approach for adequate understanding. This means that it is imperative to enhance the mathematics course objectives of pre-service mathematics teachers during their training [36] to ensure that pre-service mathematics teachers can effectively instill higher-order thinking in their future students when they are in service.

Table 2. Respondents' learning approach

Parameter	Frequency	Percentage
Deep approach	75	60.00
Surface approach	50	40.00
Total	125	100.00

3.3. Respondents' mathematics performance

Table 3 presents an in-depth analysis of the mathematics performance of the respondents. It was revealed that mathematics performance scores have ($\bar{x}$ = 23.75, SD = 4.80). These statistical figures serve as a foundation for evaluating the participants' level of performance in mathematics. To gain deeper insights into the distribution, scores were categorized into three groups: below average, average, and above average. A total of 21 (16.8%) fell below the average performance; these respondents demonstrated relatively weaker performance in mathematics. Most respondents, totaling 82 (65.6%), showed average mathematics performance; these respondents showcased mathematics abilities consistent with the average performance demonstrated by other samples. While a smaller subgroup of 22 (17.6%) exhibited above-average mathematics performance, these respondents demonstrated higher proficiency and competence in the mathematics tasks. This aligns with Dedeoğlu [37], which revealed the inadequate requirements of essential knowledge among pre-service teachers in Turkey, such as using notations, mathematical models, and generalization methods. The misalignment of teaching instructions with learning objectives also resulted in limited mathematics performance of pre-service teachers [38], and a lack of clarity and coherence in teaching necessary skills and knowledge hindered mastering mathematics concepts.

The level of mathematical performance among pre-service teachers is a critical aspect of their preparation for teaching mathematics. Thus, instances of inadequate or average levels of mathematics performance could lead to misconceptions about their readiness as future educators [3]. Most pre-service mathematics teachers examined in the study exhibit deficiencies in skills such as translating word problems into algebraic expressions and understanding geometric concepts. This deficiency may stem from the predominant teaching approach in mathematics education, which emphasizes providing formulas and problem-solving techniques rather than presenting real-life scenarios for application [39]. For this reason, higher education needs to enhance the pedagogical knowledge of pre-service teachers in teaching mathematics to improve their mathematics proficiency [40]. It is also vital for pre-service teachers to help them grow their sense of responsibility and attitude in their studies to manage their time in learning mathematics [41]. These discoveries of mathematical abilities among pre-service mathematics teachers are concerning, given that they are expected to impart strong mathematical performance to their students in the future. With this, it is necessary for interventions to bolster mathematical performance and ensure equal learning opportunities among pre-service mathematics teachers.

Table 3. Respondents' mathematics performance

Parameter	Scores	Frequency	Percentage
Above average	29 - 40	22	17.60
Average	20 - 28	82	65.60
Below average	0 - 19	21	16.80
Total		125	100.00

Note: $\bar{x}$ = 23.75, SD = 4.80

3.4. Respondents' critical thinking disposition (CTD) as a predictor of mathematics performance

The findings of simple regression analysis provide valuable insights into the relationship between CTD and the mathematics performance of pre-service mathematics teachers as shown in Table 4. The result shows that the CTD of the pre-service teachers is a positive predictor of math performance (β = 1.194, $p < 0.05$), implying that a one-unit increase in the level of CTD corresponds to an estimated 1,194 unit increase in mathematics performance. This only means that pre-service teachers with a high level of CTD tend to have high mathematics performance. This finding is inclined to Liu *et al.* [25], where CTD predicts academic achievement for influencing learning efficiency and better performance in speaking and learning, which could extend to other scholarly domains such as mathematics [24]. The CTD of pre-service mathematics teachers plays a crucial role in designing assessment instruments and enhancing problem-solving abilities for their students [42], which emphasizes the importance of CTD in intellectual skills.

Critical thinking is a prerequisite in learning mathematics [43], and many teaching instructions in mathematics education were created to enhance critical thinking skills and improve math learning. However, instructional materials in the enhancement of CTD are still insufficient when, in fact, for an individual to be a critical thinker, they should possess not only high critical thinking skills but also a high CTD [44], [45]. Since the study indicates a strong correlation between CTD and mathematical performance, improving crucial thinking among pre-service mathematics teachers should be considered. It is better to create a high level of questions in every mathematics task and require quality responses from every pre-service math teacher in their training to improve their habits in studying mathematics. This is because pre-service mathematics teachers can only impart positive attitudes and learning habits in mathematics to their future students if they can possess them themselves.

Table 4. Simple regression analysis of CTD in predicting mathematics performance

Model	β	E	SC	t-value	p-value
Constant	11.194	2.849	-	3.929	0.000
CTD	2.594	0.583	0.373	4.452	0.001

Note: R = 0.373, R^2 = 0.193; $F_{(1,123)}$ = 19.822, $p < 0.001$;
Unstandardized coefficients (β); Standard error (E);
Standard Coefficient (SC)

A multiple regression analysis was conducted to offer valuable insights into the relationship of mathematics performance based on CTD parameters as shown in Table 5. Among the predictors examined, two factors, reflective and intrinsic goal motivation, emerged as significant contributors. Reflective was found to have a considerable positive correlation with mathematics performance (β = 1.149, $p < 0.05$), implying that a one-unit increase in the reflective level corresponds to an estimated 1,149-unit increase in mathematics performance, which suggests that pre-service mathematics educators who engage in reflecting upon their learning experiences are more likely to excel in mathematics courses. Reflective thinking forms part of the higher-order thinking skills that have to be mastered by students of mathematics education [46] and is a well-known factor in impacting achievement in mathematics. The results can be related to Aldahmash *et al.* [47], which underscores the usefulness of reflective thinking for pre-service mathematics teachers in exploring themselves and enhancing their professional development. Pre-service mathematics teachers with the more vital ability for reflective thinking tended to dedicate more time to mathematics activities like recognizing, grasping, and putting together knowledge and rethinking solving problems [48]. It can also enhance the cognitive skills needed in learning mathematics [49]. This active involvement has the potential to positively impact their performance in mathematics and nurture their thinking abilities, which in turn can lead to academic success.

Table 5. Multiple regression analysis summary of CTD subscales in predicting mathematics

Model	β	E	SC	t-value	p-value
Constant	4.220	3.274	-	1.289	0.200
Reflective	1.149	0.374	0.252	3.076	0.003
Attentiveness	0.081	0.348	0.019	0.233	0.816
Open-mindedness	0.431	0.285	0.132	1.514	0.133
Organization	0.824	0.515	0.291	1.599	0.112
Perseverance	0-.729	0.543	-0.244	-1.342	0.182
Intrinsic Goal Motivation	2.293	0.551	0.339	4.164	0.000

Note: R = 0.541, R^2 = 0.293; $F_{(6,118)}$ = 8.152, $p < 0.001$; Unstandardized coefficients (β); Standard error (E); Standard Coefficient (SC)

Likewise, intrinsic goal motivation also demonstrated a significant positive relationship with mathematics performance (β = 2.293, $p < 0.001$), which indicates that the increase of one-unit level in intrinsic goal motivation is associated with an estimated increase of 2.293 units in mathematics performance. Thus, individuals with a high internal motivation to learn mathematics tend to perform better in related courses. Teachers can significantly impact their students' intrinsic goal motivation. Thus, it is imperative to dispel the beliefs that can affect their teaching methods and student motivation, such as the notion that mathematical understanding requires innate ability [50]. Pre-service mathematics teachers with high intrinsic goal motivation can establish high academic targets by overcoming challenges during their mathematics studies [51]. With high intrinsic motivation learners can still drive to attain high academic standards in math regardless of disadvantaged backgrounds [52]. This motivation can be further developed through interventions focusing on an incremental mindset [53], resulting in positive performance in mathematics.

These findings highlight the multifaceted interplay of reflective and intrinsic goal motivation as a parameter of CTD in influencing mathematics performance. Enhancing these two specific predictors through instructional materials can significantly influence CTD, affecting mathematics performance. Previous studies have proposed interventions to enhance CTD. For instance, developing the 'critical thinking cycle model' [54] can be a foundation for creating mathematical tasks to improve math performance. Additionally, a game called 'uManage' is used for analyzing learners' CTD [55] and different types of teaching, like blended learning, for its efficacy in enhancing CTD [56]. These proposed interventions align with 21^{st}-century learning principles, emphasizing technology's significant role in improving critical thinking, particularly CTD. Thus, since reflective and intrinsic goal motivation parameters of CTD serve as predictors of math performance in the present study, then including activities like journaling, games with representation of real-life problems and involving more rewards than punishments in a classroom setting could serve as a foundation for enhancement of CTD in mathematics education teaching instructions. This propose activities would be preferably better if incorporated with technology.

On the other hand, it is also important to highlight that the four parameters, attentiveness, open-mindedness, organization, and perseverance, did not correlate with mathematics performance. This could be due to the lack of tasks or initiatives to improve these aspects in current mathematics education materials. Nevertheless, it is crucial to recognize that while these variables may not emerge as significant predictors in this study, they could still carry significance in different contexts or with a larger sample size. The regression equation derived from the analysis: y = 11.194 - 2.594x, where y = mathematics performance; x = level of CTD; and 11.194 is the constant term. This equation allows us to estimate an individual's mathematics performance based on their CTD level. While regression equation derived from CTD parameters: y = 4.220 + 1.149x_1+ 2.293x_2, where y = Mathematics performance; x_1 = Reflective level; x_2 = intrinsic goal motivation level; and 4.220 is the constant term. This equation allows us to estimate an individual's mathematics performance based on their reflective tendencies and intrinsic goal motivation levels.

3.5. Respondents' learning approach as a predictor of mathematics performance

The findings of the simple regression analysis provide valuable insights into the predictor of mathematics performance based on the learning approach as shown in Table 6. The deep approach significantly correlated with mathematics performance (β = -2.020, p < 0.05). This suggests that pre-service teachers who employ a deep approach will likely achieve better math performance than those who adopt a surface approach. Specifically, a one-unit increase in the profound approach predictor is associated with an estimated increase of 2,020 units in the outcome variable. This finding indicates the importance of adopting a deep learning approach in enhancing mathematics performance.

A deep approach is associated with improved performance in mathematics tasks [26], [28]. This approach requires students to think multi-dimensionally, make logical conclusions, and be prepared for adverse consequences, essential skills for mathematics success [57]. Leenknecht *et al.* [58] asserted that pre-service teachers who use a deep approach seek feedback to enhance their learning and develop their higher-order thinking abilities [59] frequently. This will be helpful since it can influence the learning outcomes of their future students [60] by providing clear guidelines and adequate time for engagement in mathematical discussions and activities. Additionally, the instructional techniques utilized, such as lectures and the nature of test queries provided by teachers, tend to encourage students to adopt a surface approach [61]. This underscores the crucial responsibility of teachers in promoting the utilization of a deep approach among learners. Thus, in-service and pre-service teachers are tasked with creating a supportive environment conducive to utilizing a deep approach. Therefore, it is essential to impart to pre-service mathematics teachers the utilization of the deep approach in their instructional practices.

Diverse strategies and considerations can support the implementation of a deep approach to teaching mathematics. For instance, integrating interactive and engaging activities into mathematics teaching can support a deep approach [62]. Additionally, the role of language in teaching mathematics has been emphasized to play a crucial role in helping learners reflect, communicate, and deepen their understanding of mathematics problems [63]. Moreover, applications utilizing augmented reality technology in mathematics education have been suggested to enhance deep approach learning [64], indicating the potential for innovative and technology-enhanced approaches in teaching mathematics in pre-service mathematics teachers. Thus, integrating different instructional teaching to promote a deep approach to thinking, such as active engagement activities, adaption of real-life word problems, and maximizing the use of technology, can facilitate the adoption and enhancement of the deep learning approach in mathematics education. Furthermore, the regression equation derived from the analysis is as follows: y = 26.580 - 2.020x, where y = mathematics performance; x = the learning approach (code 1-deep approach and code 2-surface approach); and 26.580 is the constant term. This equation allows us to estimate the pre-service mathematics performance based on their learning approach, indicating that a deep approach is associated with better mathematics performance.

Table 6. Simple regression analysis summary of learning approach in predicting mathematics performance

Model	β	E	SC	*t*-value	*p*-value
Constant	26.580	1.277		20.808	0.000
Learning approach	-2.020	0.861	-0.207	-2.345	0.021

Note: R = 0.207, R^2 = 0.043; $F_{(1,123)}$ = 5.501, p < 0.05; Unstandardized coefficients (β); Standard error (E); Standard Coefficient (SC). Code: 1-Deep Approach, 2-Surface Approach

4. CONCLUSION

The perception of mathematics as abstract and challenging to grasp is common among students, posing difficulty for educators to dispel such notions. The improvement of mathematics performance requires to focus on educators themselves, particularly pre-service mathematics teachers, who play a significant impact in students' attitudes toward mathematics. The utilization of positive learning habits and appropriate learning approaches by pre-service mathematics teachers significantly influences their mathematics performance. Therefore, integrating the enhancement of CTD, especially reflective thinking, and intrinsic goal motivation, in their training programs is imperative. Moreover, encouraging a deep learning approach to learning mathematics is highlighted, as it promotes higher-order thinking essential for tackling mathematical tasks and concepts. Thus, promoting the implication of interactive activities and embracing innovative technology-based methods like augmented reality applications is recommended. This holistic approach ensures that pre-service mathematics teachers and future mathematics educators are equipped to enhance mathematics education effectively.

Furthermore, for future researchers interested in investigating the same topic, it is suggested to consider including critical thinking skills as an additional factor. Additionally, enhancing the statistical significance by enlarging the sample size and encompassing pre-service teachers from different majors is highly recommended. This would help to explore in more detail how the learning approach and CTD are connected to the mathematics performance of future educators. With these, results are not applicable to all students training to be teachers. The study was specifically focused on students who want to teach mathematics in the future. Even though the findings are helpful, they might not be accurate for all pre-service teachers. It is important to remember this specific focus when using the information from the study.

ACKNOWLEDGEMENTS

Gratitude is given back to the Department of Science and Technology - Capacity Building Program in Science and Mathematics Education and the Central Luzon State University for accommodating the researchers.

REFERENCES

[1] L. Bowie, H. Venkat, and M. Askew, "Pre-service primary teachers' mathematical content knowledge: an exploratory study," *African Journal of Research in Mathematics, Science and Technology Education*, vol. 23, no. 3, pp. 286–297, Sep. 2019, doi: 10.1080/18117295.2019.1682777.

[2] A. B. Iddrisu *et al.*, "Students' characteristics and academic performance in mathematics," *Journal of Education, Society and Behavioural Science*, vol. 36, no. 3, pp. 54–67, Mar. 2023, doi: 10.9734/jesbs/2023/v36i31214.

[3] B. I. Abdulai, S. B. Christopher, O. K. Dennis, A. Stephen, G. Ayishetu, and G. K. A. Felli, "Teacher characteristics and students' performance in mathematics," *British Journal of Contemporary Education*, vol. 3, no. 1, pp. 1–21, Feb. 2023, doi: 10.52589/BJCE-JYJUYEUT.

[4] P. Güner and S. Gökçe, "Linking critical thinking disposition, cognitive flexibility and achievement: math anxiety's mediating role," *The Journal of Educational Research*, vol. 114, no. 5, pp. 458–473, Sep. 2021, doi: 10.1080/00220671.2021.1975618.

[5] X. Ren, Y. Tong, P. Peng, and T. Wang, "Critical thinking predicts academic performance beyond general cognitive ability: evidence from adults and children," *Intelligence*, vol. 82, Sep. 2020, doi: 10.1016/j.intell.2020.101487.

[6] J. Lahdenperä, J. Rämö, and L. Postareff, "Contrasting undergraduate mathematics students' approaches to learning and their interactions within two student-centred learning environments," *International Journal of Mathematical Education in Science and Technology*, vol. 54, no. 5, pp. 687–705, May 2023, doi: 10.1080/0020739X.2021.1962998.

[7] S. Gilmanshina, S. Smirnov, A. Ibatova, and I. Berechikidze, "The assessment of critical thinking skills of gifted children before and after taking a critical thinking development course," *Thinking Skills and Creativity*, vol. 39, Mar. 2021, doi: 10.1016/j.tsc.2020.100780.

[8] J. T. Jupeth *et al.*, "Demystifying the relationship between confidence and critical thinking in mathematics among preservice teachers in West Philippines," *European Journal of Educational Research*, vol. 12, no. 4, pp. 1743–1754, Oct. 2023, doi: 10.12973/eu-jer.12.4.1743.

[9] P. A. Facione, "Critical thinking: a statement of expert consensus for purposes of educational assessment and instruction executive summary "The Delphi Report," *The California Academic Press*, vol. 423, pp. 1–19, 1990.

[10] S. Sk and S. Halder, "Critical thinking disposition of undergraduate students in relation to emotional intelligence: gender as a moderator," *Heliyon*, vol. 6, no. 11, Nov. 2020, doi: 10.1016/j.heliyon.2020.e05477.

[11] H. C. Çelik and F. Özdemir, "Mathematical thinking as a predictor of critical thinking dispositions of pre-service mathematics teachers," *International Journal of Progressive Education*, vol. 16, no. 4, pp. 81–98, Aug. 2020, doi: 10.29329/ijpe.2020.268.6.

[12] G. Ali and R.-N. Awan, "Thinking based instructional practices and academic achievement of undergraduate science students: exploring the role of critical thinking skills and dispositions," *Journal of Innovative Sciences*, vol. 7, no. 1, 2021, doi: 10.17582/journal.jis/2021/7.1.56.70.

[13] R. Qiang, Q. Han, Y. Guo, J. Bai, and M. Karwowski, "Critical thinking disposition and scientific creativity: the mediating role of creative self-efficacy," *The Journal of Creative Behavior*, vol. 54, no. 1, pp. 90–99, Mar. 2020, doi: 10.1002/jocb.347.

[14] G. Astika and D. T. Y. G. Sumakul, "Students' profiles through learning approaches using biggs' study process questionnaire," *ELTR Journal*, vol. 4, no. 1, pp. 36–42, Dec. 2019, doi: 10.37147/eltr.v4i1.33.

[15] J. Biggs, D. Kember, and D. Y. P. Leung, "The revised two-factor study process questionnaire: R-SPQ-2F," *British Journal of Educational Psychology*, vol. 71, no. 1, pp. 133–149, Mar. 2001, doi: 10.1348/000709901158433.

[16] S. Khillar, "Difference between deep learning and surface learning," *Difference Between*, 2020. [Online], Available at http://www.differencebetween.net/language/difference-between-deep-learning-and-surface-learning/ (Accessed May 1, 2020).

[17] S. A. Silalahi, A. Zainal, and G. H. Sagala, "The importance of deep learning on constructivism approach," *Atlantis Press*, 2022, doi: 10.2991/aebmr.k.220104.036.

[18] E. O. Sen, "Middle school students' engagement in mathematics and learning approaches: structural equation modelling," *Pedagogical Research*, vol. 7, no. 2, Mar. 2022, doi: 10.29333/pr/11908.

[19] K. Kusaeri and A. Aditomo, "Pedagogical beliefs about critical thinking among Indonesian mathematics pre-service teachers," *International Journal of Instruction*, vol. 12, no. 1, pp. 573–590, Jan. 2019, doi: 10.29333/iji.2019.12137a.

[20] B. J. Zimmerman, "Self-regulated learning and academic achievement: an overview," *Educational Psychologist*, vol. 25, no. 1, pp. 3–17, 1990, doi: 10.1207/s15326985ep2501_2.

[21] T. J. Cleary and P. P. Chen, “Self-regulation, motivation, and math achievement in middle school: variations across grade level and math context,” *Journal of School Psychology*, vol. 47, no. 5, pp. 291–314, Oct. 2009, doi: 10.1016/j.jsp.2009.04.002.

[22] J. C. Núñez, P. Rosário, G. Vallejo, and J. A. González-Pienda, “A longitudinal assessment of the effectiveness of a school-based mentoring program in middle school,” *Contemporary Educational Psychology*, vol. 38, no. 1, pp. 11–21, Jan. 2013, doi: 10.1016/j.cedpsych.2012.10.002.

[23] E. Hidayanto, E. T. D. Cahyowati, and A. H. Ummah, “Students’ critical thinking disposition in working on numeration problems,” *Jurnal Pendidikan MIPA*, vol. 23, no. 3, pp. 1224–1240, 2022, doi: 10.23960/jpmipa/v23i3.pp1224-1240.

[24] D. Pu *et al.*, “Influence of critical thinking disposition on the learning efficiency of problem-based learning in undergraduate medical students,” *BMC Medical Education*, vol. 19, no. 1, Dec. 2019, doi: 10.1186/s12909-018-1418-5.

[25] C. Liu, M. Tang, M. Wang, L. Chen, and X. Sun, “Critical thinking disposition and academic achievement among Chinese high school students: a moderated mediation model,” *Psychology in the Schools*, vol. 60, no. 8, pp. 3103–3113, Aug. 2023, doi: 10.1002/pits.22906.

[26] K. O. Adu and N. Duku, “Learning styles and instructional materials as correlates of grade 6 learners`` mathematics performance in Buffalo City, South Africa,” *Research in Social Sciences and Technology*, vol. 6, no. 3, pp. 242–255, Dec. 2021, doi: 10.46303/ressat.2021.41.

[27] R. Kangaslampi, H. Asikainen, and V. Virtanen, “Students’ perceptions of self-assessment and their approaches to learning in university mathematics,” *LUMAT: International Journal on Math, Science and Technology Education*, vol. 10, no. 1, Jan. 2022, doi: 10.31129/LUMAT.10.1.1604.

[28] Y. F. Zakariya, H. K. Nilsen, S. Goodchild, and K. Bjørkestøl, “Self-efficacy and approaches to learning mathematics among engineering students: empirical evidence for potential causal relations,” *International Journal of Mathematical Education in Science and Technology*, vol. 53, no. 4, pp. 827–841, Apr. 2022, doi: 10.1080/0020739X.2020.1783006.

[29] S. Quinn, M. Hogan, C. Dwyer, P. Finn, and E. Fogarty, “Development and validation of the student-educator negotiated critical thinking dispositions scale (SENCTDS),” *Thinking Skills and Creativity*, vol. 38, Dec. 2020, doi: 10.1016/j.tsc.2020.100710.

[30] Y. F. Zakariya, K. Bjørkestøl, H. K. Nilsen, S. Goodchild, and M. Lorås, “University students’ learning approaches: an adaptation of the revised two-factor study process questionnaire to Norwegian,” *Studies in Educational Evaluation*, vol. 64, Mar. 2020, doi: 10.1016/j.stueduc.2019.100816.

[31] M. Q. E. Alfayez, “Mathematical proficiency among female teachers of the first three grades in Jordan and its relationship to their mathematical thinking,” *Frontiers in Education*, vol. 7, Dec. 2022, doi: 10.3389/feduc.2022.957923.

[32] A. K. Avaroğullari and B. Şaman, “Examining the relationship between social studies teacher candidates’ learning styles and critical thinking tendencies (in Turkish: Sosyal bilgiler öğretmen adaylarinin öğrenme stilleri ile eleştirel düşünme eğilimleri arasindaki ilişkinin incelenmesi),” *Mehmet Akif Ersoy Üniversitesi Eğitim Fakültesi Dergisi*, no. 53, pp. 411–434, Jan. 2020, doi: 10.21764/maeuefd.584183.

[33] H. Akgül and Ö. Ş. İzmirli, “Pre-service teachers’ decoding skills in information and communication technologies and critical thinking dispositions,” *Journal of Educational Technology and Online Learning*, vol. 4, no. 3, pp. 516–530, Sep. 2021, doi: 10.31681/jetol.945411.

[34] A. Vashe, V. Devi, R. Rao, R. R. Abraham, V. Pallath, and S. Umakanth, “Using an integrated teaching approach to facilitate student achievement of the learning outcomes in a preclinical medical curriculum in India,” *Advances in Physiology Education*, vol. 43, no. 4, pp. 522–528, Dec. 2019, doi: 10.1152/advan.00067.2019.

[35] M. Leiva-Brondo *et al.*, “Study approaches of life science students using the revised two-factor study process questionnaire (R-SPQ-2F),” *Education Sciences*, vol. 10, no. 7, Jun. 2020, doi: 10.3390/educsci10070173.

[36] F. Han and R. Ellis, “Combining self-reported and observational measures to assess university student academic performance in blended course designs,” *Australasian Journal of Educational Technology*, vol. 36, no. 6, pp. 1–14, 2020, doi: 10.14742/ajet.6369.

[37] N. Ç. Dedeoğlu, “Preservice mathematics teachers’ ability to perform the mathematizing process: the cylinder packing problem,” *Participatory Educational Research*, vol. 9, no. 6, pp. 130–155, Nov. 2022, doi: 10.17275/per.22.132.9.6.

[38] O. Kuzu and O. Çil, “Examination of preservice teachers’ skills in classifying learning objectives and problem posing involving fractions,” *Kastamonu Eğitim Dergisi*, vol. 30, no. 1, pp. 141–160, Feb. 2022, doi: 10.24106/kefdergi.801083.

[39] M. L. Mariano-Dolesh, L. M. Collantes, E. D. Ibañez, and J. T. Pentang, “Mindset and levels of conceptual understanding in the problem-solving of preservice mathematics teachers in an online learning environment,” *International Journal of Learning, Teaching and Educational Research*, vol. 21, no. 6, pp. 18–33, Jun. 2022, doi: 10.26803/ijlter.21.6.2.

[40] J. Apawu, “Contemporary preservice mathematics teachers’ technological pedagogical content knowledge levels in perspective: self-reported survey,” *Asian Research Journal of Mathematics*, pp. 130–147, Sep. 2022, doi: 10.9734/arjom/2022/v18i1130431.

[41] E. D. Peteros, “Impact of pre-service teachers’ self-regulation and self-efficacy on their mathematics performance in blended learning,” *Journal of Education and Learning (EduLearn)*, vol. 18, no. 2, pp. 526–534, May 2024, doi: 10.11591/edulearn.v18i2.21074.

[42] D. Kurniati, D. Trapsilasiwi, A. R. As’ari, H. Basri, and S. Osman, “Prospective mathematics teachers’ critical thinking disposition in designing cognitive and psychomotor assessment instruments,” *Tadris: Jurnal Keguruan dan Ilmu Tarbiyah*, vol. 7, no. 1, pp. 1–14, Jun. 2022, doi: 10.24042/tadris.v7i1.11263.

[43] R. Nurjanah, “Development of math set game to improve critical thinking skills student of class VII material set,” *AlphaMath: Journal of Mathematics Education*, vol. 8, no. 1, May 2022, doi: 10.30595/alphamath.v8i1.13042.

[44] G. C. Abiogu *et al.*, “Cognitive-behavioural reflective training for improving critical thinking disposition of nursing students,” *Medicine*, vol. 99, no. 46, Nov. 2020, doi: 10.1097/MD.0000000000022429.

[45] P. L. Anders, E. L. Davis, and W. D. McCall, “Psychometric properties of an instrument to assess critical thinking disposition and metacognition in dental students,” *Journal of Dental Education*, vol. 84, no. 5, pp. 559–565, May 2020, doi: 10.1002/jdd.12038.

[46] S. N. Martin, M. U. Gusteti, and S. Wulandari, “The analysis of reflective thinking skill of mathematics education students on mathematical problem solving,” 2023, doi: 10.1063/5.0122471.

[47] A. H. Aldahmash, S. A. Alshalhoub, and M. A. Naji, “Mathematics teachers’ reflective thinking: level of understanding and implementation in their professional practices,” *PLOS ONE*, vol. 16, no. 10, Oct. 2021, doi: 10.1371/journal.pone.0258149.

[48] Ç. Toraman, Ş. Orakcı, and O. Aktan, “Analysis of the relationships between mathematics achievement, reflective thinking of problem solving and metacognitive awareness,” *International Journal of Progressive Education*, vol. 16, no. 2, pp. 72–90, Apr. 2020, doi: 10.29329/ijpe.2020.241.6.

[49] N. N. S. P. Verawati, H. Hikmawati, and S. Prayogi, “The effectiveness of inquiry learning models intervened by reflective processes to promote critical thinking ability in terms of cognitive style,” *International Journal of Emerging Technologies in Learning*, vol. 15, no. 16, Aug. 2020, doi: 10.3991/ijet.v15i16.14687.

[50] A. Heyder, A. F. Weidinger, A. Cimpian, and R. Steinmayr, “Teachers’ belief that math requires innate ability predicts lower intrinsic motivation among low-achieving students,” *Learning and Instruction*, vol. 65, Feb. 2020, doi: 10.1016/j.learninstruc.2019.101220.

[51] A. O. A. Awofala and A. O. Lawani, "Increasing mathematics achievement of senior secondary school students through differentiated instruction," *Journal of Educational Sciences*, vol. 4, no. 1, Jan. 2020, doi: 10.31258/jes.4.1.p.1-19.

[52] J. A. Abah, K. Ogugua, and V. L. Okoh, "Impact of intrinsic motivation on junior secondary school students' academic performance in mathematics despite family background in Ohimini local government area of Benue State, Nigeria," *SSRN Electronic Journal*, 2022, doi: 10.2139/ssrn.4061815.

[53] W. C. Liu, "Implicit theories of intelligence and achievement goals: a look at students' intrinsic motivation and achievement in mathematics," *Frontiers in Psychology*, vol. 12, Feb. 2021, doi: 10.3389/fpsyg.2021.593715.

[54] A. Fikriyati, R. Agustini, and S. Suyatno, "Pre-service science teachers' critical thinking dispositions and critical thinking skills," in *Eighth Southeast Asia Design Research (SEA-DR) the Second Science, Technology, Education, Arts, Culture, and Humanity (STEACH) International Conference (SEADR-STEACH 2021)*, 2022, pp. 176–181, doi: 10.2991/assehr.k.211229.028.

[55] M. Gentile *et al.*, "The role of disposition to critical thinking in digital game-based learning," *International Journal of Serious Games*, vol. 6, no. 3, pp. 51–63, Sep. 2019, doi: 10.17083/ijsg.v6i3.316.

[56] H. Yongmei, "The influence of blending learning on undergraduates' critical thinking disposition: a quasi experimental study," *Journal of Educational Theory and Management*, vol. 5, no. 1, May 2021, doi: 10.26549/jetm.v5i1.6504.

[57] F. Çetin and Z. Demirtaş, "The relationship of lifelong learning competencies with learning approaches and self-efficacy," *Sakarya University Journal of Education*, vol. 12, no. 3, pp. 748–768, Dec. 2022, doi: 10.19126/suje.1158777.

[58] M. Leenknecht, P. Hompus, and M. van der Schaaf, "Feedback seeking behaviour in higher education: the association with students' goal orientation and deep learning approach," *Assessment & Evaluation in Higher Education*, vol. 44, no. 7, pp. 1069–1078, Oct. 2019, doi: 10.1080/02602938.2019.1571161.

[59] R. Wang, J. Han, C. Liu, and L. Wang, "Relationship between medical students' perceived instructor role and their approaches to using online learning technologies in a cloud-based virtual classroom," *BMC Medical Education*, vol. 22, no. 1, Dec. 2022, doi: 10.1186/s12909-022-03604-3.

[60] S. A. Aderibigbe, "Can online discussions facilitate deep learning for students in General Education?," *Heliyon*, vol. 7, no. 3, Mar. 2021, doi: 10.1016/j.heliyon.2021.e06414.

[61] M. H. Santosa, N. M. Ratminingsih, and L. D. S. Adnyani, "Students' learning approaches in the EFL emergency online learning context," *Journal of English Education and Linguistics Studies*, vol. 8, no. 2, pp. 185–218, Jun. 2022, doi: 10.30762/jeels.v8i2.3215.

[62] U. Tokac, E. Novak, and C. G. Thompson, "Effects of game-based learning on students' mathematics achievement: a meta-analysis," *Journal of Computer Assisted Learning*, vol. 35, no. 3, pp. 407–420, Jun. 2019, doi: 10.1111/jcal.12347.

[63] S. M. Jubran, M. Q. Al Fayez, and J. D. Abueita, "Teachers' perspectives of the sudden shift towards online learning: challenges and future lessons," *Journal of Language Teaching and Research*, vol. 14, no. 1, pp. 239–248, Jan. 2023, doi: 10.17507/jltr.1401.25.

[64] W. Yao, L. Wang, and D. Liu, "Augmented reality based language and math learning applications for preschool children education." *Universal Access in the Information Society*, 2024, doi: 10.1007/s10209-024-01101-6.

BIOGRAPHIES OF AUTHORS

Kyla Mae Agustin Salviejo is currently pursuing a Master of Science in Education, specializing in mathematics, at Central Luzon State University, previously completed her bachelor's degree in secondary education with a major in mathematics at the same institution, graduating cum laude in 2022. The same year, she participated in the Capacity Building Program in Science and Mathematics Education under the Department of Science and Technology as a scholar. Following this, she took the Licensure Examination for Teachers in 2023 and obtained her professional teaching license within that year. She can be contacted at email: salviejo.kylamae@clsu2.edu.ph.

Edwin Daniega Ibañez is a Professor VI at the Department of Mathematics and Physics, Central Luzon State University. He has been with the academe for 33 years. Currently, he serves as the University's Chief of Internal Audit Services. With expertise in mathematics, he instructs various courses at both undergraduate and graduate levels. Additionally, he fulfills roles as an adviser and trainer for scholars under the Department of Science and Technology-Science Education Institute. Furthermore, he contributes to research endeavors, having authored several published books, primarily focusing on mathematics. He can be contacted at email: edwindibañez@clsu.edu.ph.

Jupeth Toriano Pentang holds an Associate Professor I position at the Department of Science Education, Central Luzon State University. He handles mathematics and professional education courses. In addition, he provided technical services as a resource speaker in various training workshops and as a peer reviewer in internationally indexed journals. Furthermore, he is a research consultant and data analyst for various research studies. His research interests focus on mathematics education, problem-solving, preservice teachers, educational management, and action research. He can be contacted at email: jupeth.pentang@clsu2.edu.ph.