

AI-Facilitated Self-Directed Learning and Mathematics Performance: A Mixed-Methods Study on ChatGPT Use among Generation Z Students

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Abstract

The rapid adoption of generative artificial intelligence (AI) tools such as ChatGPT has raised important questions about how AI-supported learning relates to students' self-directed learning (SDL) and mathematics achievement, particularly among Generation Z learners. This study examined the relationship between AI-facilitated SDL and mathematics performance using a convergent mixed-methods design among junior high school students in accredited public schools in the Philippines. A total of 272 Grade 7–10 students completed the Self-Rating Scale of Self-Directed Learning (SRSSDL) and an AI/ChatGPT Use and Engagement questionnaire, and their responses were linked to standardized mathematics assessment scores. In addition, 73 students participated in focus group discussions to describe how they used ChatGPT for mathematics learning. Quantitative results showed that most students demonstrated moderate SDL readiness (47.79%), while 29.41% exhibited high SDL and 22.79% showed low SDL. SRSSDL scores were strongly and positively correlated with mathematics performance ($r = .849, p < .001$), whereas ChatGPT usage showed a weak but significant positive correlation with performance ($r = .227, p < .001$). SRSSDL and ChatGPT usage were not significantly related ($r = .080, p = .187$). Multiple regression indicated that SDL readiness and ChatGPT usage significantly predicted mathematics performance ($R^2 = .746$), with SDL emerging as the dominant predictor ($\beta = .836, p < .001$) and ChatGPT usage contributing a smaller but significant effect ($\beta = .159, p < .001$). Qualitative thematic analysis yielded three themes: (1) Personalized support and motivation, (2) Challenges in critical thinking and overreliance, and (3) ChatGPT as a learning companion, indicating that the benefits of ChatGPT depend on how intentionally and critically it is used. Integrated findings suggest that while ChatGPT may provide supplementary support, SDL readiness remains the primary driver of mathematics achievement, and responsible AI use practices are necessary to minimize risks such as overreliance and reduced independent reasoning.

Keywords: Self-directed learning, ChatGPT, Generation Z, Mathematics education, AI in education, Mixed-methods

Citation

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Introduction

The rapid advancement of artificial intelligence (AI) and digital technologies is transforming how education is delivered and experienced, with tools such as ChatGPT providing learners instant feedback, adaptive support, and access to vast information resources across formal and informal learning contexts (Singh et al., 2024). In mathematics education, AI integration has been promoted for its capacity to personalize instruction, streamline repetitive tasks, and respond to learners' questions in real time (Harry & Sayudin, 2023; Zreik, 2024). However, despite increased adoption, the impact of AI on mathematics learning outcomes remains debated, with limited consensus on whether these tools produce meaningful gains in mathematical understanding beyond increased engagement and convenience (How & Hung, 2019; Ali et al., 2023; Ní Shé et al., 2023). This concern is especially salient given that many learners continue to struggle with higher-order competencies such as reasoning and problem-solving, suggesting that technology alone may be insufficient to address persistent learning difficulties (Maskar et al., 2023). At the same time, these developments intersect with the learning profile of Generation Z—often characterized as digitally native students who are highly comfortable with online platforms and inclined toward self-directed learning (SDL), where they seek information independently and learn at their own pace (Gabriellova & Buchko, 2021; Lee et al., 2015; Dimock, 2019; Shatto & Erwin, 2016; Pousson & Myers, 2018). Their near-constant online presence further indicates strong tendencies toward self-initiated learning behaviors, positioning AI tools like ChatGPT as increasingly embedded in their academic routines (Anderson & Jiang, 2018).

Against this backdrop, AI tools have been widely viewed as supports for SDL because they can offer personalized feedback, adaptive practice, and step-by-step guidance—features that align with independent learning preferences in cognitively demanding subjects like mathematics (Darmayanti, 2024). Yet, research also warns that without sufficient guidance and self-regulation, students may develop patterns of overreliance that encourage surface-level engagement rather than deep learning, raising questions about whether AI-supported SDL cultivates genuine mathematical understanding or simply facilitates task completion (Ali et al., 2023; Ní Shé et al., 2023; Banitt & Van Leeuwe, 2013). These questions are particularly urgent in contexts such as the Philippines, where international assessments continue to show persistent challenges in mathematics achievement, including low performance in PISA 2022 and TIMSS 2019 (Foster & Schleicher, 2022; Orbeta & Pacqueo, 2022; Olesco et al., 2024). Consequently, the present study, *AI-Facilitated Self-Directed Learning and Mathematics Performance: A Mixed-Methods Study on ChatGPT Use Among Generation Z Students*, examines how junior high school Gen Z learners engage with ChatGPT as part of their independent study routines and investigates whether such engagement supports deeper conceptual understanding and improved mathematics performance or primarily serves as a shortcut for completing tasks.

Review of Related Literature

Self-directed learning as a foundation for independent mathematics learning

Self-directed learning (SDL) is commonly framed as learners' capacity to take initiative in diagnosing learning needs, setting goals, selecting strategies and resources, monitoring progress, and evaluating outcomes—processes that are particularly important in mathematics where sustained practice and self-monitoring are essential for mastery. A widely used instrument for operationalizing SDL is Williamson's Self-Rating Scale of Self-Directed Learning (SRSSDL), which was developed and tested as a structured measure of SDL skills and dispositions (Williamson, 2007). Validation work has further examined the SRSSDL's factor structure and provided evidence supporting its use as a practical measure of SDL dimensions (e.g., awareness, learning strategies, learning activities, evaluation, and interpersonal skills), strengthening its relevance for studies that treat SDL as a measurable learner attribute connected to academic outcomes (Cadorin et al., 2013).

Generative AI and ChatGPT in education: opportunities and unresolved concerns

The release and rapid diffusion of generative AI systems—especially ChatGPT—has accelerated research on AI-supported learning, with reported opportunities including on-demand explanations, feedback, idea generation, and personalized support. UNESCO's global guidance emphasizes that generative AI can expand learning support but also raises major concerns related to ethics, privacy, assessment integrity, bias, and the need for human-centered and policy-guided implementation (UNESCO, 2026). Consistent with this, recent systematic reviews of ChatGPT in education synthesize emerging evidence showing broad applications (tutoring-like support, writing/feedback assistance, instructional planning), while also highlighting risks such as hallucinations, academic misconduct,

unequal access, and inconsistent learning benefits depending on how the tool is used and scaffolded (Munaye et al., 2025).

ChatGPT in mathematics learning: tutoring potential but mixed evidence on performance gains

In mathematics education, ChatGPT is increasingly explored as a “tutor-like” support that can provide worked explanations and conversational guidance. Recent classroom-based research in high school mathematics (e.g., learning quadratic functions) illustrates how ChatGPT may be integrated into instruction to support learning tasks and discussion, often reporting positive engagement and instructional possibilities (Trocado et al., 2025). However, the broader literature remains cautious: while AI tools can improve access to explanations and support practice, evidence is still developing on whether such use reliably produces *improvements in mathematical performance* and *deep conceptual understanding*—especially when students may use AI outputs as shortcuts rather than as prompts for reasoning (Munaye et al., 2025).

Risks relevant to “AI-facilitated SDL”: automation misuse, overreliance, and shallow processing

A critical thread in human–automation research warns that users may **misuse** automation—over-trusting outputs even when they are incorrect—especially when monitoring is reduced or when systems appear authoritative. Parasuraman and Riley’s framework (“use, misuse, disuse, abuse”) remains foundational for understanding how automated aids can unintentionally shift users toward complacency and reduced verification (Parasuraman & Riley, 1997). Recent education-adjacent evidence also suggests that overreliance on ChatGPT recommendations can persist even after short AI-literacy interventions; for instance, a randomized study with high school seniors found substantial adoption of incorrect ChatGPT suggestions in problem-solving contexts (reported as a preprint), underscoring that “knowing the limitations” may not automatically translate into better judgment during use (Puppert & Aru, 2025). These findings are directly relevant to SDL because effective self-directed learning depends on metacognitive monitoring and evaluation—skills that can be weakened when learners outsource reasoning or accept answers without verification.

Generation Z learners and digital learning behaviors

Generation Z is frequently described as a cohort shaped by pervasive digital technology and internet-based information access. Pew Research Center’s generational framing marks Gen Z as those born from 1997 onward, making them the first cohort to move through schooling in an environment of ubiquitous online tools (Geiger, 2025). In parallel, national survey data on teens’ technology use highlight heavy engagement with online platforms and digital communication—conditions that can normalize quick information seeking and tool-mediated learning behaviors (Anderson & Anderson, 2024). This learning ecology helps explain why ChatGPT can become embedded in students’ independent study routines, making it important to examine not only frequency of use but also *how* learners use it for explanations, checking solutions, generating steps, or replacing effort.

The urgency of strengthening mathematics learning in low-performing contexts

International assessment results underscore persistent challenges in mathematics achievement in the Philippines. The OECD’s PISA 2022 country note reports very low proportions of top performers in mathematics and highlights systemic factors associated with performance differences (*PISA 2022 Results (Volume I)*, 2023). Complementary reporting on TIMSS 2019 likewise indicates very low average performance among Filipino learners at the primary level, reinforcing the need for interventions that strengthen foundational and higher-order mathematical competencies (Ornedo, 2020). Within this context, AI-supported learning approaches are attractive—but they require evidence showing whether they genuinely improve understanding and achievement rather than merely increasing completion and convenience.

Synthesis and RRL implication for the present study

Taken together, the literature suggests that ChatGPT has plausible value as an on-demand support that *could* align with SDL (planning, strategy use, self-checking, evaluation). Yet, major uncertainties remain regarding whether AI use actually strengthens the SDL processes that matter for mathematics performance, or whether it introduces patterns of overreliance consistent with known human–automation risks. This supports the need for a mixed-methods approach that links (1) measurable SDL dimensions and ChatGPT engagement patterns with (2) mathematics performance outcomes, while also documenting learners’ real-use behaviors and decision-making

during AI-assisted study—particularly among Generation Z students in contexts where mathematics achievement remains an urgent concern.

Method

Research Design

This study employed a convergent mixed-methods design in which quantitative and qualitative data were collected during the same period, analyzed separately, and then integrated to generate a more comprehensive understanding of the relationship between AI-facilitated self-directed learning (SDL) and mathematics performance among Generation Z students. The quantitative strand used a non-experimental correlational design to examine associations between SDL readiness (SRSSDL), AI/ChatGPT use patterns, and standardized mathematics assessment scores. The qualitative strand used focus group discussions (FGDs) to explore how students use ChatGPT for mathematics learning, including perceived benefits, challenges, verification practices, and possible overreliance. Integration occurred during interpretation through comparison of quantitative trends and qualitative themes.

Sampling and Participants

The study was conducted in accredited public junior high schools in the Philippines during March–April 2024. The sampling frame comprised learners currently enrolled in Grades 7–10 who had completed school-based mathematics assessments. A pragmatic purposive sampling approach was implemented across intact sections with the cooperation of school administrators and teachers. The study focused on learners who reported prior or current use of AI tools (e.g., ChatGPT) for mathematics study, screened in-class using a brief item.

Eligibility criteria included: (a) parental/guardian consent and student assent; (b) ability to complete surveys in English/Filipino; (c) willingness to link survey responses to school mathematics test scores; and (d) attendance during the data-collection window. Students whose mathematics scores could not be matched to survey IDs or who lacked consent/assent were excluded. Learners with SPED needs and accommodations were included when consent was provided and appropriate supports were available.

A total of $N = 272$ students met inclusion criteria and completed the quantitative survey battery. Participant characteristics are summarized in Table 1. For the qualitative strand, 73 students volunteered and were organized into FGDs of 6–10 participants to encourage interaction and depth. Because sampling purposively targeted students who already use AI for mathematics, the sample was appropriate for examining AI-supported SDL in relation to outcomes but was not designed to estimate the prevalence of AI use among all learners.

Table 1. Descriptive characteristics of survey participants and FGD volunteers

Variable	Category	Survey participants (N=272) n (%)	FGD volunteers (n=73) n (%)
Grade level	Grade 7	78 (28.7)	22 (30.1)
	Grade 8	70 (25.7)	19 (26.0)
	Grade 9	66 (24.3)	17 (23.3)
	Grade 10	58 (21.3)	15 (20.5)
Sex	Female	160 (58.8)	44 (60.3)
	Male	112 (41.2)	29 (39.7)
Age	Range	12–16	12–16
	Mean (SD)	14.1 (1.1)	14.2 (1.1)

AI use (math study)	Prior ChatGPT use	239 (87.9)	69 (94.5)
Other AI tools*	Photomath	122 (44.9)	38 (52.1)
	Google Gemini/Bard	76 (27.9)	22 (30.1)
	Microsoft Copilot	49 (18.0)	13 (17.8)

*Multiple responses allowed; percentages may exceed 100%.

Instruments

Self-Directed Learning Readiness (SRSSDL)

Students' readiness for self-directed learning was assessed using the Self-Rating Scale of Self-Directed Learning (SRSSDL) developed by Williamson (2007). The SRSSDL measures initiative, independence, and responsibility in managing one's learning. Total scores range from 60 to 300, categorized as: Low SDL (60–140), Moderate SDL (141–220), and High SDL (221–300) (Table 2). Higher scores indicate stronger readiness for SDL. The SRSSDL has demonstrated strong internal consistency (Cadorin, Williamson, & Seewoodhary, 2017) and acceptable content validity (Williamson, 2007).

Table 2. Self-Directed Learning Readiness Score Categories
Overall Self-directed Learning Readiness Score

Ranges	Level	Interpretation
60-140	Low	Guidance is needed from the instructor. Any specific changes necessary for improvement must be determined and a possible restructuring of the methods of learning identified.
141-220	Moderate	This range is half-way to becoming a self-directed learner. Areas for improvement must be identified and evaluated, and a strategy adopted with instructor guidance when necessary.
221-300	High	This range indicates effective self-directed learning. The goal is to maintain progress by identifying strengths and methods for consolidation of the student's effective self-directed learning.

The SRSSDL consists of five categories (12 items each plus an optional comment item): Awareness, Learning Strategies, Learning Activities, Evaluation, and Interpersonal Skills. Items are rated on a 5-point Likert scale (5 = Always to 1 = Never). Each category includes an "Any other" response space to capture additional student inputs not addressed by fixed items, as shown in Table 3.

Table 3. SRSSDL Category Definitions of Self-Directed Learner Attributes
SRSSDL Category Definitions of Self-directed Learner Attributes

Attributes	Score Range	Category Definitions
Awareness	1-60	Learner's understanding of factors that contribute to becoming a self-directed learner.
Learning Strategies	1-60	Various strategies self-directed learners should adopt in order to become self-directed in their own learning processes.
Learning Activities	1-60	Requisite learning activities learners should actively engage in order to become self-directed in their learning processes.
Evaluation	1-60	Learner specific attributes in order to help monitor their learning activities.
Interpersonal Skills	1-60	Learner skills focused on interpersonal relationships, which are pre-requisite to becoming self-directed learners.

AI/ChatGPT Use and Engagement Survey

To characterize AI-supported learning behaviors, students completed a short AI/ChatGPT Use and Engagement questionnaire. This measured: frequency of ChatGPT use for mathematics, common purposes like explanations, solution checking, step-by-step guidance, practice generation), reliance patterns, and verification behaviors like checking answers with notes/teacher/resources). Items were rated on a Likert scale with optional open-ended responses.

Mathematics Performance Measure

Mathematics performance was measured using standardized mathematics scores retrieved from school records (school-based mathematics assessments). Scores were accessed through a data-sharing agreement and linked to survey responses using anonymized codes. This approach ensured performance data reflected authentic school assessment outcomes during the study period.

Focus Group Discussion Guide

A semi-structured FGD guide was used to explore how learners use ChatGPT in mathematics study, including prompting habits, help-seeking decisions, verification practices, perceived learning gains (conceptual understanding vs task completion), and challenges such as confusion, misinformation, or dependence. FGDs were audio-recorded with participant permission.

Data Collection Procedures

After securing permissions from school authorities and obtaining ethical clearance, data collection was implemented in several coordinated steps. Students from selected intact sections were first screened in class using a brief item to determine prior or current use of AI tools (e.g., ChatGPT) for mathematics learning, and those who met the eligibility criteria were invited to participate. The researchers then explained the purpose of the study, confidentiality safeguards, voluntary participation, and the right to withdraw at any time without penalty, after which parental/guardian consent and student assent were obtained. Quantitative data were gathered through the administration of the SRSSDL and the AI/ChatGPT engagement questionnaire during school hours in classrooms

or designated research areas. To measure mathematics performance, standardized mathematics scores were retrieved from official school records under a data-sharing agreement and were linked to survey responses using anonymized participant codes to ensure that no identifying information appeared in the dataset. For the qualitative strand, students who volunteered were scheduled for focus group discussions (FGDs) conducted on campus in groups of 6–10 participants; these sessions were held in a quiet venue, audio-recorded with permission, and facilitated in a manner that minimized disruption to regular classes. Throughout the process, all survey data, linked scores, and audio files were managed securely, with identifiers removed and access restricted to the research team to protect participants' privacy.

Data Analysis

Quantitative Analysis

Quantitative data were analyzed using appropriate statistical software. The analysis began with descriptive statistics, including means, standard deviations, frequencies, and percentages, to summarize SRSSDL readiness levels, patterns of ChatGPT use and engagement, and students' mathematics performance scores. To establish the internal consistency of the instruments, reliability testing was conducted (e.g., Cronbach's alpha) for both the SRSSDL and the AI/ChatGPT engagement questionnaire. Relationships among self-directed learning readiness, ChatGPT engagement, and mathematics performance were then examined using correlation analysis, applying Pearson's r when assumptions of normality were met and Spearman's ρ when normality was violated. Finally, multiple regression analysis was performed to determine whether SDL readiness and ChatGPT engagement significantly predicted mathematics performance, with additional control variables such as grade level, sex, or access-related indicators included when available and appropriate.

Qualitative Analysis

Audio recordings were transcribed verbatim. Data were analyzed using thematic analysis, involving familiarization, initial coding, theme development, theme review, and refinement. Trustworthiness was enhanced through strategies such as code review/peer debriefing, maintaining an audit trail, and participant validation of key points when feasible.

Mixed-Methods Integration

Results were integrated using triangulation and a joint display approach. Quantitative findings (e.g., whether ChatGPT engagement is associated with performance and SDL level) were compared with qualitative themes (e.g., how students use ChatGPT: explanation-seeking vs answer-copying; verification behaviors; overreliance). Convergent, complementary, or divergent patterns were identified to strengthen interpretation.

Ethical Considerations

The study complied with the Data Privacy Act of 2012 (RA 10173). Participants were informed about the purpose of the study, voluntary participation, confidentiality, and the right to withdraw at any time without penalty. Survey responses were anonymized, and mathematics scores were linked using codes rather than names. Data were stored securely and accessed only by the research team.

Results and Discussion

Self-Directed Learning (SDL) Levels of Generation Z Students

To evaluate students' levels of self-directed learning (SDL), the study administered the Self-Rating Scale of Self-Directed Learning (SRSSDL; Williamson, 2007) to 272 junior high school students. SRSSDL scores were categorized into Low (60–140), Moderate (141–220), and High (221–300). Results showed that the majority of students (130; 47.79%) were at the moderate SDL level, indicating developing capacity to plan, implement, and evaluate their learning. Meanwhile, 80 students (29.41%) demonstrated high SDL, and 62 students (22.79%) fell within the low SDL category.

From a theoretical standpoint, this distribution is consistent with Knowles' SDL perspective, which treats SDL as a developmental capability rather than a fixed attribute. The predominance of moderate SDL suggests that many learners are in a transitional stage—capable of some independent learning behaviors but still needing structured support for goal-setting, monitoring, and evaluation. In mathematics, where learning requires persistence and metacognitive monitoring, students in the low SDL group may be at greater risk for disengagement and reliance

on external assistance. This underscores the importance of explicitly teaching SDL-related skills like planning routines, reflection prompts, self-checking strategies) as part of mathematics instruction.

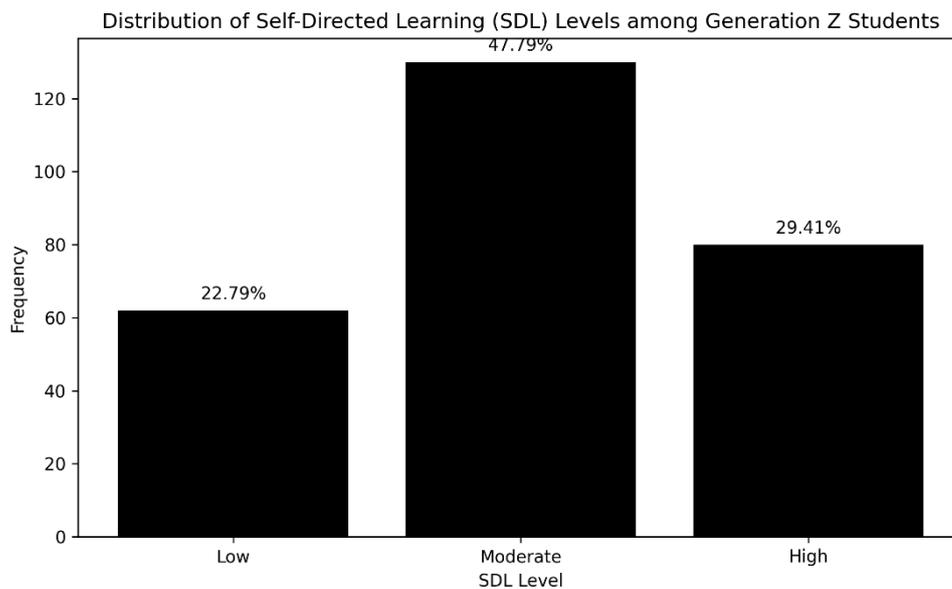


Figure 1. Distribution of Self-Directed Learning (SDL) Levels among Generation Z Students based on SRSSDL scores (N = 272).

Descriptive Statistics of Key Variables

Table 4. Descriptive Statistics of Key Variables

Variable	Mean	Standard Deviation	Minimum	Maximum
SRSSDL Score	187.89	52.10	82	295
ChatGPT Usage Score	3.89	0.98	1	5
Mathematics Performance	85.58	7.28	75	96

Note: ChatGPT usage score is based on a 5-point Likert scale (1 = Never, 5 = Always). Mathematics performance is based on standardized test scores.

Table 4 presents descriptive statistics for SRSSDL, ChatGPT usage, and mathematics performance. The average SRSSDL score ($M = 187.89$, $SD = 52.10$) indicates moderate SDL readiness overall, reinforcing the categorical distribution. ChatGPT usage (5-point scale: 1 = Never to 5 = Always) yielded a mean of $M = 3.89$ ($SD = 0.98$), suggesting that students frequently used ChatGPT to support mathematics learning. Mathematics performance was relatively high ($M = 85.58$, $SD = 7.28$, range 75–96) based on standardized assessments. The variability in SRSSDL, ChatGPT usage, and performance suggests sufficient dispersion to examine relationships among these variables.

Interpreting these patterns through Cognitive Load Theory (CLT) provides an explanatory lens: mathematics tasks often impose high intrinsic cognitive load, and AI tools may reduce barriers by providing immediate explanations or structured steps. However, CLT also cautions that supports can become counterproductive if they reduce productive struggle or shift attention to superficial cues rather than essential reasoning. Thus, frequent ChatGPT use may reflect perceived utility, but its learning value depends on whether it supports schema-building (germane load) rather than simply reducing effort.

Reliability of Instruments

Table 5. Reliability coefficients (Cronbach's alpha)

Instrument	Subscale	Cronbach's α
SRSSDL	Overall	.95
	Awareness	.88
	Learning Strategies	.91
	Learning Activities	.89

	Evaluation	.90
	Interpersonal Skills	.87
AI/ChatGPT Engagement	Overall	.86

Correlation Analysis

Pearson correlation analysis examined relationships among SDL readiness (SRSSDL), ChatGPT usage, and mathematics performance (Table 5). Results showed a very strong positive correlation between SRSSDL scores and mathematics performance ($r = .849, p < .001$). This indicates that students with higher SDL readiness tended to achieve substantially higher mathematics scores. The strength of this association suggests that SDL-related competencies—such as strategic learning behaviors and evaluative monitoring—are highly aligned with successful performance in mathematics.

Table 6. Pearson Correlation Coefficients Among Key Variables (N = 272)

Variable	1	2	3
1. SRSSDL Score	—		
2. ChatGPT Usage Score	.080	—	
3. Math Performance Score	.849**	.227**	—

Note. ChatGPT usage score is based on a 5-point Likert scale (1 = Never, 5 = Always).
** $p < .01$ (2-tailed)

ChatGPT usage showed a weak but statistically significant positive correlation with mathematics performance ($r = .227, p < .001$). This indicates that higher ChatGPT usage is associated with slightly higher performance, but the effect is modest. A theoretically grounded interpretation is that ChatGPT may function as a supplemental learning aid—offering feedback, explanations, and examples that can help students proceed when encountering difficulties, especially during independent study.

In contrast, the relationship between SRSSDL and ChatGPT usage was very weak and not statistically significant ($r = .080, p = .187$). This suggests that students' SDL readiness does not meaningfully predict how frequently they use ChatGPT; students across low to high SDL levels may use the tool. This is an important quantitative insight because it implies that use is widespread, but it does not indicate whether the tool is being used strategically or passively—an issue that is crucial when interpreting the modest correlation between ChatGPT use and performance.

Critical Evaluation

Although ChatGPT usage is positively related to mathematics performance, the small effect size suggests that frequency of use alone is not a strong driver of achievement. Several theoretical risks help explain why this relationship may be weak and why potential negative effects must still be considered even when correlations are positive. From the perspective of cognitive offloading, students may outsource key steps or reasoning to AI, reducing deep processing and weakening long-term retention, which can limit performance gains. Relatedly, automation bias or overtrust may occur when learners accept AI outputs as correct without verification; in mathematics, this can reinforce misconceptions and lead to errors during assessments. In addition, frequent AI use may reflect help-seeking pathologies, where support-seeking becomes maladaptive—such as asking for solutions too early or relying on the tool instead of persisting through problem-solving—thereby reducing effort and practice opportunities. Finally, the illusion of understanding may arise when students feel they have learned after reading AI-generated explanations but struggle to apply the reasoning independently during tests. Taken together, these risks do not contradict the positive correlation; instead, they imply that the educational value of ChatGPT likely depends on the quality of engagement which including verification, reflection, and attempt-first behavior—which cannot be fully captured by frequency measures alone.

Long-term considerations of AI use

Given the weak association between ChatGPT usage and mathematics performance ($r = .227$) and its smaller unique contribution in regression ($\beta = .159$) compared with SDL ($\beta = .836$), increased frequency of AI use alone may not produce proportionate learning gains. Consequently, the long-term normalization of ChatGPT in mathematics warrants attention to risks of overuse, dependency, and academic integrity. Habitual reliance may reduce persistence and metacognitive monitoring, encouraging convenience over productive struggle, while uncritical use can blur the line between legitimate support (explanations, hints) and misconduct (copying complete solutions), potentially compromising assessment validity and masking misconceptions. These concerns highlight

the need for sustained AI literacy, verification habits, self-regulation, and clear school policies defining acceptable use and requiring evidence of reasoning.

Regression Analysis

Multiple linear regression was conducted to determine whether SDL readiness and ChatGPT usage predict mathematics performance. The model explained 74.6% of the variance in mathematics performance ($R^2 = .746$; Adjusted $R^2 = .744$) and was statistically significant, $F(2, 269) = 395.180$, $p < .001$, indicating strong predictive power when both predictors are considered simultaneously. Both predictors were significant: SRSSDL score ($\beta = .836$, $p < .001$) and ChatGPT usage ($\beta = .159$, $p < .001$). This suggests that higher SDL readiness is the primary predictor of mathematics performance, while ChatGPT usage contributes a smaller but statistically significant incremental effect.

Theoretically, this pattern aligns with SDL and self-regulation perspectives: students who can manage their learning (planning, strategy use, monitoring, evaluation) are more likely to succeed in mathematics, regardless of tool availability. The smaller positive coefficient for ChatGPT usage suggests that AI tools may provide supplementary support, but they do not substitute for SDL competencies. Importantly, given the potential risks of cognitive offloading and automation bias, these findings support a cautious interpretation: ChatGPT may enhance performance when used as a scaffold that complements SDL (e.g., prompting explanation, checking reasoning), but it could become counterproductive if it reduces independent reasoning and evaluation—especially for students in the low SDL group.

Table 7. Model Summary of the Regression Analysis on Mathematics Performance

Model	R	R Square	Adjusted R Square
1	0.864	0.746	0.744

Table 8. ANOVA Table for the Regression Model Predicting Mathematics Performance

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	10769.102	2	5384.551	395.180	< .001
Residual	3665.277	269	13.626		
Total	14434.379	271			

Table 9. Regression Coefficients for Predicting Mathematics Performance

Predictor	B	Std. Error	Beta	t	Sig.
(Constant)	58.984	1.179	–	50.04	< .001
SRSSDL Score	0.117	0.004	0.836	27.129	< .001
ChatGPT Usage	1.188	0.23	0.159	5.171	< .001

Overall Quantitative Interpretation

Overall, the quantitative findings indicate that self-directed learning readiness is strongly associated with and predictive of mathematics performance, while ChatGPT usage shows a weaker but significant positive relationship with performance. These results imply that AI tools may add value, but the dominant factor remains learners' SDL capacity. To maximize benefits and minimize harms suggested by theory, schools may need to pair AI access with explicit instruction in verification habits, reflective use, and metacognitive monitoring so that AI functions as a facilitator of learning rather than a shortcut.

Qualitative Results and Discussion

Coding Process and Trustworthiness

Focus group discussion transcripts were analyzed using thematic analysis. The researchers began with familiarization by reading transcripts repeatedly to understand the overall meanings in students' accounts. Responses were segmented into meaning units and assigned initial open codes capturing patterns of ChatGPT use

in mathematics learning example explanation-seeking, step-by-step guidance, prompt refinement, verification, and shortcut behaviors). Through constant comparison across participants and groups, codes were refined (merged, split, and clarified), organized into categories, and clustered into subthemes. Subthemes were subsequently consolidated into overarching themes that represented consistent patterns across the dataset. A coding trail (Table 9) illustrates how representative excerpts progressed from raw statements to codes, subthemes, and final themes.

Table 10. Coding trail

Excerpt (condensed)	Initial code	Subtheme	Theme
“I ask ChatGPT when I’m stuck; it gives steps.”	Step-by-step support	Accessibility & convenience	Personalized support and motivation
“I try first then check; I’m not scared to be wrong.”	Confidence to attempt	Confidence & independence	Personalized support and motivation
“Sometimes I just copy the solution.”	Shortcut behavior	Passive learning tendencies	Challenges in critical thinking & overreliance
“It became easy so I stopped solving before asking.”	Reduced persistence	Reduced effort/persistence	Challenges in critical thinking & overreliance
“I ask again in a different way until it makes sense.”	Prompt refinement	Iterative questioning	ChatGPT as a learning companion
“It doesn’t judge me; I can ask many times.”	Judgment-free support	Emotional comfort	ChatGPT as a learning companion

Trustworthiness and Triangulation

Credibility was strengthened through methodological triangulation by linking the qualitative themes to the study’s quantitative measures (SRSSDL dimensions, ChatGPT engagement indicators, and standardized mathematics performance). Rather than treating the qualitative findings as separate, the researchers used them to clarify *how* students’ reported ChatGPT practices relate conceptually to SDL processes (planning, strategy use, monitoring, evaluation) and to plausible performance outcomes. Dependability was supported by maintaining an audit trail documenting coding decisions, codebook revisions, and theme refinements. Confirmability was strengthened through reflexive memoing and peer debriefing to check theme coherence and reduce researcher bias. Transferability was addressed through contextual description and representative quotations for each subtheme, enabling readers to judge applicability to similar junior high school contexts.

Thematic analysis yielded three major themes, each with two subthemes, reflecting Generation Z students’ experiences of using ChatGPT in support of their self-directed learning in mathematics. These themes offer insight into both the benefits and challenges of AI-enhanced learning.

Theme 1: Personalized Support and Motivation

This theme highlights the role of ChatGPT as a supportive and accessible learning tool that enhances students’ motivation and encourages independent learning. Many students shared that ChatGPT helped them clarify difficult mathematical concepts, which in turn gave them the confidence to approach problem-solving tasks independently.

Subtheme 1.1: Accessibility and Convenience

Students frequently highlighted the 24/7 availability of ChatGPT as one of its most valuable features. The ability to receive immediate assistance—especially outside of class hours—allowed them to address learning challenges as they arose, without having to wait for a teacher’s input. This real-time support was seen as empowering and helped maintain learning momentum.

This was reflected in statements such as:

“When I’m reviewing at 10 p.m. and get stuck, I ask ChatGPT right away” (P4).

“I used to wait until the next day to ask the teacher. Now, I can study right after class” (P7).

Subtheme 1.2: Boost in Confidence and Independence

The tool also played a role in boosting students' confidence to tackle challenging tasks on their own. Several participants shared that ChatGPT encouraged them to attempt problem-solving independently before turning to others for help, fostering a greater sense of self-reliance in their learning.

This perspective was captured in remarks such as:

"I don't feel scared of being wrong because I can check with ChatGPT—so I try on my own first" (P9).

"It's like having a tutor who won't get tired of my questions" (P2).

Theme 2: Challenges in Critical Thinking and Overreliance

While ChatGPT provided valuable support, some students also acknowledged its potential limitations. Several participants reflected on their tendency to rely too heavily on the tool, noting that this dependence occasionally hindered the development of deeper thinking and problem-solving skills.

Subtheme 2.1: Passive Learning Tendencies

Several participants admitted that they sometimes copied ChatGPT's responses without fully grasping the underlying concepts. This passive use of the tool limited opportunities for critical thinking and hindered the development of essential problem-solving skills.

This concern was evident in comments like:

"There are times I just copy the solution and move on" (P5).

"Even if I don't understand, I still use the answer to pass the task" (P11).

Subtheme 2.2: Reduced Problem-Solving Persistence

Students also noted that the convenience of accessing ready-made solutions sometimes discouraged them from putting in the effort to solve problems on their own, reducing opportunities for independent reasoning.

This sentiment was echoed in responses such as:

"It makes things too easy. I stopped working a problem out on paper before asking" (P1).

"I used to think first. Now I just ask ChatGPT" (P10).

Theme 3: ChatGPT as a Learning Companion

Students described ChatGPT not just as an information source, but as a conversational partner in their learning journey. Its interactive and nonjudgmental nature created a supportive space where they felt comfortable asking questions—often repeatedly—and exploring ideas without fear of being wrong. This environment encouraged reflection and allowed students to better assess and deepen their understanding over time.

Subtheme 3.1: Dialogic Exploration of Concepts

The ability to rephrase questions and receive tailored, adaptive explanations allowed students to refine their understanding, supporting both conceptual clarity and the development of metacognitive skills.

This was illustrated by remarks such as:

"If I don't get the answer, I ask again in a different way until it makes sense" (P6).

"Sometimes I ask, then try to explain the problem back. That helps me see what I missed" (P8).

Subtheme 3.2: Emotional Comfort and Stress Relief

Many students noted that ChatGPT provided a judgment-free space for asking questions, which reduced anxiety and increased their willingness to engage with difficult topics.

Examples include:

"It doesn't judge me. I can ask ten times and it never sighs" (P3).

"In class, I get shy. With ChatGPT, I ask freely" (P12).

The qualitative themes align closely with the study's quantitative findings. The strong positive correlation between SDL levels and mathematics performance may be attributed to the motivational and confidence-building effects described in Theme 1. These findings support Knowles' theory of self-directed learning, as students demonstrated autonomy and initiative in managing their learning with AI assistance.

However, Theme 2 provides a deeper explanation for the relatively weak correlation between ChatGPT usage and academic performance. Students who used ChatGPT passively or as a shortcut failed to develop critical thinking

and problem-solving skills—underscoring the importance of self-regulation as a moderating factor. This aligns with the study’s conceptual framework and with constructivist learning theory, which emphasizes cognitive engagement and meaning-making.

Theme 3 reflects ChatGPT’s role in fostering metacognitive reflection and reducing learning-related anxiety. Its dialogic nature allowed students to revisit problems, clarify understanding, and build confidence without the fear of negative judgment. These insights are consistent with the AI in Education Framework (Luckin et al., 2016), which positions AI as a personalized, adaptive learning partner.

Taken together, the qualitative findings illustrate that ChatGPT can support self-directed learning and enhance mathematics engagement—provided it is used critically and with intention. Strengthening students’ AI literacy and self-regulation is therefore essential to ensure that such tools contribute meaningfully to learning.

Mixed-Methods Integration

Triangulation indicated that the relationship between ChatGPT use, self-directed learning, and mathematics performance is best understood as conditional on how ChatGPT is used. Students’ accounts showed that ChatGPT can support AI-facilitated SDL when it is used as a scaffold for explanation-seeking, guided practice, and iterative questioning—behaviors aligned with SDL dimensions such as learning strategies and evaluation. However, narratives also revealed risks that can weaken SDL, including shortcut behaviors, reduced persistence, and limited verification, which may restrict conceptual understanding and undermine performance. Taken together, the integrated evidence suggests that ChatGPT engagement alone is not sufficient; rather, the *quality of engagement* (verification, reflection, strategy-driven use) appears central in determining whether AI-supported SDL contributes to meaningful mathematics learning outcomes.

Summary

This mixed-methods study examined the relationship between AI-facilitated self-directed learning (SDL) and mathematics performance among Generation Z junior high school students, focusing on ChatGPT use. Quantitatively, 272 learners completed the SRSSDL and a ChatGPT usage survey, and their responses were linked to standardized mathematics scores. Results showed that most students demonstrated moderate SDL readiness, with a substantial group at high SDL and a notable portion at low SDL. Descriptive statistics indicated moderate SDL overall, frequent ChatGPT use, and generally high mathematics performance. Correlational analysis revealed a very strong positive relationship between SDL and mathematics performance, a weak but significant positive relationship between ChatGPT use and mathematics performance, and a non-significant relationship between SDL and ChatGPT frequency of use. Regression analysis further showed that SDL and ChatGPT use jointly predicted mathematics performance, with SDL emerging as the strongest predictor. Qualitatively, thematic analysis of FGDs generated three themes: (1) ChatGPT as a source of personalized support and motivation, (2) challenges related to critical thinking and overreliance, and (3) ChatGPT as a learning companion that supports dialogic exploration and emotional comfort. Mixed-methods integration indicated that the benefits of ChatGPT are conditional on quality of use, particularly strategic engagement, verification behaviors, and self-regulation.

Conclusion

The findings indicate that self-directed learning readiness is a major determinant of mathematics performance among Generation Z students. Students who demonstrate stronger SDL capacities—especially in planning, learning strategies, monitoring, and evaluation—tend to achieve higher mathematics scores. While ChatGPT use shows a positive contribution to mathematics performance, its effect is smaller, suggesting that AI tools function best as supplementary supports rather than substitutes for core learning competencies. Importantly, the study also highlights potential risks: frequent AI use may encourage cognitive offloading, overtrust in AI outputs, and reduced persistence when learners rely on quick solutions instead of engaging in deeper reasoning. The qualitative findings reinforce that ChatGPT can enhance motivation, confidence, and access to help, but it can also undermine critical thinking when used passively. Overall, the study concludes that ChatGPT can support mathematics learning when integrated with strong SDL behaviors and responsible use practices; however, meaningful learning gains depend largely on students’ self-regulation, metacognitive monitoring, and intentional engagement with AI-generated feedback.

Recommendations

For mathematics teachers, it is recommended to explicitly teach AI-supported learning routines by establishing classroom norms such as requiring students to attempt problems first before consulting AI, explaining solutions in their own words, and verifying AI-generated answers using notes, teacher-provided examples, or alternative solution methods. Teachers should also strengthen students' self-directed learning skills through structured scaffolds such as goal-setting templates, weekly learning plans, reflection logs, and self-check checklists aligned with key SRSSDL dimensions like awareness, learning strategies, and evaluation. In addition, classroom assessments and learning tasks should be designed to emphasize reasoning rather than copying by incorporating open-ended problems, error analysis activities, and solution-justification tasks that discourage simply pasting AI outputs. Finally, verification and evaluation should be taught as core mathematical habits by training students to check AI solutions for accuracy in units, logical steps, computations, and final answers, and to identify common reasoning errors that may occur in AI-generated explanations.

For school leaders and program coordinators, developing school-based AI literacy guidelines is essential to promote responsible AI use, protect academic integrity, and ensure compliance with the Data Privacy Act of 2012 (RA 10173). Schools should also provide teacher capacity-building opportunities through training on AI-integrated lesson design, formative assessment strategies, and practical methods for guiding learners to use AI as a scaffold rather than a shortcut. Moreover, schools are encouraged to establish monitoring and support systems that allow teachers to track AI-related learning behaviors and provide targeted interventions, especially for students with low SDL readiness who may be more vulnerable to overreliance or passive use of AI tools.

For students, ChatGPT should be used as a learning tutor rather than a solver by prioritizing requests for explanations, examples, and hints instead of complete final answers. Learners are encouraged to practice a "verify and reflect" habit by checking AI responses using notes or alternate methods and writing brief reflections on what they learned and how their understanding improved. To build independence gradually, students should reduce reliance over time by practicing similar problems without AI support after receiving initial guidance, ensuring that learning becomes internalized rather than tool-dependent.

For future researchers, it is recommended to measure the quality of AI use rather than focusing only on frequency by including indicators such as verification behaviors, prompting strategies, and critical evaluation of AI outputs. Researchers may also test more explanatory models by examining mediators and moderators for example, whether SDL mediates the relationship between ChatGPT use and performance, or whether self-regulation moderates the benefits and risks of AI use. Longitudinal or experimental designs are encouraged to track changes over time and strengthen causal interpretation, and further studies should compare groups and contexts across grade levels, achievement levels, and access conditions like internet or device availability to explore equity implications and identify which learners benefit most from AI-supported learning.

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Author (s) Contribution Rate

Jhona Besas contributed 50% to the research, including conceptualization, data collection, analysis, and writing. Louida Patac and Adriano Patac each contributed 25%, assisting in data gathering, reviewing literature, and refining the manuscript. All authors have read and approved the final version of the paper.

Ethical Approval

For this study, ethical approval was obtained from the Surigao del Norte State University Ethics Committee under reference number F00000000069914, dated 11/05/2024.

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