**A Quantitative Study On 21st-Century Learning Skills and Mathematical Identity of Math Majors**

Abstract

This study examined the influence of 21st-century learning skills on the mathematical identity of math majors. Many students struggle to develop a strong mathematical identity, which affects their engagement and confidence. Using a descriptive-correlational design, data were gathered from 100 math majors from different schools in Davao City through two standardized tools: the 21st-Century Skills Instrument and the Mathematical Identity Instrument. Findings revealed a very high level of 21st-century learning skills and a high level of mathematical identity. The results indicate a statistically significant relationship between 21st-century learning skills and mathematical identity, which implies that for every increase in 21st-century learning skills, there is a corresponding increase in mathematical identity and vice versa. Linear Regression analysis indicated that 21st-century learning skills explained 49.7% of the variance in mathematical identity. The findings support the Constructivist Theory, suggesting that students who engage in critical thinking, collaboration, and digital literacy are more likely to develop a positive mathematical identity. The study recommends integrating 21st-century learning strategies in the mathematics curriculum to support identity formation and enhance academic development.

***Keywords:*** *21st-century learning skills, mathematical identity, math majors, engagement and confidence.*

Introduction

In today's fast-changing world, students build their mathematical identity as an individual's self-concept, and their emotional connection to mathematics has become a critical education issue. Some students often believe that mathematics is just for the "gifted," leading to feelings of isolation and math anxiety (Radišić et al., 2024). This leads to disengagement and a lack of belonging, specifically among minority populations in STEM fields. As supported by Ridho et al. (2023), identity difficulties impede students' engagement and their pursuit of math-related paths. The issues must address the global problems of weak or negative identities to ensure equitable access to mathematics education.

In the Philippines, issues concerning students' mathematical identity remain to exist. Filipino students often exhibit elevated mathematics anxiety and low self-efficacy, particularly when exposed to traditional, teacher-centered pedagogy (Mamolo, 2022). Typically, a national analysis of the 2018 PISA results found that more than half of Filipino students scored below the minimum proficiency in mathematics, underscoring the current issues of comprehension and self-efficacy (Bernardo et al., 2024). These concerns emphasize that ambiguous mathematical identity is a common issue that shapes cognitive difficulties and affective barriers. Many students are still disengaged and perform poorly without practical assistance, which enhances their confidence and sense of belonging in mathematics.

In regions such as Davao City, students continue to face challenges that hinder the development of a strong mathematical identity. Baltazar (2022) stated that students enrolled in General Mathematics courses often show different analytical problem-solving skills based on their emotional intelligence, indicating that even mathematics majors may lack the self-awareness and self-regulation required to build confidence in math-related tasks. Additionally, the use of innovative strategies significantly assisted local mathematics students in overcoming disengagement and apprehension towards mathematics, which are typical constraints to identity development (Baog & Dacudao, 2024). These studies emphasized that local mathematics majors may still need emotional and instructional support to establish an intense and persistent attraction for mathematics, even among those specializing in the subject.

Despite several studies investigating factors influencing students' performance in mathematics, limited research focuses on how 21st-century learning skills shape the mathematical identity of math majors. This gap is critical, as mathematical identity significantly influences students' belief, engagement, confidence, and perseverance in math-related fields. When these issues remain unresolved, students may experience low self-efficacy, math anxiety, and poor academic performance (Radišić et al., 2024). Moreover, lacking essential 21st-century skills such as critical thinking, collaboration, and digital literacy may hinder learners' capacity to adjust to contemporary academic and professional demands (Mahmud & Wong, 2022). Eventually, this study is urgently needed to comprehend and strengthen the role of 21st-century learning skills in developing positive mathematical identity among future educators and professionals. Thus, it is crucial to examine this study to provide insights and help educators design more effective strategies for supporting the holistic growth of mathematics in students, fostering competence and confidence in their academic journey.

This study examines the relationship between 21st-century learning skills and the mathematical identity of math majors from selected schools in Davao City. Specifically, it seeks to answer the following questions: (1) What is the level of 21st-century learning skills among math majors in terms of learning and innovation skills, life and career skills, interdisciplinary skills, and information, media, and technology skills? What is the level of their mathematical identity in terms of belief, attitude, confidence, and persistence? (2) Is there a significant relationship between 21st-century learning skills and the mathematical identity of math majors in Davao City? (3) Do 21st-century learning skills significantly influence the mathematical identity of math majors in Davao City?

Ho1: There is no statistically significant relationship between 21st-century learning skills and the mathematical identity of math majors in Davao City.

Ho2: There is no statistically significant influence between the 21st-century learning skills and the mathematical identity of math majors in Davao City.

This study was anchored on Vygotsky's Constructivist Theory, which asserts that learners construct knowledge based on their experiences, primarily through social interaction (Yasnitsky, 2014). Constructivist learning supports the significance of collaboration, dialogue, and scaffolding in cognitive development, asserting that learning transcends merely transmission and involves the co-construction of meaning through collective activities and mentorship from more knowledgeable individuals (Yilmaz & Göçen, 2022). This theory underpins the integration of active and inquiry-based learning approaches that aim to develop students' higher-order thinking skills and, by extension, their academic identities.

**MATHEMATICAL IDENTITY**

* Belief
* Attitude
* Confidence
* Persistence

**21st CENTURY- LEARNING SKILLS**

* Learning and Innovation Skills
* Life and Career Skills
* Interdisciplinary
* Information, Media, and Technology Skills
* s

*Figure 1 Conceptual Framework of the 21st Century Learning Skills and Mathematical Identity*

Method

This study employed a descriptive correlational research design to examine the relationship between the math majors' 21st-century learning skills and mathematical identity. The study respondents were 100 math majors from different Davao City, Philippines, schools during the academic year 2024 – 2025. The researchers applied stratified random sampling to select the respondents, ensuring that participants were proportionally chosen based on relevant strata such as school, year level, and academic standing.

To gather the data, the researchers adopted the two main instruments: the 21st Century Skills Instrument developed by Bala (2024), which includes 43 items rated on a 5-point Likert scale and categorized into four components such as learning and innovation skills, life and career skills, interdisciplinary skills, and information, media, and technology skills. Meanwhile, the Mathematical Identity Instrument, the study of (Sahin et al., 2019), comprises 26 items rated on a 5-point Likert scale and categorized into four components: belief, attitude, confidence, and persistence.

 Descriptive statistics, such as means and standard deviation, were used to determine the levels of 21st-century learning skills and mathematical identity among the math majors. Pearson's r correlation was applied to evaluate the relationship between these skills and mathematical identity. Additionally, regression analysis was conducted to determine the individual and combined influence of 21st-century learning skills on the mathematical identity of math majors from different schools.

Results and Discussion

**Table 1. Descriptive Table**

|  |  |  |  |
| --- | --- | --- | --- |
| **Variables and Their Indicators** | **Standard Deviation** | **Mean** | **Verbal Description** |
| **21st Century Learning Skills** | **.23** | **4.22** | **Very High** |
|  Learning and Innovation Skills | .25 | 4.26 | Very High |
|  Life and Career Skills | .27 | 4.16 | High |
|  Interdisciplinary | .32 | 4.22 | Very High |
|  Information, Media, and Technology Skills | .27 | 4.24 | Very High |
| **Mathematical Identity** | **.28** | **4.11** | **High** |
|  Belief | .32 | 4.10 | High |
|  Attitude | .30 | 4.23 | Very High |
|  Confidence | .41 | 4.12 | High |
|  Persistence | .36 | 3.99 | High |

Table 1 presents the level of 21st Century Learning Skills and Mathematical Identity among math majors. The overall mean score for 21st Century Learning Skills was 4.22, categorized as very high. This implies that the respondents perceive themselves as highly equipped with the essential skills of 21st-century learning.  Among the indicators, Information, Media, and Technology Skills had the highest mean of 4.24, which indicates the strong proficiency in digital tools and media used by the math majors. However, Life and Career Skills showed the lowest mean of 4.16, underscoring slightly less confidence in managing personal and professional goals.

The findings show that critical thinking, digital and media literacy skills, and interdisciplinary collaboration are essential for 21st-century learners, especially in Science, Technology, Engineering, and Mathematics (Voogt & Roblin, 2012). Similarly, Binkley et al. (2011) established a validated approach for evaluating 21st-century abilities and observed that students in dynamic learning contexts frequently exhibit advanced skills in innovation, ICT literacy, and collaboration. Consequently, these findings affirm the results in this study that math majors show a high to very high level of self-assessed 21st-century learning skills, indicating preparedness for modern academic and professional challenges.

Conversely, the overall mean score for Mathematical Identity was 4.11, categorized as high. This indicates that the respondents often positively perceive themselves regarding mathematics. Among the indicators, attitude obtained the highest mean of 4.23, implying a strong positive disposition toward mathematics. However, persistence had the lowest mean of 3.99, suggesting potential for improvement in maintaining effort when facing mathematical challenges. This result may have been obtained because while math majors typically appreciate and value mathematics, they may still have difficulties sustaining motivation and resilience when encountering complex tasks.

These findings support previous research that found that strong mathematical identity in attitude and confidence correlates with active participation, long-term engagement, and academic achievement in mathematics (Boaler & Selling, 2017). Additionally, Graven and Heyd-Metzuyanim (2019) discovered that belief and perseverance substantially influence the development of a positive mathematical identity. This reveals that students who often manifest confidence in math and believe in its relevance are likelier to see themselves as competent. Thus, these findings support the results in this study, indicating that while math majors possess a strong emotional and intellectual connection to mathematics, which is reflected in their high level of positive attitude, their lower persistence may stem from contextual challenges that hinder sustained motivation and resilience in practice.

**Table 2. Test of Relationship**

|  |  |
| --- | --- |
| **Independent Variable** | **Dependent Variable** |
| **r-value** | **p-value** | **Decision on Ho** | **Interpretation** |
| **21st-Century Learning Skills** | .705 | .000 | Rejected | Significant |

Table 2 shows a significant relationship between 21st-century learning skills and mathematical identity among math majors. The results show a significant positive relationship, with a computed Pearson correlation coefficient R = .705 and .000. Since the p-value is less than the standard significance level of 0.05, the null hypothesis is rejected, indicating that 21st-century learning skills correlate statistically with mathematical identity. This suggests that students who consistently manifest high levels of 21st-century competencies also demonstrate strong mathematical identities. Hence, this result may have been obtained as 21st-century learning skills strengthen students' engagement with mathematics through critical thinking, problem-solving, collaboration, adaptability, and environmental and media literacy, enabling them to navigate complex tasks confidently.

 The findings support that 21st-century learning skills are essential in enhancing learner identity and engagement, particularly when implemented in innovative, collaborative, and digital tools. Moreover, Boaler (2016) stated that students engaged in dynamic and engaging mathematics instruction, which fosters 21st-century skills, will likely grow more robust mathematical mindsets and identities. As supported by Salviejo et al. (2024), pre-service mathematics teachers who are encouraged to think critically, persevere, and embrace challenges cultivate a positive and resilient academic identity. This research asserts that 21st-century learning skills directly influence students' confidence and self-concept in mathematics.

**Table 3: Regression Table**

|  |  |
| --- | --- |
| **Independent Variable** | **Dependent Variable** |
| **R2-value** | **F-value** | **p-value** | **Decision on Ho** | **Interpretation** |
| **21st-Century Learning Skills**  | 49.7% | 96.90 | .000 | Rejected | Significant |

 Table 3 displays the regression analysis results in examining the influence of 21st-century learning skills on the mathematical identity of math majors. The regression model reveals an R² value of 49.7%, showing that nearly half of the variance in mathematical identity can be attributed to students' 21st-century learning skills. The F-value of 96.90 and the p-value of .000 imply that the result is statistically significant. This leads to rejecting the null hypothesis (Ho), which states no significant relationship exists. This means that 21st-century learning skills significantly influence mathematical identity among math majors.

The findings align with Boaler (2016), who emphasized that students develop stronger mathematical identities when exposed to innovative learning environments that encourage critical thinking, collaboration, and self-expression. Similarly, Niemi and Niu (2021) assert that students who utilize critical thinking and problem-solving using digital narratives have increased self-efficacy and resilience in mathematics contexts. This suggests that incorporating digital tools and narrative-based approaches into mathematics instruction might boost confidence and thrive to students when dealing with mathematical issues.

**Conclusion**

The study found that 21st-century learning skills have a significant relationship and strong positive influence on the mathematical identity of math majors. Based on the interpretation of the mean scores, the level of 21st-century learning skills was very high, meaning these skills are always manifested. In contrast, the level of mathematical identity was high, indicating it is often manifested. This suggests that students are regularly engaged in learning experiences that develop essential 21st-century competencies and foster a strong identity in self-concept for mathematics. The correlation results further reveal that for every increase or decrease in 21st-century learning skills, there is a corresponding increase or decrease in mathematical identity. Moreover, the regression result of (R² = 49.7%) indicates that 21st-century learning skills significantly influence mathematical identity, which implies that other factors influence mathematical identity that was not part of the present study. These results confirm the Constructivist Theory, emphasizing that integrating critical thinking, collaboration, creativity, and technology in learning environments supports students in constructing a stronger and more positive mathematical identity.

Based on the findings, it is recommended that educational institutions enhance curriculum design by integrating 21st-century learning skills, particularly life and career skills, to strengthen students' mathematical identity. Instructors may adopt constructivist-aligned teaching methods that encourage reflection, collaboration, and problem-solving to develop confidence and persistence in mathematics. This is recommended since the findings reveal that students with strong 21st-century learning skills such as critical thinking, collaboration, adaptability, and media literacy are more likely to develop a positive mathematical identity. Thus, future research may examine other contributing factors to mathematical identity beyond the scope of this study, including socio-emotional influences and digital learning contexts. Additionally, targeted interventions that foster real-world learning experiences may further support identity development and academic growth in mathematics.

**Consent:**

The researchers began data collection by obtaining informed consent from the respondents, ensuring they understood the study's purpose and that participation was voluntary, with the option to withdraw anytime. After securing consent, the researchers administered survey questionnaires to the selected math majors. Ethical standards were followed throughout the process by maintaining participants' privacy and confidentiality, keeping personal information anonymous, and using the data solely for research purposes.

**Disclaimer (Artificial intelligence)**

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

References

Bala, K. (2024). Development and validation of a 21st-century skills instrument: Measuring secondary school students’ skills. International Journal of Research in Education and Science, 10(1), 45–60. https://doi.org/10.31756/jrsmte.223

Baog, I., & Dacudao, L. (2024). Unlocking mathematical success: A qualitative case study on Grade 10 learners' challenges and triumphs with the DAMATH strategy. International Journal of Research and Innovation in Social Science, 8(7). https://dx.doi.org/10.47772/IJRISS.2024.807092

Baltazar, L. P. T. (2022). Emotional intelligence and analytical problem-solving skills of students in General Mathematics. International Journal of Innovative Science and Research Technology, 7(4). <https://doi.org/10.5281/zenodo.6555356>

Bernardo, A. B. I., Cordel, M. O. II, Lapinid, M. R. C., Teves, J. M. M., Yap, S. A., & Chua, U. C. (2024). Contrasting profiles of low-performing mathematics students in public and private schools in the Philippines: Insights from machine learning. Journal of Intelligence, 12(2), Article 34. https://doi.org/10.3390/jintelligence12020034

Binkley, M., Erstad, O., Herman, J., Raizen, S., Ripley, M., Miller-Ricci, M., & Rumble, M. (2011). Defining twenty-first-century skills. In P. Griffin, B. McGaw, & E. Care (Eds.), Assessment and teaching of 21st century skills (pp. 17–66). https://doi.org/10.1007/978-94-007-2324-5\_2

Boaler, J. (2016). Mathematical mindsets: Unleashing students' potential through creative math, inspiring messages and innovative teaching. Jossey-Bass. https://doi.org/10.1080/14794802.2016.1237374

Boaler, J., & Selling, S. K. (2017). Psychological imprisonment or intellectual freedom? A longitudinal study of contrasting school mathematics approaches and their impact on adults' lives. Journal for Research in Mathematics Education, 48(1), 78–105. <https://doi.org/10.5951/jresematheduc.48.1.0078>

Graven, M., & Heyd-Metzuyanim, E. (2019). Mathematics Identity Research: The State of the Art and Future Directions. ZDM Mathematics Education, 51(3), 361–372. https://eric.ed.gov/?id=EJ1216241

Mahmud, M. M., & Wong, S. F. (2022). Digital age: The importance of 21st century skills among undergraduates. Frontiers in Education, 7. <https://doi.org/10.3389/feduc.2022.950553>

Mamolo, L. A. (2022). Online learning and students’ mathematics motivation, self-efficacy, and anxiety in the “new normal.” Education Research International, 2022, Article 9439634. <https://doi.org/10.1155/2022/9439634>

Niemi, H., & Niu, S. J. (2021). Digital storytelling enhancing Chinese primary school students’ self-efficacy in mathematics learning. *Australasian Journal of Educational Technology, 37*(1), 137–151. <https://doi.org/10.1177/1834490921991432>

Radišić, J., Krstić, K., Blažanin, B., Mićić, K., Baucal, A., & Schukajlow, S. (2024). Am I a math person? Linking math identity with students’ motivation for mathematics and achievement*. European Journal of Psychology of Education*, 39, 1513–1536. <https://doi.org/10.1007/s10212-024-00811-y>

Ridho, M. H., Muhammad, I., & Mulyaning, E. C. (2023). Mathematical identity in learning mathematics: Bibliometric review. Science Learning and Teaching, 4(3), Article 287. https://doi.org/10.46627/silet.v4i3.287

Sahin, A., Yoon, M., & Kim, M. (2019). The development and validation of a 21st-century skills instrument: Measuring secondary school students’ skills*. Journal of Research in Science, Mathematics and Technology Education,* 2(2), 85–103. <https://doi.org/10.31756/jrsmte.223>

Salviejo, K. M., Ibanez, E., & Pentang, J. T. (2024). Critical thinking disposition and learning approach as predictors of mathematics performance. *Journal of Education and Learning (EduLearn), 18*(4), 1107–1116. https://doi.org/10.11591/edulearn.v18i4.21386

Yasnitsky, A. (2014). Vygotsky, Lev. In D. C. Phillips (Ed.), Encyclopedia of educational theory and philosophy (pp. 843–845). *SAGE Publications*. https://doi.org/10.4135/9781483346229

Yilmaz, R., & Göçen, G. (2022). Constructivist learning environment perceptions and self-regulated learning in mathematics. *International Journal of Educational Methodology*, 8(1), 105–119. https://doi.org/10.12973/ijem.8.1.105