EXAMINING STUDENTS' DIGITAL LITERACY, CRITICAL THINKING SKILL DISPOSITION, CREATIVE THINKING ABILITY, AND THEIR ACADEMIC ACHIEVEMENT AT THE PUBLIC SECONDARY SCHOOL LEVEL

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Abstract

The study investigated the contributing effect and intricate interplay of students' digital literacy, critical thinking skill disposition and creative thinking ability, and academic achievement. We adapted a predictive correlational research design. The sample size is made up of 960 secondary school students in Anambra State. Four research questions and three null hypotheses were formulated to guide the study. Standardized research instruments namely; "How Creative Are You? Scale, Digital Literacy Scale, and Critical Thinking Disposition Scale were used for data collection. Students' mathematics achievement scores from Anambra State wide promotion examination were used to represent mathematics achievement. The methods used for validating the instruments were face and construct validity by the three experts from the Faculty of Education, Nnamdi Azikiwe University Awka. Cronbach's alpha was used to determine the reliability of the items in the instruments. A reliability indices were found to be 0.64, 0.73, and 0.67 were obtained for digital literacy, critical thinking skill disposition, and creative thinking ability respectively. The standard multiple regression was used to analyze the collected data. The research question 1 was answered using multiple regression. The research question 2 was answered using unstandardized β. The research question 3 was answered using adjusted R^2. The research question 4 was answered using standardized β. The null hypothesis 1 was tested using F-test for regression model. The null hypothesis 2 was tested using t-test for adjusted R^2. The null hypothesis 3 was tested using t-test for β at .05 level of significance. The result showed that the relationship among digital literacy, critical thinking skill disposition and creative thinking ability, and academic achievement recorded a low negative and moderate significant relationship. Also, result revealed that students' digital literacy and critical thinking skill disposition and creative thinking ability contributed positively to the predicting model, while creative thinking ability contributed negatively to the predicting model Based on these findings, it was recommended that further improvements can be made in developing students' digital literacy, critical thinking skill disposition, and creative thinking ability, especially on creative thinking ability that contributed negatively in predicting their academic achievement.

Keywords: Digital literacy, critical thinking skill disposition, creative skill ability, academic achievement

Introduction

Digital literacy (DL) is a media-based learning that combines education and technology with the hope that students can make the most of it. This requires learning skills, which involve divergent reasoning (critical thinking skill disposition) and constructive reasoning (creative thinking ability) as the abilities to take initiative to be responsible for learning materials as well as providing multiple solutions to the existing problems in the learning situations. Digital literacy is very important for students as a basis for being able to compete in the world of work (Riswaati *et al*, 2022). The digitally literate students will be able to use digital tools and contents not when they learn but in solving other challenges

that come their way. Such students can make their own digital content and can socially contribute to solving innovative problems (World Literacy Foundation, 2020).

Digital literacy according to Riswaati *et al,* (2022) is described as the ability to use information obtained through digital systems that are obtained effectively and efficiently in the context of academic, career, and everyday life. This means that DL is related to interests, attitudes and abilities of individuals in using digital technologies and communication tools to access, manage, integrate, analyze, and evaluate information, build new knowledge, create and communicate with others (Potter, 2005). In essence, this is a digital media-based effort, in which there are two fields of knowledge, namely; education and technology (Riswaati *et al,* 2022). In the essence, there could be significant improvement in the field of education by integrating technology with the students' instructional materials. The recent challenging situation demands technology-based learning by utilizing technology to find sources of information (Hassan, *et al,* 2021). In other words, the existence of digital incompetent teachers will hamper the improvement of students' online learning which can result in low quality of education outcome (Hassan & Mirza, 2020). For this reason, Chusni *et al* (2021) suggested that teachers required to be trained on how to use online media. This is because in the swiftly evolving realm of education, digital learning has emerged as a transformative force, revolutionizing how learners and educators interact with knowledge. It indicates that there is an intricate interplay between digital learning abilities, instructional design, and learning support, particularly within the context of blended learning, where traditional educational paradigms merge with technological advancement.

The proliferation of digital learning environments has opened new avenues for instruction and learning, underscoring the paramount importance of effectively navigating these digital spaces (Zhaoxi, 2023). Through digital literacy, students are required to have the ability to make maximum use of digital technology so that the need to have soft skills to embrace using their critical thinking disposition and creative thinking ability to relatively influence their educational outcomes. Based on this challenging observations, we hypothesized that students' digital literacy could predict their level of academic achievement. Of note, if students' DL has direct link with their creative thinking ability and critical thinking skill disposition, insight to generate constructive ideas as imperative solutions to the existing learning gaps will emerge. This is because the optimization of digital learning is not only supported by the availability of adequate facilities but also through thinking, developing students' potential in the aspect of creative thinking ability and critical thinking disposition. These creative thinking ability and critical thinking disposition are absolutely needed by the 21st students to adapt to the learning process. One of which will also affect their learning achievement improvement. The level of critical thinking skill disposition is one of the determining factors for the student's success in the learning process. As early as mid-20th century, Facione *et al* (1995) previously revealed that student's critical thinking skill disposition level was not influenced by the length of study time (semester level). They found that students studying mathematics had a higher level of critical thinking skill disposition than students studying Turkish. This indicates that critical thinking skill disposition strengthens the ability to question the validity of mathematical arguments and to test hypotheses logically (Peter, 2012). This definition views critical thinking disposition not only as an analytical process but also as the continuous questioning and development of one's own thoughts.

Hasret and Fatma (2024) described critical thinking skill disposition as individual's ability to analyze complex problems, evaluate information from a critical

perspective, and reach an objective conclusion. Thus critical thinking should be evaluated in terms of both skill and disposition. The critical thinking skill disposition reflects an individual's willingness and readiness to use this skills (Lipman, 2023). This idea represents a person's attitude and motivation to reason rationally and divergently. Previously, Ennis (2018) had demonstrated that critical thinking skill disposition is a complex and challenging process that requires concentration and special training in the thinking and application of skills learned in new situations. On the other hand, this potential may have a positive impact on the individual's creative thinking ability, and this is the kind of intellectual activity that facilitates the constructive reasoning to solve difficult and unresolved issues and uncovers solutions for the unresolved issues. It is on these observations that we hypothesized that students' critical thinking skill disposition could potentially predict their academic achievement during the learning context, mostly when it has a link with digital awareness and creative thinking ability. Of note, creative thinking ability and critical thinking skill disposition play a significant role in many subject domains such as mathematics teaching and learning (Hasert & Fatima, 2024). These two forms of higher-other thinking contribute to individuals' problem-solving, decision-making, and knowledge generation processes. Teachers, in particular have a significant role in fostering students' creative thinking ability and critical thinking skill disposition. Recently, technological advancements signify changes in the skills demanded by the educational institutions. Creative thinking ability and critical thinking skill disposition are among the skills expected of students to engage in digital learning as an approach to facilitate knowledge based development through teaching and learning. At this point, it should be noted that education is the source of the development of these intellectual facilitating skills for learning. For example, research made it clear that creative thinking ability is closely related to divergent thinking pattern where an individual is able to provide more than one solution in solving a particular problem (Warren, *et al*, 2018). An individual's level of creative thinking ability enables him/her to combine unrelated topics in unique and different ways to find new and flexible ideas (Krumm *et al*, 2016).

Taylor and Callohan, (2005) opined that creative thinking ability is related to originality of ideas, openness to new experiences, willingness to accept something new and different or perhaps unreasonable, willingness to accept risks in thoughts and ideas, and sensitive to the beauty of the character of these ideas. It is on this assertion that Warren *et al* (2018) suggested three factors that could influence creative thinking ability such as; fluency (number of ideas), flexibility (diversity of ideas), and authenticity (new and useful idea). In addition to these, (Agnoli *et al*, 2018a, Agnoli *et al*, 2018b) assert that two factors such as; attitude of openness to new experiences and intrinsic motivation that comes from within the students (conation) can predict the level of creative thinking ability. Gralewski and Karwowski (2018) noted that family socio-economic status and extrinsic support (such as intellectual activities at home and the availability of books at home) have a positive effect on students' creative thinking levels, but only during the early stages (when they were children). The influence of these external factors no longer has an effect when a student grows up. Meanwhile, the extrinsic motivation from parents for example in helping children identify their mistakes rather than giving gift, was found to have no effect on the development of a child's creativity. However, a supportive social environment can influence student's creative thinking ability. For example, students that get support from the school to develop their creativity have more creative self-efficacy and become creative individuals (Shin *et al*, 2015). However, student's creative thinking ability can be

hampered by negative social relationship, cultural views, or the environment and obstacles that came from within a person (Warsihna *et al*, 2019).

Creative thinking ability provides students with different ways of solving problems, enabling a deeper understanding of abstract concepts through constructive innovating. This helps students to develop more flexible and versatile thinking skills (Leikin & Sriraman, 2022). On this note, we hypothesized that students' application of creative thinking ability during the learning process could predict their academic achievement if properly strengthened in the area of mathematics and other subjects. Since academic achievement in mathematics has become a subject that requires creative thinking ability, critical thinking skill disposition and digital literacy. Academic achievement has been defined as scores obtained from the examination that measure the extent to which a person has acquired certain information or mastered certain skills, usually as a result of specific instruction (Meherns & Lehman, 2008). It is assumed that the perceptions of students toward their academic peace of mind on digital literacy, critical thinking skill disposition, and creative thinking ability may have a robust relative impact on their academic achievement. Surprisingly, the dramatic increase in the prevalence of poor academic achievement among the secondary school students in many core subjects and the mathematics in particular has broken the traditional view that academic success is the only standard in assessing good students. In the Nigerian settings, it is not only students' academic achievement, but also their learning behaviors are being examined. In the present study digital literacy, critical thinking skill disposition, and creative thinking ability are given considerable attention as panacea to the incessant students' poor academic achievement. To get an optimal learning achievement in the digital native society, digital literacy, creative thinking ability and critical thinking skill disposition could be considered as robust facilitators of students' cognitive development. It could also be assumed that these endogenous variable could jointly predict students' academic achievement both in mathematics and other subjects at the secondary school level in Anambra State.

Despite the fact that, there is paucity of studies on the relations of student's digital literacy, critical thinking skill disposition, creative thinking ability, and their academic achievement at the secondary school level in Anambra State, there are some studies that examined related issue with the western assumptions. For example, Prakoso *et al* (2020) in their study that examined critical thinking, creativity and academic performance in virtual learning, revealed that creativity has a significant and linear relationship with critical thinking disposition, where the higher a person's creativity, the higher their critical thinking disposition and vice versa. Hasret and Fatima (2024) examined creative thinking skills and critical thinking dispositions of post service mathematics teachers, and it was revealed that a medium, positive and significant correlation was found between creative thinking skills and critical thinking disposition of post service mathematics teachers. Furthermore, creative thinking skills of post service mathematics teachers were identified as a significant predictor of critical thinking dispositions explaining 23% of the variance in critical thinking dispositions. Also, the study of Jodion *et al* (2019) on the correlation between critical thinking skills and creative thinking skills on cognitive learning showed a significant correlation between critical thinking skills and creative thinking skills on cognitive learning results. Also, the contribution of critical thinking skills and creative thinking skills simultaneously result to cognitive learning was explained by .78%. The effect contributions of creative thinking skills and critical thinking skills on cognitive learning results was .91%, and 7.39%, respectively. The study of Bagus *et al* (2020) which

examined relationship between creativity, critical thinking and students' academic performance during online learning recorded that creativity has a significant linear relationship with critical thinking. In their remark, creativity and critical thinking could be considered factors that determine students' academic performance. Based on these backdrop, the present study examined students' digital literacy, critical thinking skill disposition, creative thinking ability, and their academic achievement at the secondary level in Anambra State, Nigeria.

Research Questions

The following research questions were raised to guide the study.

1. To what extent are the assumptions of multiple regression equation for predicting students' academic achievement in mathematics scores using their digital literacy, critical thinking skill disposition and creative thinking ability scores?
2. What is the nature of the regression equation for predicting students' academic achievement in mathematics scores using their digital literacy, critical thinking skill disposition and creative thinking ability scores?
3. What is the unique contributions students' digital literacy, critical thinking skill disposition and creative thinking ability scores in predicting their academic achievement in mathematics?
4. Which of the independent variables such as; students' digital literacy, critical thinking skill disposition and creative thinking ability scores that best predicted their academic achievement in mathematics scores?

Hypotheses

The following null hypotheses were tested at .05 level of significance.

1. The regression equation did not significantly predict students' academic achievement in mathematics scores using their digital literacy, critical thinking skill disposition and creative thinking ability scores.
2. The unique contributions of students' digital literacy, critical thinking skill disposition and creative thinking ability scores to predict their academic achievement in mathematics scores was not significant.
3. Students' digital literacy, critical thinking skill disposition and creative thinking ability scores do not significantly predict their academic achievement in mathematics scores.

Methods

The researchers adopted a predictive correlational design and used questionnaires to collect data for the study. The sample size of our study consists of 960 secondary school students in Anambra State. Multi-stage sampling procedure was used to select the respondents. The first stage consisted of randomly sampling 30 secondary schools (five from each education zone) that made up six Education Zones in Anambra State. At the second stage, a simple random sampling technique was used to select 32 students from each secondary school, which resulted to 960 teachers The study adapted standardized research questionnaires namely, students' creative thinking ability using The "How Creative Are You? Scale developed by Whetton and Cameron (2002). Digital literacy was examined with Digital Literacy Scale (DLS) (Wordu *et al*, 2021). Critical Thinking Disposition Scale (CTDS) developed by Sosu (2013) was used to examine students' critical thinking skill disposition. The students' achievement scores were obtained from that state wide Senior Secondary One (SS1) promotion examination in mathematics from the schools before the administration of the instruments. The methods used for validating

the instruments were face and construct validity by the three experts from the Faculty of Education, Nnamdi Azikiwe University Awka. Cronbach's alpha reliability method was used to determine the internal consistency of the items in the research questions and 0.64, 0.73, and 0.67 were obtained for digital literacy, critical thinking skill disposition, and creative thinking ability respectively. The data were analyzed using standard multiple regression analyses. Research question 1 was answered using multiple regression equation. Research question 2 was answered using unstandardized β. Research question 3 was answered using adjusted R^2. Research question 4 was answered using unstandardized β. Hypothesis 1 was tested F-test for regression model. Hypothesis 2 was tested using t-test for adjusted R^2. at .05 alpha level significance. While hypothesis 3 was tested using t-test for β. Then, using multiple regression tool for investigating the study is significant because it is convenient to examine the relationships between multiple variables by relating one variable to a set of variables. This helped to identify the effect of one variable while adjusting for other observable differences. The decision rule for research questions was that the proportion for variable that is below 10% is low, 11% to 30% is moderate, 31% to 50% is high while 51% and above is considered very high according to Cohen's *d* (1988) statistics guideline. The decision rule was to accept the null hypotheses if the p-value was greater than 0.05 level of significance ($p > 0.05$). Reject the null hypotheses if the p-value was less than 0.05 level of significance ($p < 0.05$). Also, Reject the null hypotheses if the p-value was equal to 0.05 level of significance ($p = .05$).

Results

Table 1: Correlation and descriptive statistics of independent and dependent variables in the regression model for this study (N = 865).

Variables	DL	CTSD	CTA	AACH	X	SD	VAR	SK	KU	TF	VIF
DL	1				23.28	3.69	13.62	-.484	-.363	.918	1.089
CTSD	-.285**	1			21.27	3.81	14.51	-.076	-.813	.830	1.205
	.000										
CTA	-.065	.316**	1		20.67	3.75	14.12	.222	-.575	.899	1.112
	.055	.080									
AACH	.303**	-.077**	-.103**	1	21.64	4.01	16.09	-.016	-.695	……	…….
	.918	.830	.002								

Std. Residual Min = -2.409, Std. residual Max = 2.446, Durbin Waston statistics = 1.028. DL = Digital Literacy, CTSD = Critical Thinking Skill Disposition, CTA = Creative Thinking Ability and AACH = Academic Achievement.

Fig 1 the normal P.P plot of standardized residuals data points of students' academic achievement.

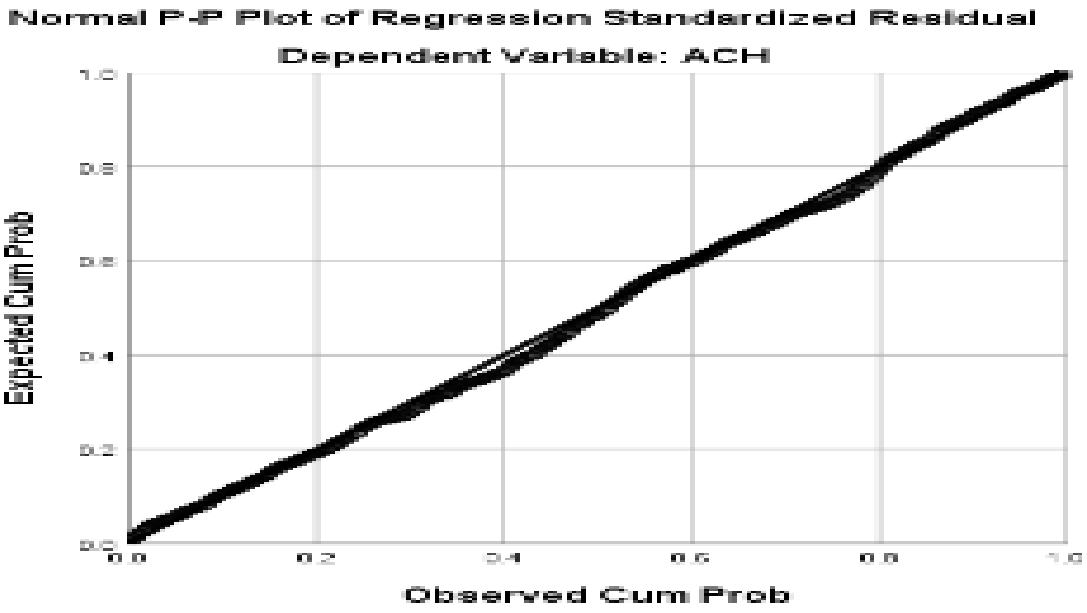


Fig 2 the normal distribution curve of standardized residuals data points of students' academic achievement.

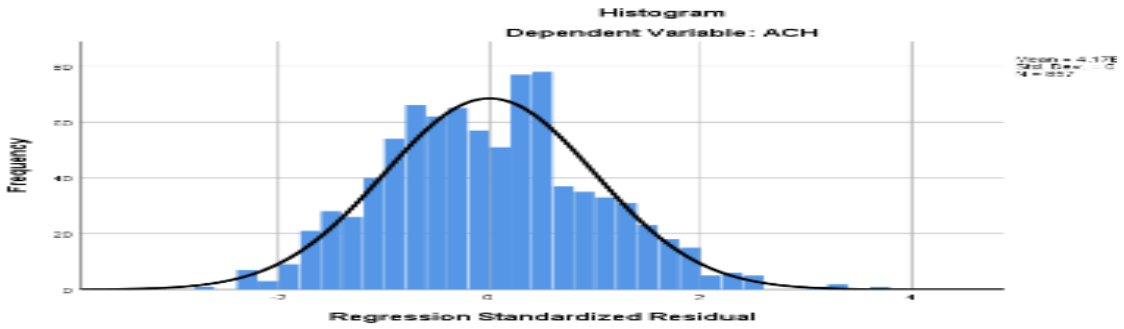
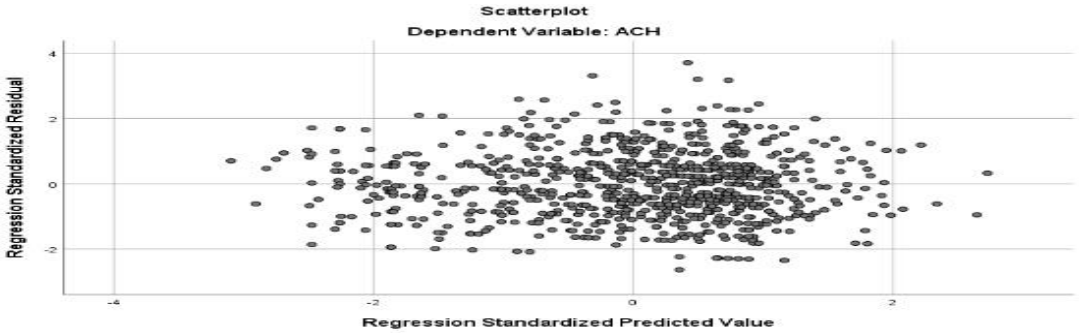


Fig 3 the scatter plot of standardized residuals data points of students' academic achievement.



To answer research question 1, seven assumptions of multiple linear regression were tested in this study. First, the assumptions of normality of the data were tested using Skewness and Kurtosis. The assumptions were made since none of the Skewness and Kurtosis values of each of the variables do not exceed + 3 and – 3 as recommended. Second, the assumptions of absence of multivariate outliers was checked using

standardized residual statistics and Cook's distance statistics (1977). Result of standardized residual values indicated that the (Std, Residual Min = -2.409, Std, Residual Max = 2.446). It lies between -3 to 3 as recommended by (Tabachnick and Fidell, 2018). While the result of the Cook's distance shows a maximum value of .021 which is less than 1 as recommended by (Cook, 1977). Hence, the assumptions of absence of multivariate outliers was not violated. Third, the assumptions of absence of multicollinearity among the predicting variables were checked using Variance Inflated Factor (VIF), and Tolerance Factor (TF). The Tolerance Factors and Variance Inflated Factors (Digital literacy, TF = .918, VIF = 1.089; Critical thinking skill disposition, TF = .830, VIF = 1.205; Creative thinking ability, TF = .899, VIF = 1.112 of the independent variables show that the values were less than 10 for Variance Inflated Factor and greater than .20 for Tolerance Factor respectively as recommended by (Schumaker, 2015). Hence, this assumption of absence of multicollinearity was made. Forth, the assumption of independent of error was tested using Durbin Waston statistics. The result shown a Durbin Waston statistics of .1.028 which is less than 3 but greater than 0 as recommended by (Denis, 2020). Hence, the assumption of independent of error was not violated. Fifth, the assumptions of normality of error distribution were tested using normal P.P plot of standardized residual. Figure 1shows that the normal P.P plot of standardized residual data points were normally distributed. Histogram of the standardized residual in figure 2 also testified to that. Sixth, the assumption of homogeneity of variance and linearity was tested using scatter plot of standardized predicted values. The result in figure 3 shows that the data met the assumption of homogeneity of variance and linearity as the predicted values were distributed above zero in both dimensions and do not show any pattern. Seventh, the assumptions of non-zero variance were tested using variance statistics and the data also met the assumptions of non-zero variances (Digital literacy, Variance = 13.628; Critical thinking skill disposition, Variance = 14.517; Creative thinking ability, Variance = 14.122; Academic achievement, Variance = 16.093) as there is no zero variance for the variables in the study as shown in the table 1.

Table 2: Regression coefficient for digital literacy, critical thinking skill disposition and creative thinking ability scores (N = 865).

Model	Unstandardized βeta	Std. Error	Standardized βeta
Constant	15.032	1.384	
Digital literacy	.335	.037	.309
Critical thinking skill disposition	.043	.037	.041
Creative thinking ability	-.102	.036	-.096

Using the information in table 2, the nature of the regression equation for predicting students' academic achievement in mathematics scores using their digital literacy, critical thinking skill disposition and creative thinking ability scores follows:

Y = b0 + b1x 1 + b2 x 2 + b3 x 3

Y = 15.032+.335 x 1+.041 x 2+ -.102 x 3

Ach = 15.032+ 0.335 + 0.086 - 0.306

Ach = 15.032 + 0.335DL+ 0.086CTSD - 0.306CTA

DL = Digital Literacy, CTSD = Critical Thinking Skill Disposition, CTA = Creative Thinking Ability. The equation shows that for every unit increase in digital literacy,

students' academic achievement in mathematics increased by 0.335 with percentage of (0.039%). For every unit increase in critical thinking skill disposition, students' academic achievement in mathematics increased by 0.066 with percentage of (0.0076%). For every unit decrease in creative thinking ability, students' academic achievement in mathematics decreased by – 0.306 with percentage of (-0.035%).

Table 3: Regression model summary of students' digital literacy, critical thinking skill disposition and creative thinking ability scores in predicting their academic achievement in mathematics (N = 865).

Model	R	R-Square	Adjusted R-Square	Std. Error of the Estimate
	.317[a]	.100	.097	3.81198

To answer this research question, the adjusted multiple regression R square was used. The result of study shows that using students' digital literacy, critical thinking skill disposition and creative thinking ability scores yielded an adjusted R squared of .100. This implies that predictors accounted for about 9.7% of the variance scores in professional competence.

Table 4: Regression coefficient for students' academic achievement in mathematics scores using digital literacy, critical thinking skill disposition and creative thinking ability scores. (N = 865).

Model	Unstandardized βeta	Std. Error	Standardized βeta
Constant	15.032	1.384	
Digital literacy	.335	.037	.309
Critical thinking skill disposition	.043	.037	.041
Creative thinking ability	-.102	.036	-.096

Table 4: Regression coefficient for students' academic achievement in mathematics using their digital literacy, critical thinking skill disposition and creative thinking ability scores. To answer this research question 4, the standardized regression coefficient (β) in table 4 was used for comparison. The regression coefficients presented in table 4 shows unstandardized (β) and standardized regression coefficient (β) digital literacy scores are .335 and .309. For critical thinking skill disposition scores are .043 and .041. For creative thinking ability scores are -.102 and -.096. Using the standardized (β) for comparison, digital literacy mostly predicted students' academic achievement in mathematics as shown by the β of .309 with (0.036%). Critical thinking skill disposition is the second most predicted students' academic achievement in mathematics as shown by the β of .041 with (0.0050%). Creative thinking ability is the third most predicted students' academic achievement in mathematics as shown by the β of -.096 with (-0.011%) respectively.

Table 5: F- test for regression model of students' digital literacy, critical thinking skill disposition, and creative thinking ability scores (N = 865).

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	1393.294	3	64.431	31.961	.000[b]
Residual	12511.323	861	14.531		
Total	13904.617	864			

The analysis of variance in the table 5 shows that the regression equation was significant (3, 861) = 31.961, p < .05. This implies that at least one of the independent variables significantly predicted students' academic achievement scores in mathematics.

Table 6. t-test of adjusted R square of the regression model for this study (N = 865).

Model	R	R- Square	Adjusted R- Square	Std. Error Estimate	t – cal for adj. R^2	DF	t- crt.	Remark
	.317	.100	.097	3.81198	10.3471834399	863	1.960	S

To test hypothesis 2, t-test for adjusted R square was conducted. Results of the study shown in table 6 indicates that t-critical for adjusted R square is 1.960 while that of the t-calculated is 10.3471834399. Since the t-calculated for adjusted R square 10.3471834399 is greater than t-critical 1.960, the null hypothesis which states that the unique contributions of digital literacy, critical thinking skill disposition and creative thinking ability scores to predict students' academic achievement scores in mathematics is not statistically significant is rejected and the alternative hypothesis is accepted. In other words, the unique contributions of digital literacy, critical thinking skill disposition and creative thinking ability scores to predict students' academic achievement scores in mathematics is statistically significant. Effect sizes were also evaluated using adjusted R^2 comparing it with Cohen's *d* statistics guideline, where d < 0.20 indicates a minimal effects size, 0.20 < d < 0.50 indicates a small effect size, 0.50 < d < 0.80 indicates a moderate effect size and d > 0.80 indicates a large effect size. The value of R adjusted square .097 indicates a large effect size.

Table 7: t-test of regression coefficient of students' academic achievement scores in mathematics using digital literacy, critical thinking skill disposition and creative thinking ability scores (N = 865).

Model	Unstandardized βeta	Std. Error	Standardized β	T	P-value	Remark
Constant	15.032	1.384		10.863	.000	S
Digital literacy	.335	.037	3.09	9.144	.000	S
Critical thinking skill disposition	.043	.037	.041	1.158	.247	NS
Creative thinking ability	-.102	.036	-.096	-.2.812	.005	S

Table 7 shows that students' digital literacy and creative thinking ability scores significantly predicted their academic achievement scores in mathematics since their p-

values are smaller than .05. While students' critical thinking skill disposition score does not predict their academic achievement scores in mathematics since the p-value is greater than .05.

Discussion

The findings from the study indicated that the seven assumptions that were tested did not violate the statistical guides being consulted in the process of checking the assumptions. This is an indication that students' digital literacy, critical thinking skill disposition, creative thinking ability and their academic achievement in mathematics represent and reflect on both agentic and social constructive desire to engage meaningfully in problem solving that involve rational reasoning in the digital native society. In the study, it was indicated that the relationship between students' digital literacy, and critical thinking skill disposition was negatively and significantly low. The relationship between digital literacy and creative thinking ability was moderately and significantly positive. The relationship between creative thinking ability and critical thinking skill disposition was moderately positive but not significant. The study also indicated that the relationship among students' digital literacy, critical thinking skill disposition, creative thinking ability and their academic achievement in mathematics was negatively and significantly low. This shows an interactive and compensatory beliefs within the minds of the students in using their digital skills in relation with critical thinking skill disposition and creative thinking ability in solving difficult intelligent problems that involves constructive approach. The positive and negative relationship being recorded in the present study supported some of the studies that were revealed in the literature. For example, the study of Prakoso *et al* (2020) revealed that creativity has a significant and linear relationship with critical thinking disposition, where the higher a person's creativity, the higher their critical thinking disposition and vice versa. In the study of Hasret and Fatima (2024) it was revealed that a medium, positive and significant correlation was found between creative thinking skills and critical thinking disposition of post service mathematics teachers. This also supported the study of the study of Jodion *et al* (2019) which showed that there was a significant correlation between critical thinking skills and creative thinking skills on cognitive learning results. The present finding also supported the study of Bagus *et al* (2020) which recorded that creativity has a significant linear relationship with critical thinking.

The findings from the result revealed that on the nature of regression equation, digital literacy and critical thinking skill disposition contributed positively to the predicting model. That is for every unit increase in digital literacy and critical thinking skill disposition, academic achievement in mathematics increased respectively and this will enhance solving cognitive problems that involve constructive reasoning in the digital native society increased respectively. While the creative thinking ability contributed negatively to the predicting model. It shows that for every unit decrease in creative thinking ability, academic achievement in mathematics decreased in that process. This implies that students' willingness to use their creative thinking ability has negative low influence in the process of learning mathematics. This supported the study of the study of Jodion *et al* (2019) which reported that the contributions of critical thinking skills and creative thinking skills were simultaneously to cognitive learning results. The effect contributions of creative thinking skills and critical thinking skills on cognitive learning were relatively low in percentage rating.

Findings from the study also indicate that the independent variables have roles to play on students' academic achievement in mathematics. For example, when students'

levels of digital literacy and critical thinking skill disposition, and creative thinking ability scores are moderately and positively low, their level of willingness to confidently adjust and engage in learning mathematics will either be moderately or lowly influenced. Also, when the students' creative thinking ability level is negatively low, it could impact on their desire to learn mathematics at the negative low level. Finding in the study using effect sizes to evaluate the contribution of adjusted R^2 to compare it with Cohen's *d* statistics guideline, the value of R adjusted square indicates a large effect. This shows that willingness to learn mathematics is increasing considering the personality constructs being tested in the present study. This shows that the level of intricate interplay that collectively links students' digital literacy, critical thinking skill disposition, and creative thinking ability scores has large effect in predicting their academic achievement scores in mathematics.

Conclusion

From the findings of the study, it was concluded that the relative and intricate interaction of students' digital literacy, critical thinking skill disposition and creative thinking ability scores significantly predicted their academic achievement in mathematics. This was found in the present study that the regression model of digital literacy, critical thinking skill disposition and creative thinking ability scores was significant.

Recommendations

Based on the findings, the following recommendations were made:

1. As a result of the significant contribution of students' digital literacy, critical thinking skill disposition, and creative thinking ability on their academic achivement, it is important for students to adopt these learning behaviours in all the education institutions expecially with the expansion of digital literacyon a global scale.
2. It was also recommended that further improvements can be made in developing students' digital literacy, critical thinking skill disposition, and creative thinking ability, expecially on creative thinking ability that conributed negatively in predicting their academic achievement.
3. In this regard, teacher training programs should be restructured to deeply support students' digital literacy, critical thinking skill disposition, and creative thinking ability to actualise a positive cognitive outcome.
4. The researchers obtained insights through these quantitative method, but recommend that another method such as in-depth interview method should be used in the future research which will record another meaningful contribution.

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