



Assessing 21st-Century Competencies In Higher Education Mathematics: A Constructivist Profiling Of Stem Learners

Hasmin T. Ignacio

College of Teacher Education, Batangas State University -
The National Engineering University, Batangas City,
Philippines/ College of Science, Technological University of
the Philippines, Philippines

Emil C. Alcantara

College of Teacher Education, Batangas State University -
The National Engineering University, Batangas City,
Philippines

Abstract: *In today's knowledge-driven economy, higher education must undergo a paradigm shift in how mathematics is taught. Traditional, procedure-heavy approaches are no longer sufficient; instead, mathematics instruction should evolve into dynamic, learner-centered experiences that cultivate critical thinking, creativity, collaboration, and communication. By reimagining the delivery of mathematics lessons, institutions can better prepare students to thrive in complex, innovation-driven environments. In addition to rote learning of the subject, deliberate instruction in 21st-century competencies is needed (Alabdulaziz et al., 2022; Hoogland, 2023). Based on the premises of Constructivist Learning Theory, this paper investigated the pre-existing proficiencies of STEM undergraduate students in four key areas: collaboration, critical thinking, creativity, and communication. Using a descriptive quantitative design, a valid survey was conducted among the mathematics teachers of 19 Philippine higher education institutions. The study found that students had moderate levels of proficiency in all the areas. Although they showed proficiency in interpersonal respectfulness, utilizing digital media, and teamwork basics, there were significant deficiencies noted in their advanced cognitive skills. Students had difficulty with reflection, managing individual projects, generating new ideas, and making academic arguments. This indicates that although students have good collaborative traits, they do not possess advanced skills that are vital for doing science in the contemporary world. Thus, it can be concluded that conventional mathematics instruction does not develop those competencies adequately. As such, it is important to shift instruction toward a more student-centered, constructivist approach that involves scaffolding. The proposed methodology would help humanize the process of studying mathematics, thereby enabling learners to think critically, solve problems creatively, and develop well-substantiated academic arguments.*

Keywords: *21st-century skills, Constructivist learning theory, Higher education, Mathematics education, STEM learners*

I. INTRODUCTION

The educational setting today is being radically transformed by the disruptive nature of the Fourth Industrial Revolution [13]. Thus, mathematical literacy cannot merely refer to students' ability to remember formulae or follow algorithms anymore. College mathematics must allow students to develop high levels of problem-solving skills, abstract thinking, and applicability of their knowledge in diverse situations [14]. Currently, global standards are calling for the development of the Four Cs: critical thinking, communication, collaboration, and creativity [15].

Unfortunately, the transition from secondary school to tertiary mathematics seems to be one of the hardest obstacles that students have to cope with. It is not uncommon that current curricula are said to be "a mile wide and an inch deep," meaning that they cover numerous mathematical areas but do not give students opportunities to comprehend or apply information in practice [3]. This problem appears to be particularly noticeable in the context of the Philippines, considering that low international results show that Filipino students find it difficult to apply mathematical knowledge for practical purposes [4].

Thus, in order to facilitate the process, the teacher should focus on constructivism rather than behaviorism as the core principle of instruction. One should envision students as individuals who generate ideas and solve problems together and whose interaction is an essential component of their learning experience [7]. Before designing such an activity, however, one needs to assess the cognitive and social status of the students in terms of their readiness to engage in collaborative learning activities. Our research aims at understanding how current STEM undergraduates demonstrate their 21st-century skills.

II. MATERIALS AND METHODS

2.1. Research Design

This research adopted a descriptive quantitative design to investigate how students enrolled in college science, technology, engineering, and mathematics (STEM) courses demonstrate their 21st-century skills [9]. With this methodology, the researchers could collect systematic quantitative data from classrooms and measure the frequency and extent to which students utilized skills such as teamwork, critical thinking, creativity, and communication.

Using these data, the researchers constructed objective profiles of students' strengths and weaknesses across the four domains of 21st-century skills: collaboration, critical thinking, creativity, and communication. For example, the quantitative results highlighted areas where students demonstrated independence in teamwork and idea generation while also revealing deficiencies in self-regulation, problem framing, and originality. These evidence-based portraits provided a nuanced understanding of which skills were highly evident, moderately evident, slightly evident, or least evident, based on the descriptive rating scale.

The results serve as a scientific foundation for curriculum reform in mathematics education, offering concrete guidance for shifting instruction from repetitive, practice-oriented tasks toward skill-oriented pedagogy. Specifically, the findings support integrating collaborative project work, problem-based learning, and creativity-driven activities into mathematics courses while emphasizing the need for targeted interventions to strengthen weaker areas such as critical thinking and communication. In this way, the study provides actionable evidence for implementing research-based modifications that align classroom practice with national policy goals and the broader demands of Education 4.0 [5].

2.2. Subjects of the Study

Purposive sampling was used to recruit participants for the study from 19 universities located within the Philippines. The participants included mathematics teachers who lectured in the general education subject Mathematics in the Modern World. They served as experts in observing the performance of students in classrooms in relation to 21st-century competencies. Through faculty observations, it became possible to examine how communication, teamwork, critical thinking, and creativity could be identified across various classes and linked to student performance [5].

Indeed, faculty observations have been especially beneficial due to the close connection between social and emotional aspects, namely self-perception and collaboration among students, with communication skills in mathematics classes [20], [2]. Considering the direct effect that teaching these skills has on students' ability to deal with mathematical challenges, it became important to determine the best approaches to ensure acquisition of the required competencies.

2.3. Data Gathering Instrument

The study was based on a survey questionnaire designed to collect teachers' views on how students exhibit the 21st-century skills in question. To collect such information, a Likert-type scale from 1 to 4 was used in connection with four main areas: collaboration, critical thinking, creativity, and communication. The questionnaire was focused on the description of observable behaviors that were characteristic of the aforementioned skills.

For data interpretation purposes, a descriptive rating scale was applied, linking numerical values with verbal descriptions:

- 3.50-4.00 - Highly evident: The skill is frequently demonstrated by students without much involvement of the teacher. They possess high levels of readiness for such activities and exhibit independence.
- 2.50-3.49 - Moderately evident: The skill is evident; however, students require some assistance and reinforcement from teachers in their activities.
- 1.50-2.49 - Slightly evident: The skill is not frequently displayed by students but shows signs of being developed.
- 1.00-1.49 - Least evident: The skill is seldom shown and does not appear to be adequately developed.

This approach allowed collecting information to facilitate further translation into measurement scales.

The questionnaire was designed to capture teachers' perspectives on students' 21st-century skills—collaboration, critical thinking, creativity, and communication—through observable behaviors. Content validity was established through expert review, ensuring alignment with the intended constructs.

Reliability was assessed using Cronbach's alpha in SPSS. The overall scale showed good internal consistency ($\alpha = 0.810$). Subscales also demonstrated strong reliability: Collaboration ($\alpha = 0.871$), Critical Thinking ($\alpha = 0.813$), Creativity ($\alpha = 0.838$), and Communication ($\alpha = 0.771$). Values above 0.70 indicate acceptable reliability, while those exceeding 0.80 reflect high reliability. These results confirm that the instrument is both valid and reliable, providing a robust tool for examining teachers' perceptions of students' 21st-century skills.

Procedure and Data Analysis

After ensuring the appropriate permissions and consent forms were in place, the team distributed the questionnaires either electronically or in person. Quantitative data were analyzed using frequencies, means, and standard deviations, enabling the researchers to determine at what point on the scale the students demonstrated each ability. These means were then used in the interpretation stage of the findings by means of a descriptive rating scale.

The higher the calculated mean, the greater the extent of demonstration of that particular ability, implying its consistency and independent use by the students. In essence, these means were used to measure the extent of each ability among the four skills – collaboration, critical thinking, creativity, and communication.

Results and Discussion

3.1 Evidence of Collaboration Skills. The STEM college students were found to exhibit moderate levels of collaboration skills ($M = 3.15$, $SD = 0.68$). They were good at interpersonal and digital collaboration, especially in terms of appreciating and valuing another perspective ($M = 3.45$), being respectful and friendly towards teammates ($M = 3.42$), and making use of technology to do task management ($M = 3.41$). This indicates that they possess excellent social skills and digital collaboration skills.

There were weaknesses in areas requiring self-regulation and organizational skills. In other words, the students did not excel at getting the job done without reminders ($M = 2.92$) or scheduling time/meetings effectively ($M = 2.84$). This indicates that although they have

social skills, they do not possess project management skills, which are absolutely necessary for effective teamwork. Therefore, instructional interventions must focus on facilitating self-regulation and leadership abilities.

3.2 Expression of Critical Thinking Skills. Critical thinking skills, too, exhibited a moderate level ($M = 2.97$, $SD = 0.73$). The students were quite competent at collecting the relevant information from various sources ($M = 3.09$) as well as assessing reasoning and evidence ($M = 3.02$). This means that there is an increase in the ability of the students to conduct academic research.

However, they lack in-depth critical thinking skills. Specifically, it is hard for them to justify evaluation criteria ($M = 2.91$) and understand what data is needed to solve a problem ($M = 2.92$). Thus, they are unable to frame problems themselves as well as evaluate their own approach to solving a particular problem.

3.3 Representation of Creativity Skills. The students displayed moderately high levels of creativity skills ($M = 3.07$, $SD = 0.72$). They performed well in developing and improving ideas ($M = 3.19$) and in employing their imagination ($M = 3.13$). Besides, they were good at seeking sources of inspiration when others could not ($M = 3.08$).

There was, however, some difficulty with showing originality. In other words, they were unable to employ imagination and originality in their work ($M = 3.00$). Moreover, it was difficult for them to create ideas according to the needs of the client or user ($M = 3.02$). It indicates that they could refine a certain idea, but they had trouble coming up with a completely new one.

3.4 Evidence of Communication Skills. The communication skills were quite moderately evident ($M = 3.07$, $SD = 0.68$). Specifically, the students were quite good at selecting media that would help understand the message better ($M = 3.30$) as well as adjusting the style to the audience ($M = 3.13$). Furthermore, they communicated effectively and in a professional way ($M = 3.11$).

There were, however, difficulties in structuring the message. For instance, they had trouble explaining their ideas clearly in order to show different perspectives ($M = 2.92$) or constructing an effective introduction and conclusion ($M = 2.97$). Hence, they are very good at presenting messages using multimedia, but not at presenting written and spoken arguments in mathematics.

Wherever Times is specified, Times Roman or Times New Roman may be used. If neither is available on your word processor, please use the font closest in appearance to Times. Avoid using bit-mapped fonts if possible. True-Type 1 or Open Type fonts are preferred. Please embed symbol fonts, as well, for math, etc.

CONCLUSION

This research clearly depicts the 21st-century skills among STEM university students, illustrating their current developmental stage. Students demonstrated strong interpersonal, teamwork, computer-mediated communication, and basic inquiry skills. However, several limitations remain, particularly in independent thinking, leadership, originality, and formulation of academic arguments.

It is important to recognize that conventional teaching approaches relying heavily on procedural instruction cannot fully foster higher-order cognitive skills. Thus, higher education mathematics programs should incorporate constructivist and student-centered learning models grounded in the theories of Piaget [17] and Vygotsky [22]. Through systematic facilitation of self-directed project management, empathic problem definition, and peer-reviewed discourse, educators can transform students from collaborative recipients of mathematical information into independent problem solvers in the contemporary knowledge economy.

ACKNOWLEDGMENT

The authors extend their profound gratitude to the administrations of Batangas State University - The National Engineering University and the Technological University of the Philippines, and to the mathematics faculty across the 19 participating higher education institutions, for their invaluable cooperation and contributions to the data collection process.

REFERENCE

- [1] M. S. Alabdulaziz, I. A. H. Abdelkarim, and H. A. Madkhali, "Economy skills among female mathematics students at university according to their perceived future roles," *International Journal of Instruction*, vol. 15, no. 4, pp. 889–914, 2022, doi: 10.29333/iji.2022.15448a.
- [2] A. B. Caminse, J. M. Cadal, and C. P. Yurango, "A quantitative study on 21st-century learning skills and mathematical identity of math majors," *Asian Journal of Education and Social Studies*, vol. 51, no. 6, pp. 1481–1487, 2025, doi: 10.9734/ajess/2025/v51i62090.
- [3] L. S. Cogan, C. C. McKnight, and W. H. Schmidt, *Facing the Consequences: Using TIMSS for a Closer Look at U.S. Mathematics and Science Education*. Dordrecht, The Netherlands: Kluwer Academic Publishers, 1999.
- [4] J. K. L. Dinglasan, D. R. C. Caraan, and D. A. Ching, "Effectiveness of realistic mathematics education approach on problem-solving skills of students," *International Journal of Educational Management and Development Studies*, vol. 4, no. 2, pp. 64–87, 2023, doi: 10.53378/352980.
- [5] J. M. Fajardo and C. J. Flores, "Title of the study regarding 21st-century skills and mathematics," unpublished manuscript, 2025.
- [6] G. Gunadi, H. Haryono, and E. Purwanti, "The analysis of 21st-century learning implementation and competency achievement of junior high school students in 3T regions," *Innovative Journal of Curriculum and Educational Technology*, vol. 11, no. 1, pp. 10–18, 2022, doi: 10.15294/ijcet.v11i1.44847.
- [7] C. E. Hmelo-Silver, R. G. Duncan, and C. A. Chinn, "Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark (2006)," *Educational Psychologist*, vol. 42, no. 2, pp. 99–107, 2007, doi: 10.1080/00461520701263368.
- [8] K. Hoogland, "The changing nature of basic skills in numeracy," *Frontiers in Education*, vol. 8, Art. no. 1293754, 2023, doi: 10.3389/educ.2023.1293754.
- [9] S. Isaac and W. B. Michael, *Handbook in Research and Evaluation: A Collection of Principles, Methods, and Strategies Useful in the Planning, Design, and Evaluation of Studies in Education and the Behavioral Sciences*. San Diego, CA, USA: EDITS, 1971.
- [10] B. Masava, C. N. Nyoni, and Y. Botma, "Scaffolding in health sciences education programmes: An integrative review," *Medical Science Educator*, vol. 33, no. 1, pp. 255–273, 2022, doi: 10.1007/s40670-022-01691-x.
- [11] P. Miksza, J. T. Shaw, L. K. Richerme, P. M. Hash, D. A. Hodges, and E. C. Parker, "Descriptive statistics," in *Music Education Research*. Oxford, U.K.: Oxford Univ. Press, 2023, pp. 325–346, doi: 10.1093/oso/9780197639757.003.0016.

- [12] N. Mózes, J. Takács, Z. Ungvári, and H. J. Feith, "Screening attendance disparities among Hungarian-speaking Roma and non-Roma women in central and eastern European countries," *Frontiers in Public Health*, vol. 11, Art. no. 1292598, 2023, doi: 10.3389/fpubh.2023.1292598.
- [13] T. T. Nguyen and T. Q. Pham, "Philosophy of education in the VUCA environment," manuscript submitted for publication, 2025.
- [14] C. Paolucci, "Mathematical reasoning for global competitive advantage," *Journal of Mathematical Economics*, 2024.
- [15] Partnership for 21st Century Learning, P21 Framework Definitions. Washington, DC, USA: Battelle for Kids, 2015.
- [16] C. I. C. Pericano and L. Leonard, "Implementation of 21st-century skills in general mathematics and its impact on student performance: Bases for developing a self-learning module," *Formatif: Jurnal Ilmiah Pendidikan MIPA*, vol. 15, no. 1, 2025, doi: 10.30998/formatif.v15i1.23179.
- [17] J. Piaget, *Structuralism*. New York, NY, USA: Basic Books, 1970.
- [18] V. P. Rapada, "The extent of implementation of printed modules as a learning modality under the new normal: Input to the existing learning continuity plan," *International Journal of Information and Education Technology*, vol. 13, no. 3, pp. 566–576, 2023, doi: 10.18178/ijiet.2023.13.3.1840.
- [19] R. Salhab and M. M. Aboushi, "Influence of AI literacy and 21st-century skills on the acceptance of generative artificial intelligence among college students," *Frontiers in Education*, vol. 10, Art. no. 1640212, 2025, doi: 10.3389/educ.2025.1640212.
- [20] N. Sridana, H. Soeprianto, and A. Amrullah, "Analysis of TPACK incorporated learning devices: An exploratory descriptive study of mathematics teachers," *European Journal of STEM Education*, vol. 10, no. 1, Art. no. 9, 2025, doi: 10.20897/ejsteme/16757.
- [21] T. Vuletic, A. Holliman, and A. Thomson, "Fostering divergence during conceptual design with industrial-based students," *Proceedings of the Design Society*, vol. 3, pp. 1915–1924, 2023, doi: 10.1017/pds.2023.192.
- [22] L. S. Vygotsky, *Mind in Society: The Development of Higher Psychological Processes*. Cambridge, MA, USA: Harvard Univ. Press, 1978.

Table 1
Level of Manifestation of Collaboration Skills Among STEM College Students

| Collaboration Skills We Focused On | Mean | SD | Verbal Interpretation |
|--|------|------|-----------------------|
| Acknowledge and respect other perspectives | 3.45 | 0.59 | Moderately Evident |
| Be polite and kind to teammates | 3.42 | 0.61 | Moderately Evident |
| Consistently use technology as agreed upon by the team to manage project tasks | 3.41 | 0.61 | Moderately Evident |
| Interact with team members effectively | 3.28 | 0.70 | Moderately Evident |
| Follow rules for team decision-making | 3.25 | 0.64 | Moderately Evident |
| Make detailed plans about how the team will work together | 3.00 | 0.71 | Moderately Evident |
| Complete tasks without having to be reminded | 2.92 | 0.70 | Moderately Evident |
| Use time and run meetings efficiently | 2.84 | 0.67 | Moderately Evident |
| Overall | 3.15 | 0.68 | Moderately Evident |

Note. Indicators were identified based on response variance. All items were rated on a 4-point scale.

Table 2
Critical Thinking Skill Levels Among STEM College Students

| Critical Thinking Skills in Action | Mean | SD | Verbal Interpretation |
|---|------|------|-----------------------|
| Gather relevant and sufficient information from different sources | 3.09 | 0.73 | Moderately Evident |
| Evaluate reasoning and evidence that support an argument | 3.02 | 0.75 | Moderately Evident |
| Develop follow-up questions that focus or broaden inquiry | 3.00 | 0.80 | Moderately Evident |
| Understand how knowledge or insights might transfer to other situations | 2.97 | 0.69 | Moderately Evident |
| Thoroughly assess the quality of information | 2.97 | 0.69 | Moderately Evident |
| Identify in detail what needs to be known to answer an inquiry question | 2.92 | 0.74 | Moderately Evident |
| Justify choices of evaluation criteria | 2.91 | 0.75 | Moderately Evident |
| Overall | 2.97 | 0.73 | Moderately Evident |

Note. Indicators were identified based on response variance. All items were rated on a 4-point scale.

Table 3
Creativity Skills Displayed by STEM College Students

| What Each Creativity Skill Means | Mean | Standard Deviation | What We Found |
|--|------|--------------------|--------------------|
| Elaborate and improve on ideas | 3.19 | 0.64 | Moderately Evident |
| Use creativity and imagination | 3.13 | 0.70 | Moderately Evident |
| Find sources of information and inspiration when others do not | 3.08 | 0.65 | Moderately Evident |
| Create new, unique, surprising products | 3.05 | 0.82 | Moderately Evident |

| | | | |
|--|------|------|--------------------|
| Create ideas geared to the intended client or user | 3.02 | 0.70 | Moderately Evident |
| Employ imagination and originality | 3.00 | 0.71 | Moderately Evident |
| Overall | 3.07 | 0.72 | Moderately Evident |

Note. Indicators were identified based on response variance. All items were rated on a 4-point scale.

Table 4
Communication Skills of STEM College Students

| Practical Communication Skills | Mean | SD | Rating in Words |
|--|------|------|--------------------|
| Use appropriate media to enhance understanding | 3.30 | 0.66 | Moderately Evident |
| Adapt a communication style appropriate for the purpose, task, or audience | 3.13 | 0.60 | Moderately Evident |
| Speak clearly and professionally | 3.11 | 0.67 | Moderately Evident |
| Answer questions clearly and concisely | 3.05 | 0.63 | Moderately Evident |
| Create a clear and interesting introduction and conclusion | 2.97 | 0.76 | Moderately Evident |
| Clearly communicate alternative or opposing perspectives | 2.92 | 0.80 | Moderately Evident |
| Overall | 3.07 | 0.68 | Moderately Evident |

Note. Indicators were identified based on response variance. All items were rated on a 4-point scale.