

The Moderating Role of AI Literacy in the Relationships Between Generative AI Reliance, Academic Self-Efficacy, and Cognitive Engagement Among Adolescents

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ABSTRACT

Objective: This study aimed to examine the relationships between generative AI reliance, academic self-efficacy, and cognitive engagement among Canadian adolescents and to determine whether AI literacy moderates the associations between generative AI reliance and these two academic outcomes.

Methods and Materials: A cross-sectional correlational design was employed with 612 secondary school students aged 14–18 years from Ontario, British Columbia, Alberta, and Quebec, Canada. Participants completed self-report measures assessing generative AI reliance, AI literacy, academic self-efficacy, and cognitive engagement. Data were analyzed using Pearson correlation coefficients and multiple regression-based moderation analyses using the PROCESS macro in SPSS. Generative AI reliance was specified as the predictor, AI literacy as the moderator, and academic self-efficacy and cognitive engagement as separate dependent variables. Age, gender, grade level, and frequency of academic generative AI use were included as covariates. Interaction effects were examined using simple-slope and Johnson-Neyman analyses.

Findings: Generative AI reliance was significantly and negatively correlated with academic self-efficacy, $r = -.36$, $p < .001$, and cognitive engagement, $r = -.41$, $p < .001$, whereas AI literacy was positively associated with academic self-efficacy, $r = .44$, $p < .001$, and cognitive engagement, $r = .51$, $p < .001$. The moderation model predicting academic self-efficacy was significant, $F(7, 604) = 51.11$, $p < .001$, $R^2 = .372$, and the interaction between generative AI reliance and AI literacy was significant, $B = 0.18$, $SE = 0.04$, $\beta = .15$, $p < .001$, $\Delta R^2 = .021$. The cognitive engagement model was also significant, $F(7, 604) = 70.87$, $p < .001$, $R^2 = .451$, with a significant interaction effect, $B = 0.21$, $SE = 0.04$, $\beta = .17$, $p < .001$, $\Delta R^2 = .025$. In both models, the negative effects of generative AI reliance weakened as AI literacy increased and became nonsignificant at high levels of AI literacy.

Conclusion: AI literacy appears to function as a protective factor that attenuates the negative associations of generative AI reliance with adolescents' academic self-efficacy and cognitive engagement, highlighting the importance of developing critical, evaluative, and responsible AI competencies alongside increased educational use of generative AI.

Keywords: generative artificial intelligence, AI literacy, academic self-efficacy, cognitive engagement, adolescents, generative AI reliance, moderation analysis

1. Introduction

Generative artificial intelligence has rapidly become embedded in educational environments, transforming how learners search for information, generate ideas, organize written work, solve problems, and interact with instructional content. Unlike earlier digital tools that primarily supported access to information, generative AI systems can produce explanations, examples, drafts, summaries, feedback, and problem-solving pathways in response to natural-language prompts, thereby occupying a more active role in the learning process. This development has created substantial educational opportunities, but it has also intensified concerns about the extent to which students may transfer cognitive work from themselves to algorithmic systems. Recent scholarship increasingly distinguishes productive AI-supported learning from patterns of excessive dependence in which learners routinely consult AI before attempting a task independently, rely on generated responses as substitutes for their own reasoning, or become less willing to persist when direct AI assistance is unavailable. Such patterns are particularly important during adolescence, when cognitive, motivational, metacognitive, and self-regulatory capacities are still developing and educational habits may become relatively stable over time. Research on young people has therefore emphasized that AI use should not be evaluated only according to frequency or access, but according to the ways in which AI changes agency, effort, autonomy, and cognitive participation in learning (Giansanti, 2026). Related work on digital cognition has similarly argued that generative AI can create a new form of cognitive delegation in which external systems increasingly perform functions previously carried out through memory, reasoning, planning, and evaluation, potentially reshaping the boundaries between technological assistance and human agency (Giansanti & Cosenza, 2026). At the same time, generative AI can support creativity, explanation, scaffolding, and cognitive development when it is used as a complementary rather than substitutive tool (Niu, 2026). Accordingly, the educational consequences of generative AI are unlikely to be uniformly beneficial or harmful; instead, they appear to depend on how students use these systems, the level of autonomy retained during learning, and the competencies that enable them to critically regulate AI-supported activity.

One of the most consequential constructs in this emerging area is generative AI reliance. Reliance differs conceptually from ordinary use because it reflects the degree to which

learners come to depend on AI systems to initiate, sustain, complete, or validate academic work. A student may use generative AI frequently while still independently evaluating its outputs, whereas another student may use it less often but rely on it whenever cognitive effort, uncertainty, or difficulty arises. Recent research has begun to differentiate qualitatively distinct forms of reliance, showing that students may use large language models for idea generation, drafting, verification, or direct substitution of cognitive work, and that these patterns are associated with different motivational and academic processes (Hossain, 2026). Concerns about over-reliance are especially pronounced because generative AI can reduce the immediate cost of effort by providing rapid answers, explanations, and finished products. From a cognitive perspective, such convenience can encourage offloading, whereby learners externalize demanding cognitive processes rather than exercising them internally. This issue has been discussed explicitly in relation to students with learning difficulties, where generative AI may provide meaningful support but may also reduce opportunities for strategy development and independent cognitive practice if used without appropriate regulation (Seung & Basham, 2026). More broadly, evidence suggests that excessive AI reliance may be associated with reduced active thinking, weaker independent problem solving, and possible long-term cognitive risks when users repeatedly delegate mentally demanding tasks to automated systems (Hoque et al., 2026). Dependence on AI has also been analyzed through behavioral models of problematic technology use, with recent findings indicating that emotional, cognitive, and situational factors can contribute to increasing dependence on generative AI in academic writing contexts (Liu et al., 2026). Trust is also central to this process. When students perceive AI-generated outputs as highly credible or epistemically authoritative, they may become less likely to verify information independently, which can shape both learning outcomes and the depth of their engagement with academic material (Tian, 2026). These findings suggest that generative AI reliance should be treated as a distinct psychological and educational construct rather than as a simple indicator of exposure to AI.

Academic self-efficacy represents one pathway through which generative AI reliance may influence adolescents' educational functioning. Academic self-efficacy refers to students' beliefs about their capacity to successfully understand, organize, and perform academic tasks, and it is closely related to persistence, willingness to attempt difficult work, resilience following setbacks, and effective self-

regulation. Generative AI may strengthen self-efficacy when it provides scaffolding that helps students understand difficult concepts, obtain feedback, or overcome initial barriers to task completion. However, repeated dependence on AI may also undermine students' confidence in their own competence if successful performance becomes increasingly attributed to technological assistance rather than personal capability. In such circumstances, students may begin to perceive academic success as contingent on access to AI, thereby weakening confidence in their ability to perform independently. Recent studies have demonstrated close relationships between AI literacy and self-efficacy, suggesting that students' confidence in using and evaluating AI is embedded within broader perceptions of academic and technological competence (Feng, 2026). Research with nursing students likewise indicates that heterogeneous profiles of AI literacy are associated with differences in self-efficacy, technology attitudes, and ethical concerns, underscoring the importance of perceived competence in determining how students interact with AI systems (Sun et al., 2026). In the context of AI-supported self-regulated learning, self-efficacy has also been identified as a key psychological resource that helps students move from passive technological assistance toward more autonomous, reflective, and purposeful learning (Mohamed, 2026). Similarly, research on AI-assisted revision has shown that psychological empowerment and learner agency may be more educationally effective than externally imposed control, particularly when students are encouraged to use AI to deepen rather than replace their own reasoning (Li, 2026). These findings indicate that the relationship between AI reliance and academic self-efficacy is likely to depend on whether students experience AI as a scaffold that expands their competence or as a substitute that gradually displaces confidence in their independent abilities.

Cognitive engagement is another central outcome because it reflects the depth and quality of students' mental investment in learning. Cognitive engagement includes active processing, elaboration, organization, critical evaluation, metacognitive monitoring, strategic problem solving, and persistence in the face of difficult academic material. Generative AI can potentially enhance these processes by offering alternative explanations, adaptive examples, immediate feedback, and opportunities for iterative questioning. However, when learners rely on AI-generated answers without evaluating, reconstructing, or extending them, the same technology may reduce the need for sustained cognitive effort. Recent research has

demonstrated that AI-supported learning can promote engagement when it is embedded within appropriate instructional and motivational conditions. For example, multimodal AI-assisted learning has been associated with academic engagement when students possess sufficient AI literacy and receive appropriate teacher support (Dong & Gan, 2026). Similarly, AI literacy has been found to predict learning engagement, with psychological resources and contextual identity factors influencing the strength of this relationship (Wang et al., 2026). Research on learning engagement and digital literacy also suggests that students' engagement with educational tasks is closely related to their ability to use digital tools meaningfully rather than mechanically, while acceptance of AI tools can further shape this relationship (Liu, 2026). At the same time, AI-related technostress may diminish learning engagement, particularly when students experience cognitive overload, uncertainty, or difficulty adapting to AI-mediated learning environments (Su, 2026). The educational consequences of AI use therefore appear to depend not only on whether students employ AI tools, but on whether those tools encourage deeper participation or enable disengagement from cognitively demanding processes.

Within this framework, AI literacy emerges as a particularly important moderating factor. AI literacy extends beyond technical proficiency and includes knowledge of how AI systems operate, awareness of their limitations, the capacity to evaluate generated content critically, the ability to formulate effective prompts, and understanding of ethical issues such as bias, privacy, authorship, and academic integrity. Recent research portrays AI literacy as a multidimensional and developmentally evolving competence rather than a fixed skill. Longitudinal and mixed-method evidence indicates that AI literacy develops through interactions among knowledge, experience, reflection, and contextual support, suggesting that students progressively learn not only how to use AI but also when and why particular forms of use are appropriate (Zhuge & Li, 2026). Among K-12 students, distinct latent profiles of AI literacy have been identified, and these profiles are linked to self-regulated learning, indicating that younger learners vary substantially in their ability to use AI autonomously and strategically (Wang, 2026). AI literacy has also been associated with responsible use of generative AI, particularly when learners possess stronger self-regulatory capacities that allow them to balance technological assistance with independent learning (Luyo, 2026). These findings suggest that AI literacy may function as a protective educational

resource by enabling students to benefit from AI without becoming excessively dependent on it. A highly AI-literate adolescent may recognize when an AI response is uncertain, compare it with other sources, reject inaccurate suggestions, and deliberately use AI as a scaffold rather than as a replacement for thinking. By contrast, a student with low AI literacy may be more likely to accept outputs uncritically, overestimate system reliability, and substitute AI-generated content for personal reasoning.

The moderating role of AI literacy is particularly plausible because several recent studies have shown that the educational effects of AI are contingent on learners' digital competencies, self-regulation, and psychological characteristics. In university contexts, digital competence has been shown to shape the relationship between ChatGPT use and learning motivation, indicating that the same level of AI use can produce different outcomes depending on students' ability to manage digital learning environments effectively (Ibrahim et al., 2026). Research examining AI literacy and responsible AI use has similarly shown that self-regulated learning and technostress alter how AI-related competence translates into behavior (Luyo, 2026). In other contexts, AI acceptance has been found to modify the relationship between learning engagement and educational outcomes, further supporting the proposition that AI-related psychological competencies act as boundary conditions rather than merely direct predictors (Liu, 2026). Evidence from sustainable education also indicates that the perceived intelligence of AI assistants can either support or hinder innovative behavior depending on how learners cognitively and behaviorally respond to technological assistance (Hao, 2026). Systematic reviews of AI integration in professional education likewise emphasize that digital competence is critical for converting AI availability into meaningful academic performance rather than superficial technological use (Espina-Romero et al., 2026). Together, these findings suggest that AI literacy may attenuate the negative effects of generative AI reliance because knowledgeable students are more capable of maintaining epistemic control, preserving autonomous judgment, and deciding when AI support should be accepted, modified, or rejected.

These issues may be especially significant during adolescence. Although much of the emerging empirical literature on generative AI has focused on university students, adolescents differ developmentally in their autonomy, metacognitive maturity, susceptibility to external guidance, and dependence on family and school contexts. Responsible AI use among younger learners is therefore

shaped not only by individual competencies but also by autonomy-supportive practices in families and schools (Fan, 2026). Developmental perspectives suggest that excessive restriction may be less effective than guided autonomy, where adolescents are supported in making informed decisions about when and how to use generative AI. At the same time, adolescents are increasingly encountering AI-mediated information outside formal learning settings. Research on AI-supported information behavior among adolescents demonstrates that technology-related beliefs and behavioral determinants shape whether young people engage with AI-generated content and how they interpret it (Tubi-Nwangwu & Adewole, 2026). This developmental context strengthens the relevance of AI literacy because adolescents may possess high levels of practical familiarity with digital technologies while still lacking sophisticated understanding of algorithmic limitations, source credibility, data privacy, and the distinction between plausible language generation and verified knowledge. The increasing incorporation of AI into both formal education and everyday digital life therefore raises a central question: under what conditions does reliance on generative AI become associated with weaker academic self-beliefs and reduced cognitive engagement, and when can students use the same technologies without such adverse consequences?

A further reason to examine these relationships is that the existing literature remains fragmented across different constructs and educational levels. Some studies have concentrated on AI literacy and engagement, others on self-efficacy, dependence, technostress, self-regulation, or academic performance, and many have been conducted among university students rather than adolescents. For example, investigations of AI literacy have demonstrated associations with engagement, psychological capital, self-regulation, and responsible use (Wang et al., 2026; Zhuge & Li, 2026), while studies of dependence have highlighted patterns of problematic reliance and cognitive offloading (Hossain, 2026; Liu et al., 2026). Other work has emphasized potential cognitive benefits of AI-assisted learning when technology is used to stimulate creativity and conceptual development rather than replace student thinking (Niu, 2026). There is also increasing recognition that the psychological effects of AI cannot be understood without accounting for user characteristics, contextual supports, and individual differences in competence (Hoque et al., 2026). Yet relatively little research has integrated generative AI reliance, academic self-efficacy, cognitive engagement, and AI literacy within a single explanatory model among

secondary school students. This gap is important because academic self-efficacy and cognitive engagement capture complementary dimensions of learning: the former reflects students' confidence in their capability to succeed, whereas the latter reflects the degree to which they actively invest cognitive effort in that success. If AI reliance is negatively associated with both constructs, but these associations weaken among adolescents with stronger AI literacy, then AI literacy may represent a key educational resource for reducing the risks associated with increasing dependence on generative AI.

The need for such research is also reinforced by the broader shift toward AI-integrated education. As educational institutions move from debating whether students should use generative AI toward determining how it should be incorporated responsibly, attention must increasingly focus on learner competencies rather than access alone. Evidence from AI-supported learning indicates that positive outcomes are most likely when students possess sufficient digital competence, critical thinking, self-regulation, and evaluative capacity to use AI purposefully (Espina-Romero et al., 2026; Mohamed, 2026). At the same time, the growing normalization of AI assistance may make dependence more difficult to identify because extensive AI use can appear educationally productive even when it is accompanied by reduced independent reasoning. Studies of AI trust, cognitive offloading, and digital agency therefore suggest the importance of distinguishing support from substitution (Giansanti & Cosenza, 2026; Seung & Basham, 2026; Tian, 2026). This distinction is especially relevant for schools because adolescents are still developing the habits of persistence, independent thought, critical evaluation, and confidence that underpin later academic and occupational functioning. Accordingly, research should move beyond simple comparisons between AI users and nonusers and instead examine the mechanisms through which different patterns of AI use interact with learner competencies. AI literacy is theoretically well positioned to serve this moderating role because it may enable adolescents to remain cognitively active and academically confident even when generative AI becomes a regular component of their learning environment.

Therefore, the aim of this study was to examine the relationships between generative AI reliance, academic self-efficacy, and cognitive engagement among Canadian adolescents and to determine whether AI literacy moderates the relationships between generative AI reliance and both academic self-efficacy and cognitive engagement.

2. Methods and Materials

2.1. Study Design and Participants

This study employed a quantitative, cross-sectional correlational design to investigate the relationships between reliance on generative artificial intelligence, academic self-efficacy, and cognitive engagement among adolescents and to examine whether AI literacy moderated these relationships. The target population consisted of secondary school students in Canada who were enrolled in Grades 9 through 12 and had prior experience using at least one generative AI application for educational purposes. A total of 612 adolescents participated in the study. Participants ranged in age from 14 to 18 years, with a mean age of 16.21 years ($SD = 1.19$). To enhance the heterogeneity of the sample, students were recruited from public secondary schools located in Ontario, British Columbia, Alberta, and Quebec. A multistage sampling procedure was employed in which schools were first approached through school boards and administrative authorities, after which eligible students within participating schools were invited to take part in the study. Eligibility criteria included being between 14 and 18 years of age, current enrollment in a Canadian secondary school, sufficient English proficiency to understand the questionnaires, and self-reported use of a generative AI system such as ChatGPT, Gemini, Microsoft Copilot, Claude, or a comparable platform for at least one school-related activity during the preceding three months. Students who reported no previous educational use of generative AI, submitted substantially incomplete questionnaires, or demonstrated invariant or clearly patterned responding across the survey were excluded from the final analytical sample. Data were collected electronically through a secure online questionnaire administered during the academic year. Participation was voluntary, and respondents were informed that their responses would remain confidential and would be used exclusively for research purposes. Because the participants were adolescents, informed assent was obtained from the students, and parental or guardian consent was obtained where required by institutional and school-board regulations. Participants were also informed that they could withdraw from the study at any stage before submitting the questionnaire without academic or personal consequences. No identifying information was included in the analytical dataset. The study procedures were designed in accordance with established ethical principles for research involving minors and educational populations, including the protection

of confidentiality, voluntary participation, and minimization of potential risks.

2.2. Measures

Data were collected using a structured self-report questionnaire consisting of demographic questions and measures assessing generative AI reliance, AI literacy, academic self-efficacy, and cognitive engagement. Demographic information included age, gender, grade level, province of residence, average frequency of generative AI use for academic purposes, and the types of educational activities for which generative AI was used, including information searching, idea generation, writing support, summarization, problem solving, homework completion, and examination preparation. Generative AI reliance was conceptualized as the extent to which students depended on generative AI systems to initiate, support, complete, verify, or improve academic tasks rather than relying primarily on their own cognitive and academic resources. It was assessed using a multi-item Generative AI Reliance Scale adapted for the educational context. The items addressed behavioral and cognitive dependence on generative AI, including the tendency to consult AI before attempting a task independently, reliance on AI-generated explanations when encountering academic difficulties, dependence on AI for generating ideas or structuring assignments, use of AI-generated responses as a primary basis for completing academic tasks, difficulty completing certain tasks without AI assistance, and reliance on AI to verify one's own academic judgments. Responses were recorded on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Item scores were averaged to produce an overall reliance score, with higher values indicating greater dependence on generative AI in academic activities. The wording of the items specifically emphasized reliance rather than frequency of use so that frequent but autonomous and critically monitored AI use would not automatically be interpreted as psychological or academic dependence.

AI literacy was assessed as the proposed moderating variable and was defined as students' capacity to understand the basic functioning and limitations of artificial intelligence, use AI systems effectively, critically evaluate AI-generated information, recognize ethical and social implications of AI use, and make informed decisions regarding when and how AI should be incorporated into learning activities. The AI literacy measure covered four interrelated dimensions: technical and conceptual

understanding, practical application, critical evaluation, and ethical awareness. Items assessed, for example, whether students understood that generative AI outputs are probabilistic rather than inherently factual, recognized the possibility of inaccurate or fabricated information, could formulate and refine prompts to obtain more useful responses, compared AI-generated information with reliable external sources, understood potential problems related to bias, privacy, authorship, and academic integrity, and could determine when independent problem solving was more appropriate than AI assistance. Responses were provided using a five-point Likert scale from 1 (strongly disagree) to 5 (strongly agree). After reverse-scoring negatively phrased items where applicable, responses were averaged to obtain a total AI literacy score, with higher scores representing greater ability to use generative AI knowledgeably, critically, effectively, and responsibly. In the present conceptual model, high AI literacy was expected to distinguish strategic use of generative AI from uncritical dependence on AI-generated content and therefore potentially alter the strength or direction of the relationship between generative AI reliance and students' academic functioning.

Academic self-efficacy referred to students' beliefs regarding their ability to successfully organize and perform behaviors necessary to accomplish academic tasks and achieve desired educational outcomes. The academic self-efficacy measure included items assessing confidence in understanding difficult academic material, successfully completing challenging assignments, learning complex concepts, solving academic problems, maintaining performance when coursework became demanding, organizing learning activities, and achieving satisfactory academic outcomes through personal effort. Students rated each statement on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). A mean score was calculated across the items, with higher scores indicating stronger academic self-efficacy. The measure was framed around perceived capability rather than students' actual grades so that the construct represented beliefs about personal academic competence rather than objective achievement. Particular attention was given to maintaining conceptual separation between self-efficacy and generative AI reliance. Accordingly, academic self-efficacy items asked participants to evaluate their own capability to manage academic demands, whereas the generative AI reliance items assessed the extent to which external AI assistance had

become important or necessary for completing those demands.

Cognitive engagement was defined as the degree to which students invested sustained mental effort and employed meaningful learning strategies when engaging with academic material. The measure assessed deep processing, elaboration, organization, metacognitive regulation, persistence in cognitively demanding tasks, critical evaluation of information, and willingness to invest mental effort in understanding rather than merely completing academic work. Students responded to statements concerning behaviors such as connecting new material with previous knowledge, attempting to understand underlying principles, comparing different explanations, monitoring their comprehension, reconsidering an approach when they did not understand a topic, persisting with difficult problems, independently evaluating the quality of information, and seeking conceptual understanding instead of relying solely on memorization or externally generated answers. Items were scored on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), and the mean of the relevant items was used as the total cognitive engagement score. Higher scores reflected greater strategic, effortful, and cognitively active participation in learning. Before the main administration, the complete questionnaire was reviewed for clarity and developmental appropriateness by specialists in educational psychology, adolescent learning, and educational technology. A small pilot administration with secondary school students who were not included in the main sample was also conducted to ensure that the wording of items, particularly terms related to generative AI and AI literacy, was understandable to adolescents. Internal consistency of all multi-item measures was evaluated in the final sample using Cronbach's alpha and composite reliability coefficients, with coefficients of .70 or above considered indicative of acceptable reliability.

2.3. Data Analysis

Data analysis was conducted using IBM SPSS Statistics and the PROCESS macro for moderation analysis. Before testing the research hypotheses, the dataset was screened for missing values, invalid responses, response-pattern irregularities, and potential outliers. Cases with substantial missing data were excluded, whereas limited item-level missingness was handled using an appropriate scale-level procedure when the participant had completed a sufficient proportion of the relevant measure. Descriptive statistics,

including mean, standard deviation, minimum, maximum, skewness, and kurtosis, were calculated for generative AI reliance, AI literacy, academic self-efficacy, and cognitive engagement. The internal consistency of the study measures was examined using Cronbach's alpha, and item-total relationships were inspected to identify potentially problematic items. Assumptions relevant to correlational and regression-based analyses were evaluated prior to hypothesis testing. Approximate normality was assessed through skewness and kurtosis coefficients and graphical inspection of distributions; linearity and homoscedasticity were evaluated using scatterplots and residual plots; independence of residuals was examined using the Durbin-Watson statistic; and multicollinearity was assessed using tolerance and variance inflation factor values. Standardized residuals, leverage statistics, and Cook's distance were additionally examined to identify potentially influential observations. Pearson product-moment correlation coefficients were first calculated to determine the bivariate relationships among generative AI reliance, AI literacy, academic self-efficacy, and cognitive engagement.

The principal hypotheses were tested using multiple regression-based moderation analyses. Generative AI reliance was specified as the focal predictor, AI literacy as the moderator, and academic self-efficacy and cognitive engagement were examined separately as dependent variables. This analytical specification made it possible to determine not only whether greater reliance on generative AI was associated with adolescents' perceived academic competence and cognitive involvement in learning, but also whether these associations differed according to students' level of AI literacy. Before constructing the interaction terms, generative AI reliance and AI literacy scores were mean-centered to reduce nonessential multicollinearity and facilitate interpretation of the regression coefficients. For each dependent variable, the model included the main effect of generative AI reliance, the main effect of AI literacy, and the interaction term between generative AI reliance and AI literacy. Age, gender, grade level, and frequency of academic generative AI use were entered as covariates to reduce the possibility that observed associations could be explained by basic demographic or exposure-related differences. A statistically significant interaction coefficient was interpreted as evidence that AI literacy moderated the association between generative AI reliance and the corresponding academic outcome. When an interaction was statistically significant, conditional effects of generative AI reliance were estimated at low, moderate, and high levels of

AI literacy, conventionally represented by one standard deviation below the mean, the mean, and one standard deviation above the mean. Simple-slope analyses were then used to determine the direction and magnitude of the association at each level of the moderator, and the Johnson-Neyman procedure was used where appropriate to identify the range of AI literacy values for which the conditional effect of generative AI reliance was statistically significant. Statistical significance was evaluated at an alpha level of .05 using two-tailed tests. Unstandardized regression coefficients, standard errors, standardized coefficients where appropriate, *t* values, *p* values, confidence intervals, coefficients of determination, changes in explained variance associated with the interaction terms, and relevant effect-size indicators were reported to provide a comprehensive interpretation of the moderation models.

3. Findings and Results

The final analytical sample consisted of 612 adolescents enrolled in Grades 9 through 12 in Canadian secondary schools. Participants ranged in age from 14 to 18 years, with a mean age of 16.21 years (*SD* = 1.19). Of the total sample, 321 participants (52.45%) identified as female, 278

(45.42%) identified as male, and 13 (2.12%) identified as nonbinary or another gender identity. Regarding grade level, 151 students (24.67%) were enrolled in Grade 9, 158 (25.82%) in Grade 10, 156 (25.49%) in Grade 11, and 147 (24.02%) in Grade 12. Geographically, 226 participants (36.93%) attended schools in Ontario, 144 (23.53%) in British Columbia, 128 (20.92%) in Alberta, and 114 (18.63%) in Quebec. With respect to the frequency of generative AI use for academic purposes, 201 students (32.84%) reported using generative AI applications on a daily basis, 248 (40.52%) reported using them several times per week, 103 (16.83%) used them approximately once per week, and 60 (9.80%) reported using them less than once per week. The most frequently reported academic applications included obtaining explanations of difficult concepts, generating ideas for assignments, summarizing educational materials, receiving writing assistance, solving or checking academic problems, and preparing for examinations. Examination of the dataset before the principal analyses indicated that no variable contained a level of missingness sufficient to compromise statistical analysis, and no case demonstrated an extreme response pattern warranting removal after the initial screening procedures. Accordingly, all 612 valid cases were retained in the final analyses.

Table 1

Descriptive Statistics and Reliability Coefficients for the Main Study Variables

Variable	M	SD	Minimum	Maximum	Skewness	Kurtosis	Cronbach's α	CR
Generative AI Reliance	3.21	0.74	1.25	4.92	0.18	-0.41	.89	.90
AI Literacy	3.64	0.69	1.42	5.00	-0.31	-0.18	.91	.92
Academic Self-Efficacy	3.58	0.66	1.50	5.00	-0.27	0.14	.88	.89
Cognitive Engagement	3.46	0.71	1.33	5.00	-0.16	-0.29	.92	.93

As shown in Table 1, the participants demonstrated a moderate level of reliance on generative AI for academic activities, with a mean score of 3.21 (*SD* = 0.74), whereas the mean AI literacy score was comparatively higher at 3.64 (*SD* = 0.69). Academic self-efficacy also exhibited a relatively favorable level, with a mean of 3.58 (*SD* = 0.66), while the mean cognitive engagement score was 3.46 (*SD* = 0.71). The observed score ranges indicated substantial individual variability across all four constructs, which was important for examining both direct associations and interaction effects. The distributional characteristics were satisfactory, as skewness values ranged from -0.31 to 0.18 and kurtosis values ranged from -0.41 to 0.14, providing no indication of substantial departures from approximate normality. Reliability analyses further demonstrated

satisfactory internal consistency for all measures. Cronbach's alpha coefficients ranged from .88 for academic self-efficacy to .92 for cognitive engagement, and composite reliability coefficients ranged from .89 to .93, exceeding the conventional criterion of .70. These results indicated that the measures provided internally consistent representations of the study constructs and were suitable for the subsequent correlational and moderation analyses. Additional examination of the regression assumptions indicated acceptable linearity and homoscedasticity based on residual and scatterplot inspection. Variance inflation factor values ranged from 1.08 to 1.47, with corresponding tolerance values exceeding .68, indicating that multicollinearity was not a concern. The Durbin-Watson statistics were 1.92 for the academic self-efficacy model and 1.96 for the cognitive

engagement model, suggesting adequate independence of residuals. Examination of standardized residuals, leverage values, and Cook's distance likewise revealed no influential

observations of sufficient magnitude to materially alter the regression estimates.

Table 2

Pearson Correlations Among Generative AI Reliance, AI Literacy, Academic Self-Efficacy, and Cognitive Engagement

Variable	1	2	3	4
1. Generative AI Reliance	—			
2. AI Literacy	-.18***	—		
3. Academic Self-Efficacy	-.36***	.44***	—	
4. Cognitive Engagement	-.41***	.51***	.57***	—

Table 2 presents the bivariate relationships among the principal study variables. Generative AI reliance was significantly and negatively correlated with AI literacy, $r = -.18$, $p < .001$, suggesting that adolescents with greater knowledge of AI functioning, limitations, evaluation procedures, and responsible use tended to demonstrate somewhat lower levels of uncritical dependence on generative AI for academic tasks. Generative AI reliance was also negatively associated with academic self-efficacy, $r = -.36$, $p < .001$, indicating that students who reported greater dependence on generative AI tended to report less confidence in their own ability to understand difficult material, solve academic problems, and successfully manage educational demands. A somewhat stronger negative association was observed between generative AI reliance and cognitive engagement, $r = -.41$, $p < .001$, showing that greater dependence on AI was associated with lower levels of deep processing, persistence, metacognitive regulation, and active cognitive investment in learning. In contrast, AI

literacy demonstrated significant positive relationships with both academic outcomes. AI literacy was positively correlated with academic self-efficacy, $r = .44$, $p < .001$, and with cognitive engagement, $r = .51$, $p < .001$. Thus, adolescents who demonstrated stronger capacities to understand, critically evaluate, and responsibly use AI also tended to report greater confidence in their academic abilities and greater active engagement with learning materials. Finally, academic self-efficacy and cognitive engagement were strongly and positively related, $r = .57$, $p < .001$, indicating that adolescents who felt more capable of handling academic demands also tended to invest greater cognitive effort in learning. Although these correlations established significant associations among the variables, their magnitude remained below levels typically associated with problematic construct redundancy, thereby supporting their treatment as conceptually distinct variables in the subsequent moderation analyses.

Table 3

Moderation Analysis Predicting Academic Self-Efficacy From Generative AI Reliance, AI Literacy, and Their Interaction

Predictor	B	SE	β	t	p	95% CI for B
Constant	3.57	0.07	—	51.00	<.001	[3.43, 3.71]
Age	0.03	0.02	.05	1.50	.134	[-0.01, 0.07]
Gender	0.04	0.04	.03	1.00	.318	[-0.04, 0.12]
Grade Level	-0.02	0.02	-.03	-1.00	.318	[-0.06, 0.02]
Frequency of Generative AI Use	-0.07	0.02	-.11	-3.50	<.001	[-0.11, -0.03]
Generative AI Reliance	-0.18	0.03	-.20	-6.00	<.001	[-0.24, -0.12]
AI Literacy	0.31	0.03	.33	10.33	<.001	[0.25, 0.37]
Generative AI Reliance $\times$ AI Literacy	0.18	0.04	.15	4.50	<.001	[0.10, 0.26]

As shown in Table 3, the regression model predicting academic self-efficacy was statistically significant, $F(7, 604) = 51.11$, $p < .001$, and accounted for 37.2% of the variance in adolescents' academic self-efficacy, with an adjusted R^2

of .365. After controlling for age, gender, grade level, and frequency of generative AI use, generative AI reliance emerged as a significant negative predictor of academic self-efficacy, $B = -0.18$, $SE = 0.03$, $\beta = -.20$, $t = -6.00$, $p < .001$,

95% CI [-0.24, -0.12]. This finding indicated that, at the mean level of AI literacy, greater reliance on generative AI was associated with lower confidence in students' own academic capabilities. AI literacy, in contrast, demonstrated a substantial positive main effect, $B = 0.31$, $SE = 0.03$, $\beta = .33$, $t = 10.33$, $p < .001$, 95% CI [0.25, 0.37], indicating that adolescents with higher levels of AI literacy tended to report stronger academic self-efficacy even after the effects of generative AI reliance and the covariates had been statistically controlled. Most importantly, the interaction between generative AI reliance and AI literacy was positive and statistically significant, $B = 0.18$, $SE = 0.04$, $\beta = .15$, $t = 4.50$, $p < .001$, 95% CI [0.10, 0.26]. The addition of the interaction term explained a further 2.1% of variance in academic self-efficacy, $\Delta R^2 = .021$, $\Delta F(1, 604) = 20.25$, $p < .001$, providing evidence that AI literacy significantly moderated the relationship between generative AI reliance and academic self-efficacy. Simple-slope analyses showed that among adolescents with low AI literacy, defined as one

standard deviation below the mean, generative AI reliance had a pronounced negative association with academic self-efficacy, $B = -0.31$, $SE = 0.04$, $t = -7.75$, $p < .001$. At the mean level of AI literacy, the relationship remained negative and significant, $B = -0.18$, $SE = 0.03$, $t = -6.00$, $p < .001$. However, among adolescents with high AI literacy, defined as one standard deviation above the mean, the negative relationship was substantially attenuated and was no longer statistically significant, $B = -0.06$, $SE = 0.04$, $t = -1.50$, $p = .134$. The conditional pattern therefore indicated that greater AI literacy buffered the negative association between reliance on generative AI and students' beliefs in their own academic competence. The Johnson-Neyman analysis further indicated that the negative association between generative AI reliance and academic self-efficacy diminished progressively as AI literacy increased and ceased to reach statistical significance among adolescents scoring in the upper range of the AI literacy distribution.

Table 4

Moderation Analysis Predicting Cognitive Engagement From Generative AI Reliance, AI Literacy, and Their Interaction

Predictor	B	SE	β	t	p	95% CI for B
Constant	3.45	0.07	—	49.29	<.001	[3.31, 3.59]
Age	0.02	0.02	.03	1.00	.318	[-0.02, 0.06]
Gender	0.03	0.04	.02	0.75	.453	[-0.05, 0.11]
Grade Level	0.01	0.02	.02	0.50	.617	[-0.03, 0.05]
Frequency of Generative AI Use	-0.05	0.02	-.08	-2.50	.013	[-0.09, -0.01]
Generative AI Reliance	-0.22	0.03	-.23	-7.33	<.001	[-0.28, -0.16]
AI Literacy	0.38	0.03	.37	12.67	<.001	[0.32, 0.44]
Generative AI Reliance $\times$ AI Literacy	0.21	0.04	.17	5.25	<.001	[0.13, 0.29]

The second moderation model, presented in Table 4, examined cognitive engagement as the dependent variable. The overall regression equation was statistically significant, $F(7, 604) = 70.87$, $p < .001$, explaining 45.1% of the variance in cognitive engagement, with an adjusted R^2 of .445. Generative AI reliance demonstrated a significant negative main effect, $B = -0.22$, $SE = 0.03$, $\beta = -.23$, $t = -7.33$, $p < .001$, 95% CI [-0.28, -0.16], indicating that adolescents who relied more heavily on generative AI tended to demonstrate lower levels of deep cognitive processing, persistence, metacognitive monitoring, information evaluation, and active mental investment in school-related learning. AI literacy was a strong positive predictor of cognitive engagement, $B = 0.38$, $SE = 0.03$, $\beta = .37$, $t = 12.67$, $p < .001$, 95% CI [0.32, 0.44], suggesting that adolescents who better understood how AI systems functioned and who were more capable of critically evaluating and strategically using AI-

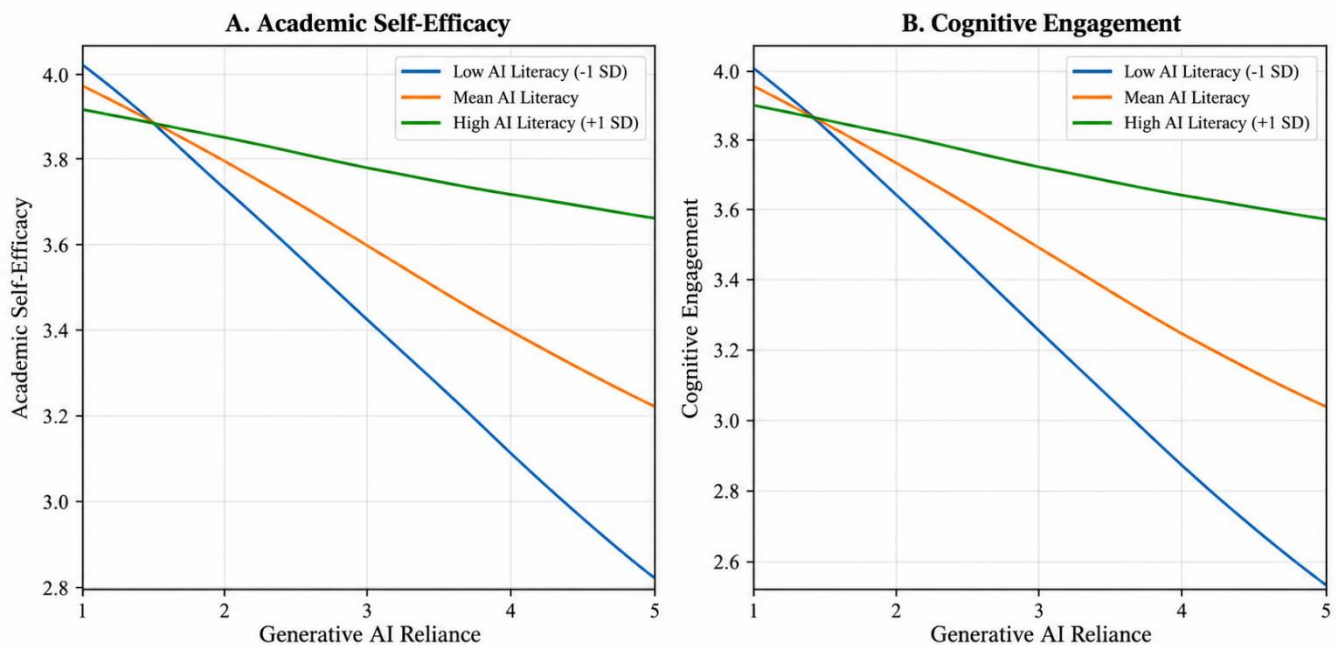
generated information also displayed higher cognitive engagement. The interaction between generative AI reliance and AI literacy was positive and statistically significant, $B = 0.21$, $SE = 0.04$, $\beta = .17$, $t = 5.25$, $p < .001$, 95% CI [0.13, 0.29]. Introducing the interaction term produced an additional 2.5% of explained variance, $\Delta R^2 = .025$, $\Delta F(1, 604) = 27.56$, $p < .001$, demonstrating a meaningful moderation effect beyond the main effects and control variables. Examination of the conditional effects revealed that generative AI reliance was strongly negatively related to cognitive engagement among adolescents with low AI literacy, $B = -0.36$, $SE = 0.04$, $t = -9.00$, $p < .001$. At the mean level of AI literacy, reliance remained significantly associated with reduced cognitive engagement, $B = -0.22$, $SE = 0.03$, $t = -7.33$, $p < .001$. At high levels of AI literacy, however, the magnitude of this relationship declined substantially and was no longer statistically significant, $B =$

-0.07, $SE = 0.04$, $t = -1.75$, $p = .081$. Thus, although greater generative AI reliance was generally associated with reduced cognitive engagement, this pattern was primarily concentrated among adolescents who possessed relatively limited AI literacy. Students with high AI literacy appeared better able to use generative AI without exhibiting the same reduction in independent cognitive involvement. The Johnson-Neyman analysis supported this interpretation by showing a progressive weakening of the adverse conditional effect as AI literacy increased, with the relationship

becoming statistically indistinguishable from zero in the upper portion of the AI literacy distribution. Among the demographic covariates, age, gender, and grade level did not independently predict cognitive engagement, whereas frequency of generative AI use demonstrated a small negative association, $B = -0.05$, $SE = 0.02$, $\beta = -.08$, $p = .013$, indicating that frequent exposure to generative AI was modestly associated with lower cognitive engagement even after reliance, literacy, and their interaction were taken into account.

Figure 1

Moderating Effect of AI Literacy on the Relationships Between Generative AI Reliance and Academic Self-Efficacy and Cognitive Engagement Among Adolescents



Taken together, the findings provided consistent evidence for the proposed moderating role of AI literacy. Generative AI reliance was independently associated with both lower academic self-efficacy and lower cognitive engagement, while AI literacy was positively associated with both outcomes. More importantly, the statistically significant positive interaction coefficients demonstrated that the negative relationships involving generative AI reliance became progressively weaker as adolescents' AI literacy increased. The pattern was similar across both dependent variables but was somewhat stronger for cognitive engagement, as reflected by the larger interaction coefficient and the greater proportion of additional variance explained by the interaction term. At relatively low levels of AI literacy, reliance on generative AI was accompanied by

pronounced reductions in adolescents' confidence in their own academic capabilities and in their willingness to engage deeply and independently with academic material. At moderate levels of AI literacy, these adverse associations remained significant but were smaller. At high levels of AI literacy, neither conditional effect remained statistically significant, indicating that adolescents with stronger conceptual, critical, practical, and ethical understanding of AI were comparatively less vulnerable to the negative academic correlates of generative AI reliance. Accordingly, the findings supported the central proposition of the study that the academic implications of generative AI reliance cannot be understood solely in terms of how frequently or extensively adolescents use AI. Rather, students' capacity to understand, evaluate, regulate, and strategically integrate

generative AI into their learning appears to constitute an important boundary condition determining whether reliance on these systems is associated with diminished academic self-beliefs and reduced cognitive engagement.

4. Discussion

The present study examined the relationships between generative AI reliance, academic self-efficacy, and cognitive engagement among Canadian adolescents and tested whether AI literacy moderated the relationships between generative AI reliance and the two academic outcomes. The findings showed a consistent pattern across the analyses. Generative AI reliance was negatively associated with both academic self-efficacy and cognitive engagement, whereas AI literacy was positively associated with both outcomes. More importantly, AI literacy significantly moderated both relationships. The negative association between generative AI reliance and academic self-efficacy was strongest among adolescents with low AI literacy, weaker at average levels of AI literacy, and statistically nonsignificant among those with high AI literacy. A similar pattern emerged for cognitive engagement: greater reliance on generative AI predicted lower cognitive engagement among adolescents with low and average AI literacy, but this adverse relationship was substantially attenuated among those with high AI literacy. These findings suggest that reliance on generative AI is not inherently associated with the same academic consequences for all adolescents. Instead, the effects of reliance appear to depend partly on whether students possess the knowledge, evaluative judgment, and regulatory competence necessary to use AI strategically rather than passively. This interpretation is consistent with the growing literature emphasizing that the educational implications of AI depend less on access or frequency of use alone and more on the quality of students' interaction with AI systems, their capacity for critical evaluation, and their ability to preserve cognitive agency during technology-supported learning (Giansanti, 2026; Giansanti & Cosenza, 2026).

The negative association between generative AI reliance and academic self-efficacy is theoretically important because academic self-efficacy reflects students' perceived capability to manage learning demands, solve academic problems, and succeed through their own efforts. In the present study, adolescents who reported greater dependence on generative AI also reported lower confidence in their own academic competence. One plausible explanation is that repeated reliance on AI may gradually shift the perceived

source of successful task completion from the student to the technological system. When learners repeatedly consult AI before attempting tasks independently or depend on AI-generated responses for planning, explanation, or validation, they may have fewer opportunities to experience mastery based on their own cognitive effort. Over time, this may weaken internal attributions of competence and foster the belief that academic success is contingent on external technological assistance. This interpretation aligns with recent work showing that self-efficacy is closely intertwined with the development of AI-related competence and with students' broader sense of control over technology-mediated learning (Feng, 2026). Research has also demonstrated that students with stronger AI literacy tend to display more favorable self-efficacy profiles, suggesting that confidence in using AI critically may coexist with greater confidence in independent academic functioning rather than replacing it (Sun et al., 2026). Similarly, studies of AI-assisted self-regulated learning have emphasized that self-efficacy is a central psychological resource enabling learners to move from dependence on external assistance toward more autonomous learning processes (Mohamed, 2026). The present findings therefore support the view that generative AI becomes problematic when it serves as a substitute for competence rather than as a scaffold through which competence can be strengthened.

The negative relationship between generative AI reliance and cognitive engagement was even stronger than its relationship with academic self-efficacy, which is also consistent with concerns about cognitive offloading. Cognitive engagement requires sustained mental effort, elaboration, monitoring, critical evaluation, and persistence. These processes can be reduced when a technological system immediately supplies explanations, ideas, solutions, or finished outputs that would otherwise require active reasoning. The present findings suggest that adolescents who relied more heavily on generative AI were less likely to report deep processing and active mental involvement in academic tasks. This pattern closely corresponds with concerns raised in the literature regarding the possibility that excessive AI use may shift learners from active problem solvers to passive consumers of generated content. Work on cognitive offloading has argued that generative AI can reduce the amount of internal cognitive processing students perform, particularly when learners turn to AI before engaging in independent strategy use or problem solving (Seung & Basham, 2026). Similarly, concerns about potential cognitive decline associated with over-reliance on

AI have focused on the possibility that repeated outsourcing of reasoning, memory, and evaluation may weaken the exercise of these capacities over time (Hoque et al., 2026). The current results are also consistent with research suggesting that dependence on generative AI in academic work is influenced by motivational and behavioral processes that can reinforce habitual externalization of cognitive effort (Liu et al., 2026). These findings do not imply that AI-assisted learning necessarily reduces cognitive engagement, but they indicate that the manner in which AI is used is crucial. When AI is employed to extend thinking, compare perspectives, generate alternatives, or stimulate reflection, it may support engagement; when it is used to bypass cognitively demanding stages of learning, it may undermine them.

The positive association between AI literacy and academic self-efficacy provides further support for the idea that competence in understanding and evaluating AI can strengthen rather than weaken students' perceived agency. Adolescents with greater AI literacy may be better able to interpret AI as one tool among many rather than as an indispensable source of academic performance. Such students are more likely to recognize the limitations of generated outputs, understand that AI responses may contain inaccuracies, and retain responsibility for evaluating and integrating information. These capacities may preserve a sense of personal control over learning and thereby support stronger self-efficacy. This interpretation is consistent with evidence showing that AI literacy develops dynamically through experience, reflection, and interaction with educational contexts rather than through technical exposure alone (Zhuge & Li, 2026). It is also supported by findings among K-12 students showing that different profiles of AI literacy are associated with meaningful differences in self-regulated learning (Wang, 2026). The present results therefore extend previous work by suggesting that AI literacy may have broader psychological value beyond technical competence. It may help students maintain a stronger sense of themselves as the primary agents of learning even when AI is deeply integrated into academic activity.

A similar explanation applies to the positive relationship between AI literacy and cognitive engagement. Students who understand how AI systems work and who possess stronger evaluative skills may be more likely to use AI in ways that stimulate rather than replace thinking. For example, an AI-literate student may use a generated explanation as a starting point, compare it with other

sources, identify inconsistencies, ask follow-up questions, or reformulate the output in relation to existing knowledge. Such use preserves cognitive effort and may even increase the depth of engagement by creating opportunities for iterative questioning and critical analysis. This interpretation is consistent with research showing that AI literacy is positively related to academic engagement in AI-assisted learning contexts (Dong & Gan, 2026). Likewise, AI literacy has been associated with higher learning engagement through psychological resources that support active participation in academic tasks (Wang et al., 2026). Related research has shown that digital literacy can mediate the association between learning engagement and outcomes, suggesting that students benefit most from technology when they possess the skills needed to integrate it meaningfully into learning processes (Liu, 2026). In this sense, AI literacy may act not merely as knowledge about AI, but as a form of metacognitive protection that helps learners decide when AI should assist, when it should be questioned, and when independent reasoning should take priority.

The most important contribution of the present study lies in the significant moderation effects. The interaction between generative AI reliance and AI literacy indicated that the negative relationship between reliance and academic self-efficacy weakened substantially as AI literacy increased. Among adolescents with low AI literacy, reliance on AI was associated with markedly lower academic self-efficacy, whereas among highly AI-literate students the relationship was no longer statistically significant. This finding suggests that AI literacy may buffer adolescents from the self-efficacy costs of dependence. One explanation is that highly literate users are better able to distinguish between strategic assistance and dependency. They may rely on AI for selected functions while still retaining control over planning, evaluation, and final decision-making. Consequently, reliance may not necessarily be experienced as evidence of personal inadequacy. This pattern aligns with research showing that responsible AI use is closely connected to literacy and self-regulation (Luyo, 2026). It is also consistent with evidence that digitally competent learners can benefit from AI-supported environments without losing motivational autonomy (Ibrahim et al., 2026). Similarly, research on AI-assisted revision has suggested that empowerment-oriented use of AI, in which learners remain active decision-makers, is more likely to support deep learning than externally controlled or substitutive use (Li, 2026). The present moderation finding therefore

supports a conditional rather than deterministic interpretation of AI reliance.

The moderation pattern was equally clear for cognitive engagement and was slightly stronger than that observed for academic self-efficacy. At low AI literacy, generative AI reliance was strongly associated with reduced cognitive engagement, whereas at high AI literacy the relationship diminished and became statistically nonsignificant. This finding is particularly important because it suggests that AI literacy may preserve mental effort even when students make frequent use of AI tools. Highly AI-literate adolescents may be less inclined to accept generated content at face value and more likely to treat AI outputs as prompts for further reasoning. In contrast, students with low AI literacy may be more vulnerable to passive acceptance and may therefore replace rather than supplement cognitive activity. The result aligns with work showing that AI-supported engagement is strengthened when learners possess sufficient literacy to use AI productively (Dong & Gan, 2026). It also corresponds with findings that AI-related stress and uncertainty can reduce engagement when students lack the capacity to manage the technological environment effectively (Su, 2026). Research on AI assistant intelligence similarly suggests that the educational consequences of advanced AI depend on the manner in which students respond to and interpret the support provided by the system (Hao, 2026). Thus, the present findings reinforce the idea that AI literacy functions as a boundary condition that changes the academic meaning of reliance.

The results also contribute to emerging debates about whether generative AI should be conceptualized primarily as a risk to cognition or as a tool for cognitive enhancement. The findings suggest that both interpretations may be valid under different conditions. Greater generative AI reliance was associated with less favorable academic outcomes overall, but the adverse associations weakened considerably among students with high AI literacy. This pattern is consistent with systematic evidence suggesting that generative AI can support creative thinking and cognitive development when used interactively and reflectively rather than as a shortcut to task completion (Niu, 2026). At the same time, research on human agency warns that repeated delegation of cognitive functions to AI may alter how users approach reasoning, memory, and decision-making (Giansanti & Cosenza, 2026). The current findings help reconcile these perspectives by indicating that AI literacy may determine whether AI functions more as a scaffold or as a substitute. When students understand AI capabilities and

limitations, critically evaluate outputs, and preserve control over decisions, the technology may support rather than displace cognition. When those capacities are weak, reliance may become more closely associated with reduced effort, lower confidence, and greater cognitive disengagement.

The developmental context of adolescence makes these findings particularly significant. Adolescents are still developing self-regulatory capacities, epistemic judgment, and stable patterns of academic motivation, and their technology use is strongly influenced by educational and family contexts. Research has emphasized that responsible generative AI use among young people is more likely to develop under conditions of autonomy support than under purely restrictive approaches (Fan, 2026). The present findings are consistent with this perspective because they suggest that the goal should not necessarily be to eliminate AI use, but to develop the competencies that enable students to use AI without relinquishing cognitive agency. Adolescents are also increasingly exposed to AI-mediated information in both educational and noneducational settings, making the ability to evaluate AI-generated content a broader developmental necessity. Recent evidence on adolescent use of AI-supported information indicates that behavioral determinants and user characteristics shape how young people interpret and act on AI-generated content (Tubi-Nwangwu & Adewole, 2026). The present study extends this concern into the academic domain by showing that students' level of AI literacy is related not only to their use of technology but also to their confidence and depth of engagement with learning.

5. Conclusion

The findings have implications for how academic reliance should be measured and interpreted. The negative correlations observed in this study should not be taken to mean that frequent use of AI is necessarily harmful. Reliance is conceptually different from frequency because it reflects the degree to which students depend on AI to perform tasks they might otherwise complete through independent cognition. This distinction is consistent with research identifying multiple forms of large language model reliance, ranging from selective support to more extensive substitution of cognitive work (Hossain, 2026). Similarly, trust in generative AI has been shown to influence academic writing behaviors and learning outcomes, particularly when students treat AI as an authoritative source rather than as a fallible tool (Tian, 2026). The current results therefore

support the importance of evaluating the quality, purpose, and epistemic role of AI use rather than relying exclusively on measures of usage frequency. They also support broader reviews of AI integration in education that emphasize digital competence and critical literacy as prerequisites for beneficial outcomes (Espina-Romero et al., 2026). Overall, the findings suggest that generative AI reliance becomes educationally risky when it is accompanied by low literacy, weak evaluation, and reduced independent effort, whereas higher AI literacy can substantially reduce these risks.

6. Limitations & Suggestions

The study has several limitations that should be considered when interpreting the findings. First, the cross-sectional design does not permit causal conclusions regarding whether generative AI reliance reduces academic self-efficacy and cognitive engagement or whether students with lower self-efficacy and engagement are more likely to become reliant on AI. Second, all principal variables were measured through self-report questionnaires, which may be influenced by social desirability, recall bias, and differences in students' interpretation of their own AI use. Third, although the sample included adolescents from several Canadian provinces, it did not represent all geographic, linguistic, cultural, and educational contexts within Canada, and the findings should therefore not be generalized to the entire adolescent population without caution. Fourth, the study focused on overall generative AI reliance and did not distinguish between specific forms of reliance, such as reliance for brainstorming, information retrieval, writing, problem solving, or verification. Fifth, the analysis did not directly assess objective academic achievement, task performance, actual AI-generated interaction logs, or experimentally observed cognitive effort. Finally, although relevant demographic and usage variables were controlled statistically, other potentially important factors, including parental mediation, teacher practices, school AI policies, socioeconomic background, prior achievement, personality characteristics, and general digital competence, were not incorporated into the models.

Future research should employ longitudinal and experimental designs to clarify the direction of causality among generative AI reliance, AI literacy, self-efficacy, and cognitive engagement. Repeated-measures studies could examine whether reliance increases over time and whether changes in AI literacy predict corresponding changes in academic confidence and cognitive participation.

Experimental research could compare different modes of AI use, such as unrestricted answer generation, guided prompting, reflective verification, and AI-supported Socratic questioning, to determine which patterns enhance or reduce cognitive engagement. Future studies should also distinguish between productive reliance and maladaptive dependence by examining specific functions of AI use rather than treating reliance as a single undifferentiated construct. Behavioral measures, learning analytics, screen-recorded interactions, prompt histories, and performance-based assessments of AI literacy would provide more objective evidence than self-report alone. Comparative research across countries, age groups, school systems, and socioeconomic contexts would also help determine whether the moderation effect observed in this study is developmentally and culturally stable. Further work should investigate additional moderators and mediators, including self-regulated learning, critical thinking, academic motivation, metacognitive awareness, teacher support, parental guidance, peer norms, technostress, and trust in AI.

From a practical perspective, schools should prioritize the development of AI literacy rather than relying primarily on prohibition or unrestricted access. Educational programs should explicitly teach students how generative AI systems produce responses, why outputs can be inaccurate or biased, how to verify claims against reliable sources, how to formulate effective prompts, and how to distinguish appropriate assistance from substitution of independent thinking. Teachers should design learning activities in which AI use requires explanation, comparison, justification, revision, and reflection rather than simple submission of generated answers. Assignments can be structured so that students must document how they used AI, identify weaknesses in generated content, explain how they modified outputs, and demonstrate their own reasoning before and after AI assistance. Schools should also establish developmentally appropriate guidelines that encourage students to attempt cognitively demanding tasks independently before turning to AI support. Professional development for teachers should focus on recognizing signs of unhealthy reliance and on designing AI-integrated instruction that preserves student agency, confidence, and cognitive effort. In this way, generative AI can be incorporated into adolescent education as a scaffold for learning rather than as a replacement for the mental processes that education is intended to develop.

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Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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Authors' Contributions

All authors equally contributed to this article.

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