Cultural Cybermath System in Enhancing Students' Mathematical Creativity

Allan Jay S. Cajandig

Sultan Kudarat State University, Philippines

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ABSTRACT

The study investigates the effectiveness of the Cultural CyberMath System (CCMS), a culturally embedded cyber-learning environment grounded in the 5I's learning path (Impress–Identify–Inspire–Inspect–Invoke), in enhancing students' mathematical creativity. Drawing on gaps in technology-enhanced, culturally responsive mathematics education, the study focuses on three indicators of creativity: fluency, flexibility, and originality. A quasi-experimental pretest–posttest control group design was implemented with 62 first-year hospitality management students enrolled in Mathematics in the Modern World at a Philippine state university, randomly assigned by class to an experimental group (CCMS) and a control group (contextualized blended instruction). Mathematical creativity was measured using a validated, rubric-scored Mathematical Creativity Test composed of open-ended, multiple-solution tasks. Data were analyzed using descriptive statistics and ANCOVA with pretest scores as covariates. Results showed substantial gains in fluency, flexibility, and originality in both groups, with no significant differences in posttest fluency and flexibility. However, CCMS produced a statistically higher level of originality, indicating stronger support for generating uncommon and innovative solutions. Overall, the findings position CCMS as a viable alternative to contextualized blended instruction for fostering broad mathematical creativity, with added value for originality, and highlight the potential of culturally grounded cyber-learning designs to cultivate creative mathematical thinking.

Keywords: Cultural CyberMath System, Mathematical Creativity, Fluency, Flexibility, Originality

INTRODUCTION

Mathematics education continues to face the pressing challenge that many students experience mathematics as rigid, procedural, and disconnected from their lived realities, which suppresses creativity and engagement despite curriculum calls for higher-order thinking and problem solving. Traditional instruction in many classrooms still emphasizes routine exercises, algorithmic practice, and preparation for high-stakes tests, leaving little space for open-ended exploration, multiple solution paths, and creative reasoning. At the same time, the rapid expansion of digital technologies has not been fully leveraged to design culturally responsive learning environments that integrate learners' cultural practices, local contexts, and digital experiences into mathematical activity. This gap is especially critical in diverse societies where students' cultural knowledge and digital habits could be powerful resources for creative mathematical thinking but often remain untapped in conventional lessons. A Cultural Cyber Math System directly responds to this issue by using technology to embed culturally meaningful tasks and interactive features that invite students to experiment, represent ideas in varied ways, and collaboratively construct solutions, thereby positioning creativity as central rather than peripheral to learning mathematics.

Indeed, mathematics education often underutilizes technology's potential to connect formal mathematics with students' cultural experiences and higher-order thinking, especially creativity. Technology-enhanced, culturally responsive models are shown to improve problem solving, numeracy, engagement, and identity, yet they remain relatively rare and fragmented in practice (Fitri et al., 2025; Hidayat & Firmanti, 2024; Nursyahidah et al., 2025; Sunzuma & Umbara, 2025; Viberg et al., 2020). These studies highlight that digital tools such as GeoGebra, AR/VR, interactive slides, and game-based platforms can mediate culturally grounded tasks that promote mathematical reasoning, discovery, and student agency, but most implementations focus on content mastery and motivation rather than systematically nurturing creativity in mathematics (Bertrand et al., 2024; Sianipar et al., 2025; Dosinaeng et al., 2025; Salsabila et al., 2025). This body of work therefore substantiates the need for intentional designs that link culture, technology, and creative mathematical activity, aligning closely with the rationale for developing a Cultural Cyber Math System.

From a global perspective, research in Indonesia, Sweden, and other international contexts illustrates both promising practices and persistent gaps in technology-supported, culturally responsive mathematics teaching. In Indonesia, systematic reviews and intervention studies document growing use of ethnomathematics-based technologies and digital media that embed local wisdom and cultural narratives, leading to gains in mathematical understanding, motivation, and appreciation of culture (Sunzuma & Umbara, 2025; Dosinaeng et al., 2025; Hasbi et al., 2025). In Sweden, case studies show that digital tools can support conceptual understanding and engagement, but also reveal that teacher practices and school cultures often limit deep integration of technology into inquiry-based, collaborative learning (Viberg et al., 2020). Within the Philippine setting, phenomenological findings indicate that mathematics teachers recognize the value of culturally responsive pedagogy yet face challenges related to resources, training, and systemic support, resulting in uneven implementation of culture- and technology-infused approaches (Madriaga & Cajandig, 2025). These scenarios point to a shared international struggle: moving from isolated, tool-centered innovations to coherent, culturally grounded, technology-rich ecosystems that consistently support creative mathematical thinking (Bertrand et al., 2024; Hendri et al., 2025; Hu, 2025).

A closer look at these studies reveals several critical gaps that justify and shape the present investigation. First, existing models often foreground achievement, numeracy, or computational skills, while creativity in mathematics—such as generating multiple strategies, posing problems, and producing novel representations—is seldom treated as a primary outcome or systematically assessed (Fitri et al., 2025; Kurniasi et al., 2025; Hidayat & Firmanti, 2024). Second, many interventions are short-term, tool-specific, or topic-bound (for example, algebra units, exponent lessons, or particular AR/VR activities), which limits understanding of how sustained, technology-mediated, culturally responsive environments can transform students' broader mathematical dispositions and creative practices (Bertrand et al., 2024; Sianipar et al., 2025; Dosinaeng et al., 2025; Salsabila et al., 2025). Third, there is a lack of integrated system designs that intentionally weave together culture, cyber-technology, and creativity within a coherent pedagogical framework, particularly in the Philippine context where teacher beliefs and contextual constraints strongly shape implementation (Madriaga & Cajandig, 2025; Singh, 2025; Hasbi et al., 2025). These gaps underscore the need for a Cultural Cyber Math System that is not merely a collection of digital tools, but a structured environment explicitly aimed at enhancing students' creativity in mathematics through culturally meaningful, technology-rich learning experiences.

Present situations consistently show that when instruction is intentionally designed to be rich in problem solving, problem posing, open-ended tasks, games, and real-world contexts, students' mathematical creativity and related outcomes improve, yet such practices are still exceptions rather than norms in typical classrooms (Bicer, 2021; Khalid et al., 2020; Nilimaa, 2023; Zioga & Desli, 2025). Interventions such as creative problem solving lessons, differentiated curricula, lateral-thinking problems, game-based activities like Bachet's game, flipped and problem-based environments, and creativity-oriented assessments demonstrate positive effects on students' creative thinking, problem-solving, motivation, and self-efficacy in mathematics (Applebaum, 2025; Mariani et al., 2025; Shodiq et al., 2025; Bingol & Ozyaprak, 2025; Bicer et al., 2020). However, systematic reviews and empirical work also reveal that many teachers still prioritize procedural fluency and exam performance, that creativity-promoting tasks are unevenly implemented, and that classroom practices frequently lag behind policy aspirations to foster creativity in mathematics education (Susilawati et al., 2024; Istikomah et al., 2024; Zioga & Desli, 2025; Khalil et al., 2023).

Aligned with this body of work, the present study adopts mathematical creativity indicators that capture how students generate, vary, and innovate in their mathematical thinking, focusing on fluency, flexibility, and originality. Fluency typically refers to producing a large number of relevant mathematical ideas, strategies, or solutions; flexibility reflects the ability to shift perspectives and use diverse approaches or representations; and originality captures the production of uncommon or novel responses compared to peers (Susilawati et al., 2024; Istikomah et al., 2024). These three indicators are widely used in mathematics education research on creative thinking and are frequently operationalized through problem-solving and problem-posing tasks, where students are expected to generate multiple solutions, change conditions, or construct new problems in non-routine ways (Bicer, 2021; Bicer et al., 2020; Nilimaa, 2023). Reviews and empirical studies emphasize that nurturing fluency, flexibility, and originality requires learning environments with rich, open tasks, space for exploration, and supportive assessment practices (Khalid et al., 2020; Susilawati et al., 2024; Istikomah et al., 2024) reinforcing their suitability as core creativity indicators for evaluating the impact of a Cultural Cyber MathSystem,

The Cultural CyberMath System builds directly on the work of Cajandig and Lomibao (2020), which designed and tested a 5I's learning path—impress, identify, inspire, inspect, and invoke—with a cultural approach embedded in computer-aided instruction (CAI) to enhance students' conceptual understanding in mathematics. In that study, culturally grounded problem situations and contexts familiar to first-year hospitality management students were carefully integrated into an interactive digital environment, allowing learners to encounter, explore, and make sense of mathematical ideas through locally meaningful scenarios rather than decontextualized exercises. The 5I's learning path embedded in the Cultural CyberMath System enhances mathematical creativity by engaging students in progressive and reflective learning experiences. The Impress stage stimulates curiosity through culturally relevant situations, while Identify encourages learners to recognize patterns and explore multiple strategies. Inspire promotes collaborative and technology-supported exploration that develops confidence in expressing original ideas. The Inspect stage strengthens higher-order thinking through reflection, self-assessment, and evaluation of alternative solutions, enhancing flexibility and originality. Lastly, Invoke encourages students to apply and innovate mathematical concepts in new situations. Overall, the inquiry-oriented and cyclical nature of the 5I's framework transforms mathematics learning into an active creative process grounded in cultural experiences and supported by technology-rich environments.

The purpose of the present study is to test the effectiveness of the Cultural CyberMath System—an extension of the 5I's learning path with a cultural approach embedded in computer-aided instruction—in enhancing students' mathematical creativity, specifically in terms of fluency, flexibility, and originality in generating and represeting mathematical ideas.

METHODOLOGY

Research design

This study adopted a quasi-experimental pretest–posttest control group design to examine the effectiveness of the Cultural CyberMath System on students' mathematical creativity. Two intact first-year Bachelor of Science in Hospitality Management classes were randomly assigned at the section level to either an experimental group or a control group. Both groups completed pretests before the intervention and posttests after the intervention. The experimental group received instruction via the Cultural CyberMath System, whereas the control group received a contextual approach with blended instruction. Mathematical creativity was measured using a rubric-based Mathematical Creativity Test (MCT), Descriptive statistics (mean, standard deviation) and one-way analysis of covariance (ANCOVA) were employed to compare posttest scores between groups while controlling for pretest scores at a 0.05 significance level.

Setting

The research was conducted at Sultan Kudarat State University (SKSU) – Tacurong Campus, Tacurong City, Sultan Kudarat, Philippines. SKSU is a state university mandated to provide advanced instruction and professional training in science, technology, agriculture, fisheries, education and related fields, along with research and extension services. The Tacurong Campus, located in Barangay Poblacion, comprises two colleges: Arts and Science, and Hospitality Management and Business Administration. The intervention took place in the Mathematics in the Modern World course offered under the College of Hospitality Management.

Participants

Participants were 62 first-year students enrolled in the Bachelor of Science in Hospitality Management program during the second semester of Academic Year 2024–2025. The two existing sections of Mathematics in the Modern World were heterogeneous in prior academic performance and were randomly assigned, using a lottery procedure, to the experimental and control conditions. Section BSHM1A (31 students) served as the experimental group and was taught using the Cultural CyberMath System; section BSHM1B (31 students) served as the control group and was taught using a contextual approach with blended instruction.

Instrument

Mathematical Creativity Test (MCT) was a researcher-developed and underwent content validation by panels of experts in mathematics education. Inter-rater agreement for expert ratings was assessed using Krippendorff's alpha, which is suitable for nominal data and can handle missing values. The MCT is an open-ended test designed to assess students' mathematical creativity in terms of fluency, flexibility and originality. Its development was informed by prior work on mathematical creativity and creative thinking (e.g., Balka, 1974; Walia, 2017; Kattou et al., 2012; Torrance Test of Creative Thinking). Consistent with the literature, the test consists of open-ended, multiple-solution tasks intended to elicit a range of valid responses. An initial pool of nine items (three items per component) was drafted and reviewed by five experts in mathematical creativity for relevance and coverage of the three dimensions. Based on expert feedback, items with weaker ratings were removed, resulting in a final version comprising six items (two items per component). Students were prompted to generate as many distinct solutions as possible and to produce responses that differed from those of their peers. Three experienced mathematics teachers, including the researcher, independently scored responses using an analytic rubric. Krippendorff's alpha for the MCT scores was 0.5467, indicating moderate inter-rater agreement.

Procedure

The procedure comprised four main stages: development of lessons, preparation of instructional materials, implementation of the intervention and administration of pre- and posttests.

First, lessons for both conditions were designed through an extensive review of the literature and iterative consultation with the adviser and content experts. For each group, lesson plans specified the sequence of topics, learning outcomes, assessment activities and use of cultural contexts relevant to students' life and hospitality-related experiences. Second, instructional materials were prepared. For the experimental group, the Cultural CyberMath System was installed and tested in the computer laboratory; computers, software, seating arrangement, lighting and equipment layout were checked to ensure a suitable learning environment. For the control group, classroom facilities such as projectors and speakers were prepared to support contextualized approach with blended instruction using slide presentations and videos.

Third, the intervention was implemented over ten weeks (January–April 2025) with two sessions per week. To reduce teacher-related variability, the same teacher-researcher taught both classes. The experimental group used the Cultural CyberMath System structured around the 5I's learning path: Impress, Identify, Inspire, Inspect and Invoke. After logging in, students accessed an instruction guide, watched a motivational video and engaged with a culturally contextualized problem of the day (Impress). They then completed diagnostic review and drill tasks with automated feedback and identified prerequisite skills (Identify). In the Inspire phase, students interacted with multimedia resources (video lessons, audiovisual presentations, illustrated texts) for concept development. In the Inspect phase, they revised their solutions to the problem of the day and reflected on the skills and concepts applied and the learning outcomes achieved. Finally, in the Invoke phase, they worked on transfer tasks and self-reflection activities designed to extend learning and stimulate creative mathematical thinking.

In the control group, the teacher implemented a contextual approach with blended instruction, also following the 5I's logic but delivered through teacher-led activities and general educational technologies. The Impress phase included audiovisual motivation and a problem of the day. In the Identify phase, students articulated learning outcomes and completed review and drill exercises to activate prior knowledge. The Inspire phase involved teacher-led concept instruction supported by slide presentations and video lessons. During the Inspect phase, students revised their initial solutions and identified the skills and concepts used. In the Invoke phase, they completed application exercises and written reflections. Fidelity of implementation in both groups was monitored through periodic classroom observations by the course professor and the program chair.

Finally, pretests (MC)T was administered to both groups before the start of the intervention, and the same instrument was administered as posttests after completion of the ten-week sequence. Standardized procedures for instructions, time allocation and testing conditions were followed. Responses were collected, scored through an independent scoring of MCT responses by three raters and entered into a database for analysis.

Data analysis

Descriptive statistics (mean and standard deviation) were computed for pretest and posttest scores on mathematical creativity (overall and by fluency, flexibility and originality) for both groups. To estimate the effect of the Cultural CyberMath System compared with the contextual blended approach, one-way ANCOVA was conducted for each dependent variable, with instructional group (experimental vs. control) as the fixed factor, posttest scores as dependent variables and pretest scores as covariates. ANCOVA was used to adjust for initial group differences and to increase statistical precision. Assumptions of ANCOVA, including linearity, homogeneity of regression slopes and normality of residuals, were assessed prior to interpreting results. All statistical tests were performed at a 5% significance level using two-tailed criteria.

RESULTS AND DISCUSSION

Students' Level of Mathematical Creativity

The level of performance in terms of students' mathematical creativity during pre-test is the score in the examination conducted before the start of the class and post-test after the covered lessons were given. Table 1 reveals the performance of students on Mathematical Creativity during pre-test and post-test both under the Control and Experimental Groups in terms fluency.

Table 1. Mean Scores and Standard Deviation of Students' Mathematical Fluency

	Control Group n=31		**Experimental Group N=31**	
	Pre-test	**Post-test**	**Pre-test**	**Post-test**
Mean	2.89	4.95	2.90	5.12
SD	0994	1.055	0.794	1.063

Table 1 reveals that the pre-test mean scores under the experimental group which is 2.90 is slightly similar to the mean score under the control group which is 2.89. The result shows that the performances of the students in both groups are moderately creative. This means that students are more likely incoherent in answering the problems, which resulted to the wrong answer due to little knowledge or low retention of the previous learning in the topic. However, the post-test reveals that the students under the experimental group gain a mean score of 5.12, while the control group has 4.5. The result indicates that both groups have an increase in students' mathematical fluency scores, which implies that students performed better since there was an improvement when it came to carrying out correct procedures to given mathematical problems. It is noticeable that a slightly higher mean score can be observed in the students under the experimental group compared to that of the control group, which indicates that students engage in the Cultural CyberMath System had a better understanding of procedural process in problem-solving in mathematics. Regarding the pre-test of students' standard deviation in mathematical fluency, both experimental and control groups get 0.794 and 0.994, respectively, which means that their scores were all intensively closer. In the post-test, the experimental group gets 1.063, while the control group gets 1.055. The results indicate that the scores of the students both in the

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experimental and control groups are slightly similar that scores from pre-test and post-test are distributed closely from each other.

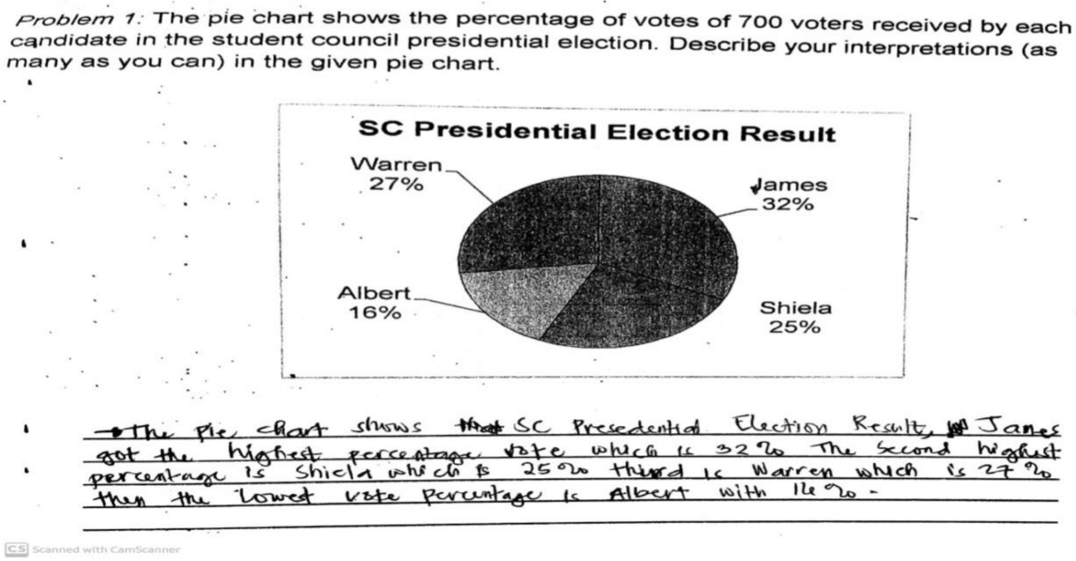

Figure 1. Student's Response on Mathematical Creativity Test Item 1 during Post-test under Control Group

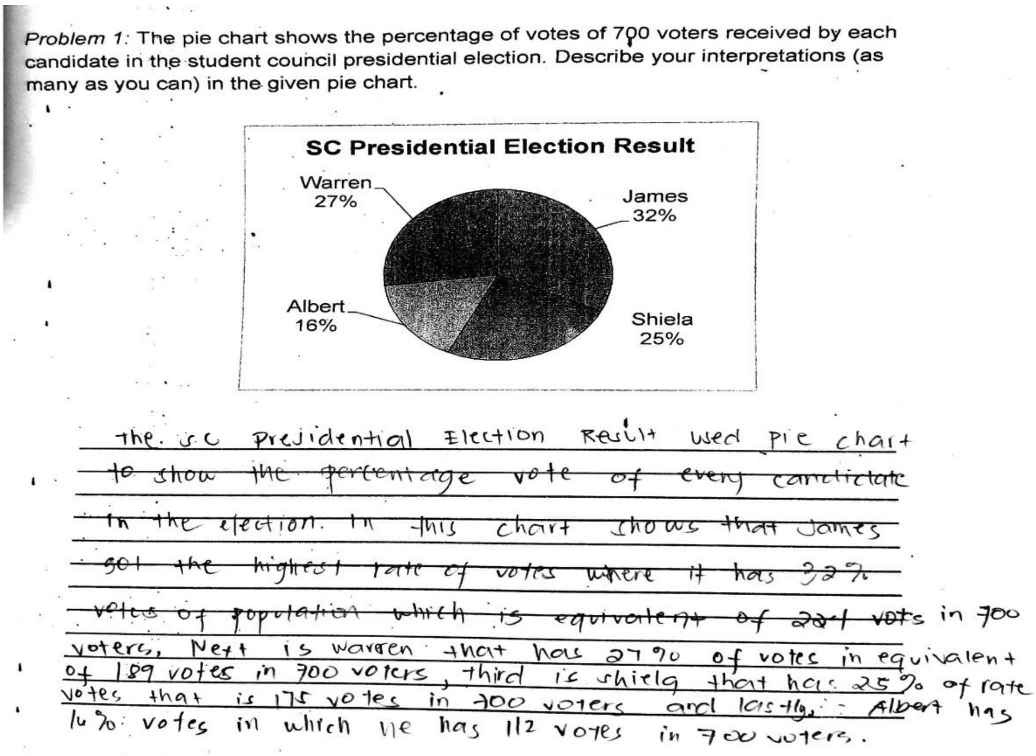

Figure 2. Student's Response on Mathematical Creativity Test Item 1 during Post-test under Experimental Group

Figures 1 and 2 show the content analysis of student's response on Mathematical Creativity Test, particularly item 1 both under control and experimental group. This item is designed to assess the demonstration of interpretation by describing the given graph. Figure 1 shows the answer of a student under the control group can carry out in describing the given graphs but no evidence of interpretation and received a score of 2 while figure 2 shows answer of student under experimental group can describe the graph but with no evidence of interpretation of its description and received a score of 2. This implies that both students under control and experimental groups knew in describing a graph but failure to manifest interpretation of the data given as shown in the graph. Hence, students prior to the management of the lesson can easily describe a particular graph, yet no depth interpretation of the data given in a specific graph.

To determine if there is a significant difference on the effects of the treatments both in Control and Experimental groups, further analysis is done using analysis of covariance (ANCOVA), as shown in table 2.

Table 2. One-Way ANCOVA Summary on Level of Mathematical Creativity in terms of Fluency

Source	**Adj Sum of Squares**	**df**	**Mean Square**	**F**	**P-value**
Group	.394	1	.394	.431	.514
Error	53.889	59	.913		
Corrected Total	67.701	61			

Note: Significant at 0.05

As shown in table 2, the analysis yielded a computed probability value of 0.514, which is greater than 0.05 level of significance. Hence, there is sufficient evidence to accept the null hypothesis. It can be inferred, therefore, that there is no significant difference in the level of fluency in the mathematics of the participants between the control and experimental groups. This indicates that the mean scores in the experimental group is remarkably comparable to the mean scores of the control group. It only shows that the use of the Cultural CyberMath System and contextualized approach with blended instruction had achieved similar improvement in students' mathematical creativity, particularly fluency.

In order to support the development of students' mathematical creativity, both the CCMS and contextualized approach with blended instruction has its disposition towards mathematical activities that foster broadly, particularly implementing inquiry-oriented mathematics instruction, which includes problem-solving. This is to avoid the impression of students that mathematics is just a set of skills and rules to memorize that will lose their natural curiosity and interest. With regards to the treatments used, both treatments organize the learning process where problem posing is given in the first stage of learning path, which is *impress.* After motivation, a problem of the day, which is the focus of the lesson, needs the students to answer before the exposure of the learning resources until the fourth stage of the learning path, which is *inspect.* The students hold their interest until the end of the lesson since there is a problem that needs to solve along the process of learning.

Moreover, in both treatments, the students are engaged in self-assessment to nurture their confidence and independence in discovering mathematics. Students checked along the process of learning their initial solution on the given problem of the day. Students had a chance to revise their initial answers to come up with a correct solution. Hence, the self-assessment allows students to take responsibility and ownership of their learning, which provides the students an opportunity to spend time reflecting on their learning. Engaging in the self-assessment method will enable students to improve their mathematical fluency.

The findings are supported by previous studies emphasizing that culturally responsive and technology-integrated mathematics instruction can similarly enhance students' mathematical creativity, particularly fluency, through inquiry-based and problem-solving activities. For instance, Bicer et al. (2020) highlighted that problem-posing activities significantly promote students' mathematical creativity by encouraging them to generate multiple ideas and solutions, which aligns with the present study where both the Cultural CyberMath System (CCMS) and contextualized blended instruction incorporated problem-solving tasks at the beginning of the learning process to sustain students' engagement and curiosity. Similarly, Khalid et al. (2020) found that instructional approaches emphasizing creative problem-solving and reflective learning experiences effectively improve students' fluency and creative thinking skills in mathematics. Their study further affirmed that self-assessment and learner autonomy strengthen students' confidence, independence, and reflective thinking, consistent with the present findings where students continuously evaluated and revised their solutions throughout the learning process. These studies substantiate the result that both CCMS and contextualized blended instruction provided comparable opportunities for students to develop mathematical fluency through active participation, inquiry-oriented tasks, and reflective self-assessment practices.

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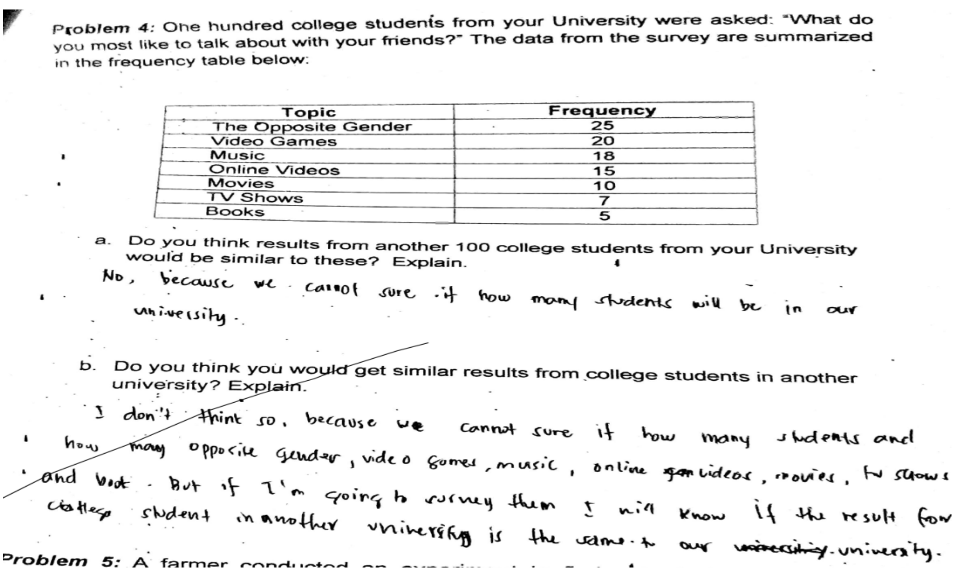
Table 3 shows the performance of students on Mathematical Creativity during pre-test and post-test both under the Control and Experimental Groups in terms flexibility.

Table 3. Mean Scores and Standard Deviation of Students' Mathematical Flexibility

	Control Group n=31		**Experimental Group N=31**	
	Pre-test	**Post-test**	**Pre-test**	**Post-test**
Mean	1.80	5.34	2.01	5.09
SD	0.949	1.243	0.941	0.999

Table 3 presents the mean and standard deviation of the students' mathematical creativity in terms of flexibility. In mathematical flexibility, the table reveals that the mean score under the experimental group which is 2.01 is slightly higher than the mean score under the control group which is, 1.80. The result shows that the performances of the students in both groups are failing scores and interpreted as slightly creative. This means that students hardly find answers in problem-solving or having no clear and well-defined solutions due to little knowledge and poor retention of the lesson. On the other hand, the mean scores of 5.09 in the post-test of the experimental group and 5.34 in the control group indicate that the students under both groups improve their performance. However, students in the control group had a better flexibility score. This implies that exposure to the Cultural CyberMath System and the contextualized approach with blended instruction helped the students improve their mathematical flexibility since they were tasked to solve mathematics problems in different ways. This result suggests that students can create their initial solution in the given problem and manage to correct and assess after exposure to other learning resources.

Regarding the variability on students' mathematical flexibility scores in the pre-test, the experimental group has a standard deviation of 0.941, and the control group has 0.949. These reveal that the mathematical flexibility scores of both groups were almost similar. As regards flexibility scores in the post-test, the experimental group has a standard deviation of 0.999, and the control group has 1.243, which means that the scores of the control group after the treatment were more scattered compared to that of the experimental group. The findings indicate that some students manage to increase relatively higher than other students who tend to have a little increase. This means that students have different capabilities of learning, particularly developing their ability to explore more feasible solutions in a given problem. Some of the students will merely rely on what is only given due to lack of persistence in carrying out other solutions in the given problem resulted to little increase in their mathematical flexibility scores.


Problem 4: One hundred college students from your University were asked: "What do you most like to talk about with your friends?" The data from the survey are summarized in the frequency table below:

Topic	Frequency
The Opposite Gender	25
Video Games	20
Music	18
Online Videos	15
Movies	10
TV Shows	7
Books	5

a. Do you think results from another 100 college students from your University would be similar to these? Explain.

No, because we cannot sure if how many students will be in our university.

b. Do you think you would get similar results from college students in another university? Explain.

I don't think so, because we cannot sure if how many students and how many opposite gender, video games, music, online videos, movies, tv shows and book. But if I'm going to survey them I will know if the result for college student in another university is the same to our university.

Problem 5: A farmer conducted an ...

Figure 3. Student's Response on Mathematical Creativity Test Item 4 during Pre-test under Control Group

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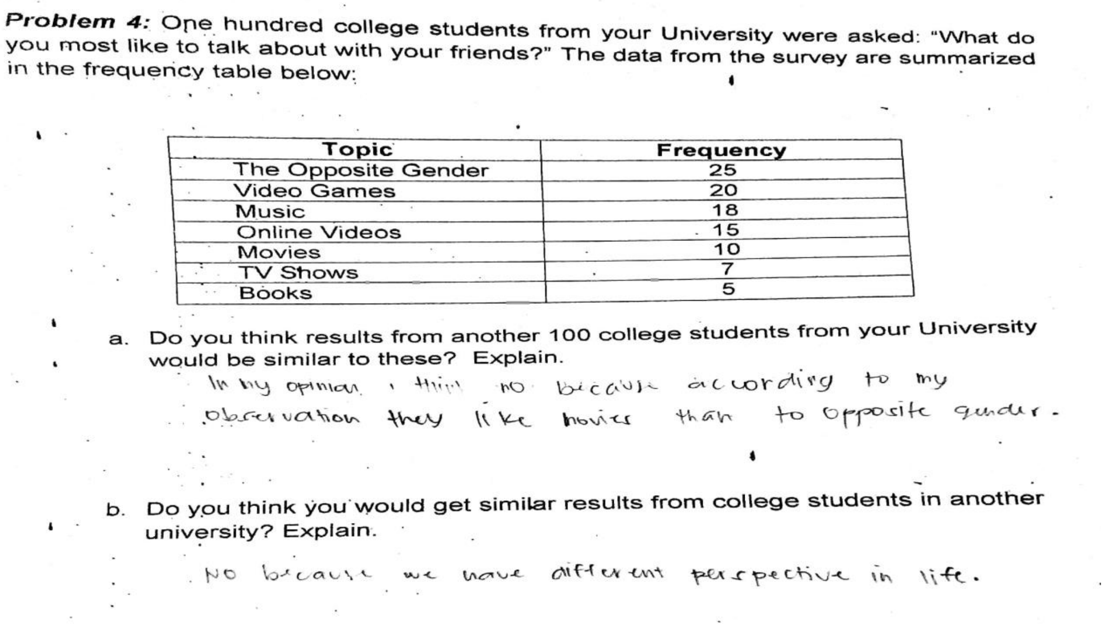


Problem 4: One hundred college students from your University were asked: "What do you most like to talk about with your friends?" The data from the survey are summarized in the frequency table below:

Topic	Frequency
The Opposite Gender	25
Video Games	20
Music	18
Online Videos	15
Movies	10
TV Shows	7
Books	5

a. Do you think results from another 100 college students from your University would be similar to these? Explain.

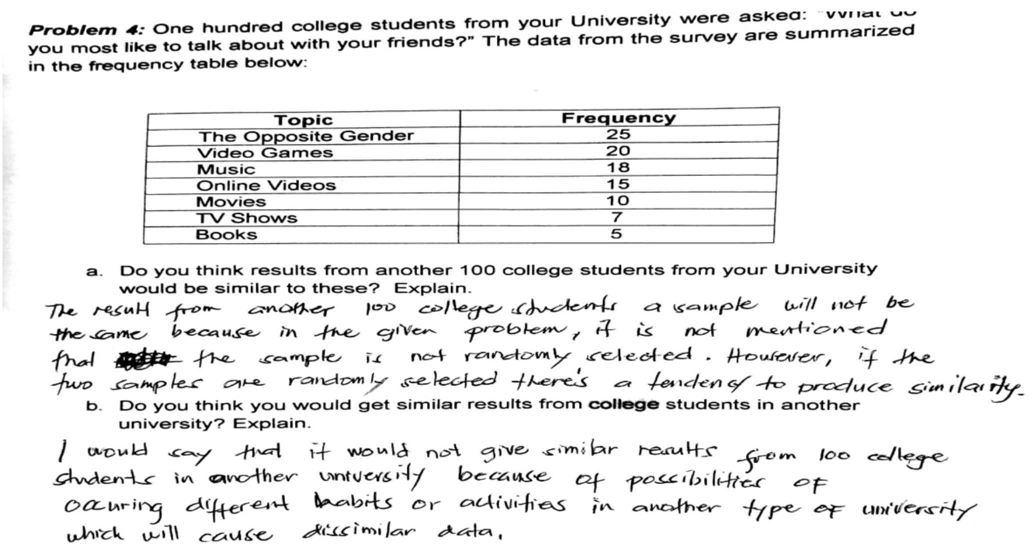
In my opinion, I think no because according to my observation they like movies than to opposite gender.

b. Do you think you would get similar results from college students in another university? Explain.

No because we have different perspective in life.

Figure 4. Student's Response on Mathematical Creativity Test Item 4 during Pre-test under Experimental Group

Figures 3 and 4 show the content analysis of student's response on the Mathematical Creativity Test, particularly on problem 4 both control and experimental groups. This item is designed to assess the student's ability to generalize from a sample to a larger population, which is considered valid if the sample is a representative of the population. Figure 3 shows students' responses on mathematical creativity test in problem 4 under the control group with no generalization and received a score of 1, similar to figure 4, which shows the answers of students under the experimental group with incorrect inference on the concept and received a score of 1. Figures 3 and 4 reflected error in responding to problem 4. Most of the students generalized that part (a) results for the two samples would be similar, but failure to justify by addressing the relevance of the role of sampling method played. Many also believe that any sample is represented as long as the sample size is large, which is considered incorrect. Moreover, in part (b), the most common error was a failure to recognize that even a large random sample, it is only appropriate to generalize from a sample to the population from which the sample was selected. The students' responses are indications that students had a little understanding on a valid generalization of population based on data in a sample. This manifests that students in answering problem 4 in mathematical creativity test had a low performance, which resulted in low mathematical flexibility before treatment.



Problem 4: One hundred college students from your University were asked: "What do you most like to talk about with your friends?" The data from the survey are summarized in the frequency table below:

Topic	Frequency
The Opposite Gender	25
Video Games	20
Music	18
Online Videos	15
Movies	10
TV Shows	7
Books	5

a. Do you think results from another 100 college students from your University would be similar to these? Explain.

The result from another 100 college students a sample will not be the same because in the given problem, it is not mentioned that the sample is not randomly selected. However, if the two samples are randomly selected there's a tendency to produce similarity.

b. Do you think you would get similar results from **college** students in another university? Explain.

I would say that it would not give similar results from 100 college students in another university because of possibilities of occuring different habits or activities in another type of university which will cause dissimilar data.

Figure 5. Student's Response on Mathematical Creativity Test Item 4 during Post-test under Control Group

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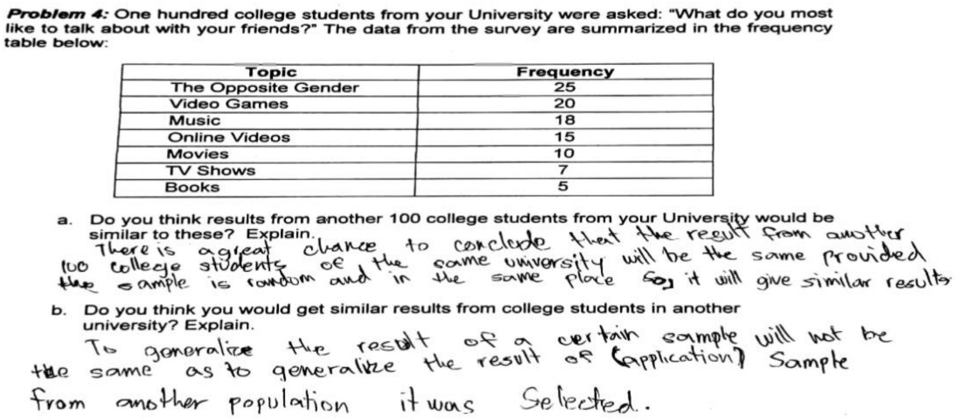
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Topic	Frequency
The Opposite Gender	25
Video Games	20
Music	18
Online Videos	15
Movies	10
TV Shows	7
Books	5

a. Do you think results from another 100 college students from your University would be similar to these? Explain.

There is agreat chance to conclude that the result from another 100 college students of the same university will be the same provided the sample is random and in the same place so it will give similar results

b. Do you think you would get similar results from college students in another university? Explain.

To generalize the result of a certain sample will not be the same as to generalize the result of (application) Sample from another population it was Selected.

Figure 6. Student's Response on Mathematical Creativity Test Item 4 during Post-test under Experimental Group

Problem 4 on the Mathematical Creativity Test assessed students' ability, particularly mathematical flexibility, on generalizing sample from the population. With regards to students' responses under control and experimental groups, students shown different ways to answer., Figure 5 and 6 show the various answers to part (a) such as indicating that the results from another sample of college students in a University would not be identical to the results of the given survey. Since problem 4 did not state that the sample was a random sample, but many students assumed that this was the case. Another response indicates that two random samples of college students would be likely to produce similar results is considered correct. Also, considered correct answers indicate that because the sample was not a random sample, the results in another sample might be quite different from the results of the given sample.

Furthermore, figures 5 and 6 show the different ideal answers among students both under control and experimental group to part (b), such as demonstrating that it is only appropriate to generalize results from a sample to the population from which the sample was selected. Also, it is considered essentially correct, a response provided a clear explanation of why it is not appropriate to generalize to college students in a different university. In this case, it is reasonable to say the students exposed either a Cultural CyberMath System or a contextualized approach with blended instruction contribute significantly to the improvement of students' mathematical flexibility.

To determine if there is a significant difference on the effects of the treatments in the mathematical creativity in terms of flexibility both in control and experimental groups, further analysis is done using analysis of covariance (ANCOVA), as shown in table 4.

Table 4. One-Way ANCOVA Summary on Level of Mathematical Creativity in terms of Flexibility

Source	**Adj Sum of Squares**	**Df**	**Mean Square**	**F**	**P-value**
Group	1.576	1	1.576	1.298	.259
Error	71.626	59	1.214		
Corrected Total	77.343	61			

Note: Significant at 0.05

As shown in table 4, the analysis yielded a computed probability value of 0.259, which is greater than 0.05 level of significance. Hence, there is sufficient evidence to accept the null hypothesis. It can be inferred, therefore, that there is no significant difference in the level of mathematical creativity of participants under the control and experimental groups in terms of flexibility. The findings reveal that the result in the experimental group is remarkably similar to control group. It only shows that the use of the Cultural CyberMath System and contextualized approach with blended instruction had better improvement in students' mathematical creativity, particularly flexibility.

The comparable result between the two groups was attributed to the fact that during the experiment, students in both groups have refrained from the perception of familiarization of rules and techniques in order to explore their creative potentials. These results further support the claim of Roble, Lomibao and Luna (2018) that teachers, who regularly design activities in mathematics classes that requires students to posit novel solutions to problems in order to develop their creative potentials. Furthermore, with the integration of culture in CCMS and contextualized approach, the students learned alternation of representations and viewing mathematical contents from different perspectives, which develops the creative ability of the students.

Table 5 shows the performance of students' mathematical creativity during pre-test and post-test both under the Control and Experimental Groups in terms of originality.

Table 5. Mean Scores and Standard Deviation of Students' Mathematical Originality

	Control Group n=31		**Experimental Group N=31**	
	Pre-test	**Post-test**	**Pre-test**	**Post-test**
Mean	1.78	4.45	1.61	4.99
SD	0.872	1.326	0.694	0.956

Table 5 presents the mean and standard deviation of the students' mathematical creativity in terms of originality. The table reveals that the mean score under the experimental group, which is 1.61 is slightly lower than the mean score under the control group, which is 1.78. The result shows that the performances of the students in both groups are at the lowest level, interpreted as slightly creative. This means that students in both groups are struggling with the given problem. This implies that students have inadequate skills in a problem or even no background on the topic.

On the other hand, it can be observed further from the table that after the treatment, the mean score of the experimental group increases to 4.99 (highly creative), while that of the control group goes up to 4.45 (moderately creative). This indicates that there was an improvement in the mean scores of both groups, with the experimental group showing a slightly higher mean score than that of the control group. Further, students in the experimental group had a better originality score. This implies that exposure to the Cultural CyberMath System and contextualized approach with blended instruction helped the students improve their mathematical originality. Although, the post-test scores also suggest that better assimilation in both treatment, the majority of the students gained improvement since they have a similar way of solving a given problem, and only a few manage to create unique solution. This result suggests that treatments honed the skills of the students in creating a unique solution in solving problems.

Regarding the variability on students' mathematical originality scores in the pre-test, the table shows that the experimental group has a standard deviation of 0.694 and the control group has 0.872. This little difference indicates that the experimental group scores were closer to each other than that of the control group. As regards flexibility scores in the post-test, the experimental group has a standard deviation of 0.956, and the control group has 1.326. These reveal that the mathematical originality scores of the control group were widely dispersed compared to the experimental group after treatment. Although students from both groups improved in their mathematical originality, only a few from the control group managed to increase their performance higher than most of the students.

Moreover, based on the given a solution of the students in both groups, it is observed that students only provide solution which is commonly used that are more likely familiar to them. Only a few who is trying to

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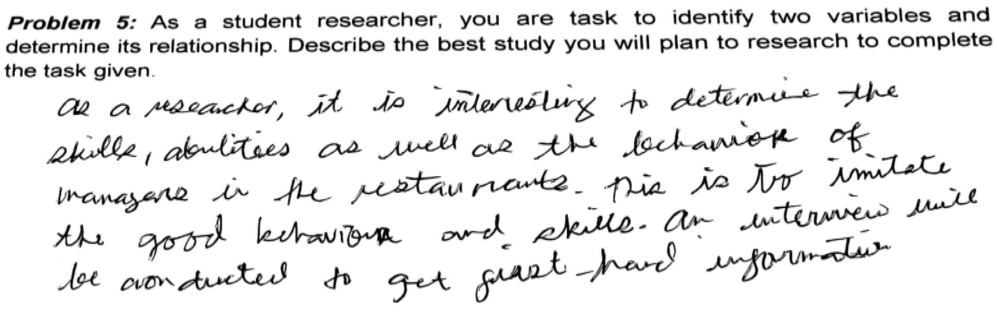
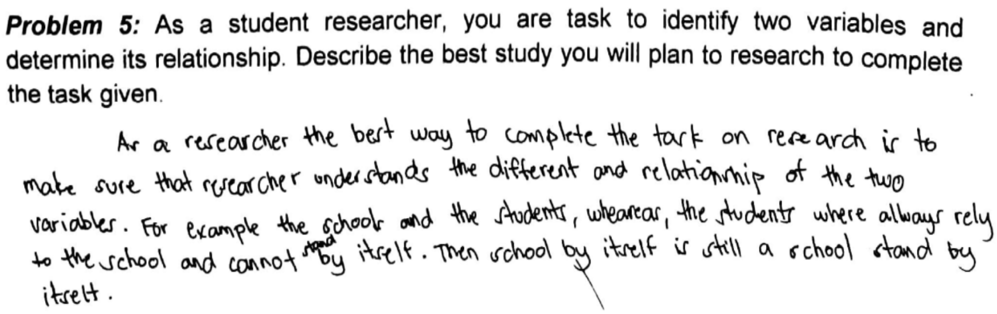
innovate their solutions carrying out the correct answer. This implies that students find a hard time creating a unique solution also considering also that problem-solving requires a time limit to answer.


Problem 5: As a student researcher, you are task to identify two variables and determine its relationship. Describe the best study you will plan to research to complete the task given.

As a researcher, it is interesting to determine the skills, abilities as well as the behavior of managers in the restaurants. This is to imitate the good behaviors and skills. An interview will be conducted to get first-hand information

Figure 7. Students' Responses on Mathematical Creativity Test Problem 5 during Pre-test under Experimental Group


Problem 5: As a student researcher, you are task to identify two variables and determine its relationship. Describe the best study you will plan to research to complete the task given.

As a researcher the best way to complete the task on research is to make sure that researcher understands the different and relationship of the two variables. For example the school and the students, whereas, the students where allways rely to the school and cannot stand by itself. Then school by itself is still a school stand by itself.

Figure 8. Students' Responses on Mathematical Creativity Test Problem 5 during Pre-test under Control Groups

Problem 5 on the Mathematical Creativity Test assessed students' ability, particularly mathematical originality, on identifying a unique variables and describing the research process to determine the relationship. Regarding students' responses under the control and experimental groups, Figure 7 and 8 show the different answers identifying variables and their relationships but failure to describe the research process. This is a manifestation that students under both groups have poor skills on the given problem or has a slight background about the application of statistics in the field of research.

To determine if there is a significant difference on the effects of the treatments in the mathematical creativity in terms of originality both in Control and Experimental groups, further analysis is done using analysis of covariance (ANCOVA), as shown in table 6b.

Table 6. One-Way ANCOVA Summary on Level of Mathematical Creativity in terms of Originality

Source	**Adj Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Group	7.191	1	7.191	8.017	.006
Error	52.920	59	.897		
Corrected Total	84.646	61			

Note: Significant at 0.05

As shown in table 6, the analysis yielded a computed probability value of 0.006, which is less than 0.05 level of significance. Hence, there is sufficient evidence to reject the null hypothesis. It can be inferred, therefore, that there is a significant difference in the level of mathematical creativity of participants under the control and experimental groups in terms of originality. The findings reveal that the result in the Experimental Group is remarkably dissimilar to the control group. It only shows that the use of the Cultural CyberMath System had better improvement in students' mathematical creativity, particularly originality.

In the use of CCMS, the students were exposed to a learning process where they can decontextualize a certain problematic situation and transform it into a mathematical concept. In particular, the *Inspect* learning path support students can generate an original mathematical idea from activating the prior knowledge, and understand its concept finding its relationship to the local context. Further, in the Invoke learning path is the application to innovate existing ideas and concepts.

The findings are supported by previous studies emphasizing that culturally responsive and technology-integrated mathematics instruction significantly enhances students' originality by encouraging the creation of unique mathematical ideas and innovative problem-solving approaches. In support of the present result, Khalil, Charitas, and Prahmana (2023) explained that learning environments that promote creative mathematical thinking allow students to construct original ideas by connecting prior knowledge with meaningful contextual experiences. Their study emphasized that students develop originality when they are encouraged to reinterpret mathematical situations and generate personal strategies rather than merely applying memorized procedures. Similarly, Nursyahidah et al. (2025) revealed that the integration of technology and cultural contexts in mathematics instruction strengthens students' ability to transform real-life cultural experiences into mathematical representations, thereby fostering innovative and original thinking. These findings affirm the present study where the Cultural CyberMath System (CCMS), particularly through the Inspect and Invoke learning paths, enabled students to decontextualize local situations, connect concepts to prior knowledge, and innovate existing mathematical ideas, resulting in greater improvement in mathematical creativity in terms of originality.

Table 7 shows the performance of students' mathematical creativity during pre-test and post-test both under the Control and Experimental Groups.

Table 7. Mean Scores and Standard Deviation of Students' Mathematical Creativity

	Control Group n=31		**Experimental Group n=31**	
	Pre-test	**Post-test**	**Pre-test**	**Post-test**
Mean	6.53	14.74	6.03	15.19
SD	2.290	2992	1.771	1.964

Table 7 presents the mean and standard deviation of the students' mathematical creativity, which is the total of their score in fluency, flexibility, and originality. In the pre-test, the table displays a mean score of 6.53 for the experimental group while that of the control group. It shows a mean score of 6.03. The control group yields a slightly higher mean compared to that of the experimental group. This indicates that the control group shows a little bit of creative ability than the experimental group. In terms of their level of mathematical creativity, the control group has shown more dispersed scores than that of the experimental group, as manifested in the standard deviation results.

It can be observed further that after the treatment, the mean of the experimental group increases to 15.19, while the control group reaches to 14.74. The experimental group yields a slightly higher mean score compared to that of the control group. This indicates that students under the experimental group improve better in their mathematical creativity than the students under the control group because of higher increase in the post-test mathematical creativity scores. This is evidence that the use of the Cultural CyberMath System improved the level of mathematical creativity of the students shown in their scores. Students under the experimental group assimilated well the lesson given and can perform ingenuity in problem-solving. Similarly, students under the control group with the use of a contextualized approach with blended instruction showed improvement on students' mathematical creativity. It seems that the two methods used during treatment can improve the mathematical creativity of the students, particularly in dealing with mathematical problem-solving with the ability to be fluent, capable of being resilient or adapting new and different ways, and being innovativeness.

To collectively describe the mathematical creativity components, further analysis is done using analysis of covariance (ANCOVA), as shown in table 8.

Table 8. One-Way ANCOVA Summary on Level of Performance in terms of Mathematical Creativity

Source	Type III Sum of Squares	Df	Mean Square	F	P-value
Group	11.569	1	11.569	3.334	.053
Error	204.733	59	3.470		
Corrected Total	387.515	61			

Note: Significant at 0.05

The analysis yielded a computed probability value of .053, which is greater than 0.05 level of significance. Hence, there is sufficient evidence to accept the null hypothesis. It can be inferred, therefore, that there is no significant difference in the level of performance of students in terms of mathematical creativity during post-test under the control and experimental groups. This implies both groups similarly performed well in developing the mathematical creativity of the students because the use of the Cultural CyberMath System, and the contextualized approach with blended instruction had better improvement in students' mathematical creativity, particularly fluency, flexibility and originality.

Further, treatments used in both groups had its disposition towards mathematical activities that foster broadly particularly implementing inquiry-oriented mathematics instruction, which includes problem-solving, which resulted that students had a better understanding of the procedural process in problem-solving in mathematics. This is similar to fostering problem-solving approaches and problem-posing activities, which are cognitively demanding have a significant effect on students' creativity in Mathematics (Roble et al., 2018). In CCMS and contextualized approach with blended instruction, students are free to answer the given problems and devised their own solutions eliciting their imagination that will not hinder their curiosity and experimentation. Also, with the integration of culture, the students learned alternation of representations and viewing mathematical contents from different perspectives, which develops creative ability of the students. This scenario is relevant to the recommendation of Roble et al. (2018) that teachers may use mathematical creative design classroom activities, which requires students to posit different solutions to mathematical problems. Further, students can generate an original mathematical idea from activating the prior knowledge then understand its concept finding its relationship to local context, particularly cultural aspect then use this to innovate existing ideas and concepts.

CONCLUSIONS

The findings indicate that the Cultural CyberMath System and the contextualized approach with blended instruction are both powerful designs for nurturing students' mathematical creativity, as shown by substantial gains in fluency, flexibility, and originality from pretest to posttest in both groups. In particular, both treatments supported students in generating more solutions, trying multiple strategies, and shifting away from purely procedural views of mathematics toward more inquiry-oriented engagement. When the three components were combined into an overall mathematical creativity score, posttest differences between the experimental and control groups were not statistically significant, which suggests that both instructional approaches can comparably enhance students' general creative performance in mathematics when they are structured around problem-posing, problem-solving, self-assessment, and culturally meaningful tasks.

At the same time, the significant advantage of the Cultural CyberMath System in the dimension of originality marks a key contribution of this study and a critical direction for further refinement. The higher originality scores in the experimental group suggest that the system's cyber-based, culturally embedded learning paths are particularly effective in prompting students to generate uncommon ideas, transform local contexts into new mathematical formulations, and innovate beyond familiar solution patterns. This dual pattern of results positions the Cultural CyberMath System as both a viable alternative and a promising enhancement to existing contextualized blended approaches: it can match them in supporting broad creativity (fluency and flexibility) while offering added value in cultivating originality. Future research can build on this contribution by optimizing and scaling the originality-supportive features of the system and examining how they interact with different student profiles, mathematical topics, and institutional settings.

RECOMMENDATIONS

Several recommendations emerge from these findings for classroom practice, curriculum design, and future research. At the classroom level, mathematics teachers are encouraged to adopt inquiry-oriented, problem-posing and problem-solving activities embedded in culturally meaningful contexts, regardless of whether they use a fully digital system or a blended approach. Structuring lessons around a learning path similar to Impress–Identify–Inspire–Inspect–Invoke can help sustain students' engagement with a focal problem across the lesson, provide opportunities for self-assessment and revision, and systematically target fluency and flexibility in mathematical thinking. Teachers should also deliberately design tasks and discussions that go beyond obtaining correct answers, by valuing multiple strategies, inviting students to compare and critique solutions, and making explicit space for reflection on how cultural experiences inform mathematical ideas.

For curriculum developers and researchers, the study suggests that the Cultural CyberMath System is a promising platform for cultivating mathematical originality and should be refined and scaled with this strength in mind. Future iterations of the system could further enrich the Inspect and Invoke phases with tasks that explicitly reward novel approaches, encourage modeling of local cultural practices, and allow students to create and share their own problems and digital artifacts. Research can extend this work by (a) examining the system's impact on creativity across different grade levels, mathematical domains, and cultural settings; (b) exploring which design features (e.g., feedback type, degree of open-endedness, nature of cultural contexts) most strongly drive originality; and (c) investigating how student characteristics such as prior achievement, creative disposition, and self-concept interact with the system. Longitudinal and mixed-methods studies are also recommended to capture how students' creative identities and practices in mathematics evolve over time within technology-rich, culturally responsive learning environments.

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