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Research Article

AI-augmented learning in design education: A structural model of critical thinking and creative engagement

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Abstract
This study investigates how AI integration and students' perception of AI influence critical thinking and creativity among undergraduate design students in Ghanaian technical universities. A cross-sectional survey was conducted among 394 students from three institutions. Partial Least Squares Structural Equation Modelling (PLS-SEM) was employed to examine the interrelationships among the variables of this study, with results indicating that AI engagement plays a significant role in fostering both critical thinking and creative performance among students. Likewise, students' perception and perceived challenges with AI had a notable positive effect on these outcomes. However, the moderating effects of gender and age on the relationship between AI variables and learning outcomes were not supported. These results contribute empirical clarity to an ongoing pedagogical debate: whether AI is a cognitive amplifier or undermines independent reasoning. In the Ghanaian context, where structured AI integration in design curricula remains limited, the findings suggest a compelling need to guide students in leveraging AI responsibly. The study confirms the role of generative AI in augmenting design cognition and calls for curricular frameworks that promote critical reflection alongside technological fluency. The findings have implications for curriculum developers, educators and policymakers aiming to future-proof design education in sub-Saharan Africa and beyond.

Keywords: Artificial intelligence, Creativity, Critical thinking, Design education, Higher education

Extended Abstract

Introduction: This study addresses a pressing pedagogical question: how does the informal and emerging integration of generative artificial intelligence (AI) shape higher-order cognition in undergraduate design education? While AI tools are increasingly present in design workflows, empirical evidence about their net effect on students' critical thinking and creative performance remains incomplete, particularly within sub-Saharan African technical universities where formal curricular guidance is nascent. Drawing on contemporary work that treats AI both as an enabling "object-to-think-with" and a potential vehicle for cognitive off-loading, the research positions AI interaction and student perceptions of AI as central drivers of design cognition. The literature review synthesizes recent empirical and theoretical findings that suggest AI can scaffold reflective reasoning and broaden ideational search spaces, but that benefits are contingent on how students interpret, interrogate and integrate machine outputs into reflective design practices.

Purpose and scope: The study's primary aim is to empirically determine the relationships among (a) students' AI interaction and usage, (b) students' perceptions of and perceived challenges with AI, and (c) two outcome constructs, critical thinking and creativity, within undergraduate design programs in Ghanaian technical universities. Secondary aims examine whether age and gender moderate the effects of AI engagement on these outcomes. The research focuses specifically on routinely enrolled design undergraduates across three public technical universities in Ghana, thereby situating findings within a context characterized by rising AI exposure but limited institutional scaffolding. The study further seeks to explain variance in cognitive and creative outcomes attributed to AI-related predictors rather than to produce descriptive ethnographies.

Method: This study adopted a quantitative, cross-sectional, descriptive-correlational design to examine the relationships between AI engagement variables and cognitive outcomes among undergraduate design students. This design was appropriate because it allowed for the simultaneous analysis of multiple latent constructs and the testing of predictive relationships without experimental manipulation. Data were collected via an online, self-administered questionnaire distributed through official class communication channels using a stratified random sampling procedure to ensure proportional representation across program levels. The sample comprised 394 valid responses, adequate for Partial Least Squares Structural Equation Modelling (PLS-SEM) per established guidelines. Data were analyzed using PLS-SEM in SmartPLS 3.2.9. This approach was selected for its suitability in predictive modelling with latent variables and small-to-medium samples. Measurement instruments employed multi-item 5-point Likert scales and were vetted by an expert panel for content validity. Reliability and validity of constructs were assessed using Cronbach's alpha, composite reliability and average variance extracted (AVE). Discriminant validity was confirmed through the Fornell-Larcker criterion. Structural paths were tested via bootstrapping (5,000 resamples) to determine significance, effect sizes and explained variance (R2). Psychometric evaluation indicated high internal consistency (Cronbach's α and composite reliability > 0.85), acceptable convergent validity (AVE > 0.50), and discriminant validity (Fornell-Larcker criterion met). Analytical procedures followed a two-stage PLS-SEM protocol: measurement model assessment followed by structural model testing. Bootstrapping with 5,000 resamples produced robust estimates of path significance, effect sizes (β), and explained variance (R2). Ethical clearance was obtained in accordance with Helsinki principles with (Ethics ID: RE #122-2025-DRIPPT).

Findings and conclusion: The structural model accounted for substantive proportions of variance in both endogenous outcomes (R2= 0.531) for critical thinking, R2 = 0.582 for creativity). Four direct paths were positive and highly significant ($p < 0.001$). AI interaction and usage positively predicted critical thinking ($\beta = 0.529$) and. Creativity ($\beta = 0.375$), indicating that meaningful, frequent engagement with AI tools correlates with stronger reflective reasoning and richer ideation among design students. Students' perceptions of AI and perceived challenges also exhibited strong positive effects on both outcomes ($\beta = 0.391$) for critical thinking, $\beta – 0.547$ for creativity), suggesting that interpretive awareness of appropriation of AI outputs. By contrast, hypothesized moderating effects of age and gender were not supported, implying that within the study context demographic differences did not significantly alter the cognitive benefits associated with AI engagement. These results reconcile two competing narratives: AI can operate as a cognitive amplifier when integrated reflectively, yet students' interpretive stance toward AI is decisive. For practical implications, educators should not treat AI as a prescriptive shortcut, rather, curricula must frame AI use within reflective, ethically informed pedagogies that cultivate critical interrogation, source verification, and creative re-appropriation. Consequently, to policymakers, institutional guidance and targeted AI-literacy training can convert casual, unguided use into disciplined pedagogical practice. The study contributes empirical clarity to debates about AI in creative education, and offers evidence-based direction for curriculum developers, instructors and policymakers seeking to future-proof design programs in contexts similar to Ghana's technical universities.

Keywords: Artificial intelligence, Creativity, Critical thinking, Design education, Higher education

INTRODUCTION

AI is quickly reshaping how people educate around the world, bringing new potential to improve learning, particularly in subjects that have long depended on creativity and problem-solving. In the world of design education, AI tools like ChatGPT, DALL·E, Midjourney and Canva's Magic Studio are well on their way to being part of the normal creative process for students. These tools help in conception, prototyping, and iteration of ideas or content production, as well as reconfiguring the role of the design student in a project (Zawacki-Richter et al., 2019: 5). Educators across the world are currently struggling to understand the ways in which AI will empower or disempower the development of critical skills like critical thinking and creativity, skills that are largely the domain of design disciplines. Although AI has been praised for its ability to speed up the process of experimentation and increase the range of references and inspiration available to students, there is the fear that it may also water down independent thinking, the originality of the process and the depth of the analysis (Omran Zailuddin et al., 2024: 282).

In Ghana, the adoption of AI in higher education is at an early stage. Technical universities that offer programs in graphic design, industrial art and visual communication are beginning to feel the impact of these AI tools through casual learning. Many design undergraduate students are exploring generative AI platforms idiosyncratically without formal curriculum guidance or critical reflection on their socio-technical implications (Tadimalla & Maher, 2024: 2). With all of this new exposure, one fact remains clear: very little is understood about the impact of such tools on students' abilities as critical thinkers or as design originators. There is a fear here that students may become overly dependent on AI as a source of perspective, which could inhibit problem-framing competence and weaken professional engagement with central elements of the design thinking process (Butrimė & Zuzevičiūtė, 2025: 190).

Considering the proliferation of AI in design education, the effectiveness of AI in developing students' intellect and creativity should be concretely measured. This research aims to determine the manner of interaction of AI tools by undergraduate students in technical universities in Ghana and whether this interaction promotes or reduces the creative and critical thinking of the students. In particular, the study explores the use of AI, including its limitations; student attitudes toward AI as a creativity aid; and the impact of AI on students' reflective and problem-solving strategies. By focusing on the intersection of AI, critical thinking and creativity, it adds to the emergent literature on the pedagogical challenges of AI in the creative education context. Also, the research provides timely evidence that can help instructors, curriculum developers, and decision-makers in the Ghanaian technical university context make evidence-based decisions regarding the ethical and productive incorporation of AI within design education. As the global context moves towards conversation on AI-enhanced learning, understanding its actual role in the design cognition and student outcomes in the local context gains significance (Bayaga, 2025: 1046; Jose et al., 2025: 2).

HYPOTHESES DEVELOPMENT/LITERATURE REVIEW

AI Integration and Usage in Critical Thinking

Recent years have witnessed growing interest in how interaction with AI tools impacts critical thinking, particularly within disciplines emphasizing creative problem-solving, such as design. Recent studies have highlighted the significant impact of AI on critical thinking, especially in academia. A study by Saritepeci & Yildiz Durak (2024: 25175) reported statistically significant gains in critical reflection among students who integrated AI tools into digital storytelling exercises compared to standard methods. This suggests that AI can support metacognitive practices by students comparing their own ideas to AI-generated alternatives, prompting deeper justification and reasoning.

Research in STEM and cross-disciplinary contexts indicates that conversational AI can act as "object-to-think-with," supporting hypothesis testing and problem redefinition. For example, Vasconcelos & dos Santos, 2023: 4 observed that ChatGPT and Bing Chat interactions fostered reflective problem-solving behaviors in STEM tasks. Similar processes can benefit critical thinking by enabling iterations driven by dialogue and critique when applied to design education. In design education, AI assists cognitive learning processes, including visualization, spatial reasoning and decision-making while emphasizing the need to balance AI use with students' intrinsic creative abilities (Wang et al., 2022: 623). Comprehensive reviews highlight both opportunities and caution. AI offers tailored feedback and scaffolding conducive to critical thought, but excessive reliance may promote cognitive off-loading habits in which students bypass analysis, particularly in open-ended design tasks. To avoid this, scholars argue for embedding AI use within pedagogical frameworks that encourage questioning, justification and reflection (Gerlich, 2025: 4). Given the foregoing discussions, the following directional relationship is suggested.

H1: *AI interaction and usage significantly influence undergraduate students' critical thinking in design education*

AI Integration and Usage on Creativity

Recent experimental research demonstrates that AI integration can significantly enhance creative cognition among design students. A large-scale survey and structural equation modeling study involving 385 design majors found a string direct effect of AI use on creative cognition ($\beta - 0.610$, $p < 0.001$), with mediators including increased self-efficacy and reduced anxiety (Hwang & Wu, 2025: 3). These findings indicate that AI tools not only provide technical support but also psychologically empower students to generate more creative outcomes. Similarly, an experimental study in digital storytelling education reported significant post-intervention gains in creative self-efficacy and reflective thinking after students used ChatGPT and Midjourney across four weeks (Saritepeci & Yildiz Durak, 2024: 25716). Importantly, the positive effect was observed in the AI group and the non-AI control, suggesting that carefully structured AI use can parallel traditional creative pedagogies in enhancing creative confidence. AI's influence emerges most strongly in ideation processes.

A study in architectural design found that text-to-image generators (Midjourney, Stable Diffusion, DALL.E) supported serendipitous discovery and imaginative exploration during early-stage concept development (Paananen et al., 2024: 458). This indicates AI's utility for enhancing divergent thinking by prompting unexpected visual stimuli. Further, a recent theoretical and empirical evaluation argues that AI can act as a digital facilitator in ideation, guiding design students through methods like Substitute, Combine, Adapt, Modify, Put to another use, Eliminate, Reverse (SCAMPER) and reverse brainstorming, offering non-judgmental feedback, and thus reducing creative inhibition (Melker et al., 2025: 4). Such facilitation fosters more varied and richer ideational output than unguided human-only sessions. Based on the foregoing discussions, the following directional relationship is suggested.

H2: *AI interaction and usage significantly influence undergraduate students' creativity in design education*

Perception of and Challenges with AI on Critical Thinking and Creativity

Surveys recently show that student perceptions, that is, how they view AI's usefulness, accuracy, and appropriateness, play a central role in shaping their cognitive engagement. A global study of university students found that while many appreciated tools like ChatGPT for summarizing and brainstorming, they were less confident in AI's reliability and less likely to view it as enhancing their critical thinking (Ibeh et al., 2025: 14; Zhumagaliyeva et al., 2025: 15). This hesitation indicates that merely having access to AI doesn't guarantee improved analytical rigor; positive perception must align with deeper evaluative trust.

Similarly, a 2025 report by Jisc (UK) highlighted that students expressed concerns that AI could diminish critical skills, especially when they relied on it without verifying its output (Sue, 2025). Students emphasized the need for clearer guidance and AI literacy training, suggesting that perceptions of risks and challenges may undermine critical engagement unless institutional structures are in place. Students commonly cite concerns over AI hallucinations, data privacy and algorithmic bias. In the Jisc study, misinformation and deepfakes were top worries, along with ethical and privacy implications. These concerns can foster skepticism, prompting critical questioning or paralysis, leading to disengagement depending on a learner's propensity to cope with ambiguity. Focus-group research with secondary students who attended AI-creativity training showed that higher AI understanding correlated with more positive views about its impact on creativity. In contrast, low familiarity led to fear and skepticism. Crucially, nearly all participants insisted that AI "could never match human creativity," highlighting the influence of perception on creative confidence (Marrone et al., 2022: 69).

Frontiers in Psychology research warns that overreliance on AI may lead to cognitive off-loading, reducing students' initiative in questioning and analyzing information unless counterbalanced by active reflection and interaction (Jose et al., 2025: 2). Students' overall attitudes towards AI act as a mediator between tool usage and critical cognition. For instance, positive perception (e.g., recognizing AI's personalized feedback) can embower engagement, while negatives (e.g., mistrust in accuracy or fear of surveillance) may discourage reflective evaluation. In Ghanaian contexts, perceptions and access challenges shape adoption: a study reported widespread awareness of ChatGPT, but limited usage due to a lack of guidelines and concerns over dependency and academic dishonesty (Baidoo-Anu et al., 2024). Therefore, it is proposed that,

H3: *Students' perception of and challenges with AI significantly influence their critical thinking in design education*

H4: *Students' perception of and challenges with AI significantly influence their creativity in design education*

Moderating Roles of Age and Gender on Creativity and Critical Thinking

Empirical research highlights developmental differences in how learners process and integrate AI assistance. A mixed-method study analyzing AI use across age cohorts (13-65+ years) reported that younger participants displayed greater reliance on AI and correspondingly lower critical thinking scores; effects not observed in older participants (Gerlich, 2025: 4). This suggests that age influences cognitive outcomes associated with AI; younger undergraduates may offload critical evaluation to AI more readily, undermining their analytical engagement.

Gender differences have also been observed in AI engagement and its creative outcomes. A study employing the UTAUT model found that performance expectancy influences ChatGPT usage more in male students than females, suggesting that AI may bolster creativity differently across genders (Elshaer et al., 2024: 1992). A MDPI study on AI-chatbot adoption reported that female users expressed more ethical concerns and lower reliance on AI, which may reduce the creative benefits or interacting with generative models in design tasks. In context, male users often approached AI with fewer reservations, allowing for freer experimentation and potentially higher creative output (Møgelvang et al., 2024: 1363). In design education, females tend to adopt experiential rather than systematic cognitive approaches, which may influence their use of AI during creative problem-solving. This could mean that men derive greater creative gains from AI's ideation prompts unless pedagogical supports address motivational and affective concerns among female students Chellappa & Luximon, 2024: 100281). The study, therefore, hypothesizes that:

H5: *Age moderates the relationship between AI interaction and usage and critical thinking.*

H6: *Gender moderates the relationship between AI interaction, usage and creativity*

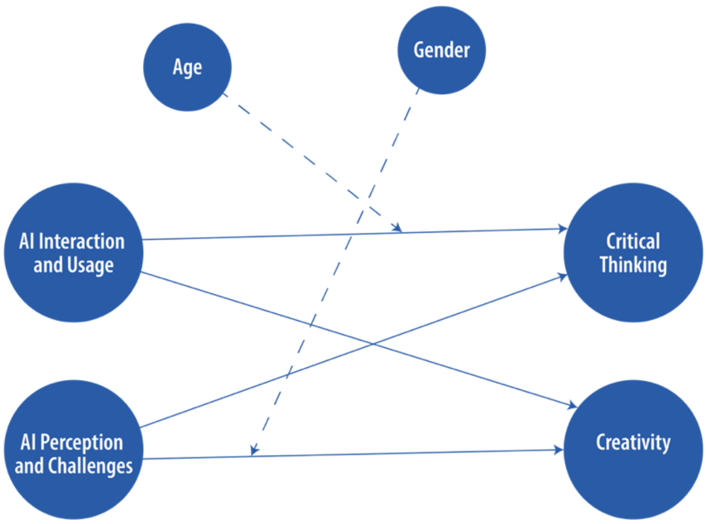

Figure 1. Research model

METHOD

The study adopted a cross-sectional, descriptive-correlational design to investigate relationships between AI engagement and cognitive outcomes. It employed a quantitative approach to analyze structured data from design undergraduates. The target population comprised undergraduate design students across three public technical universities in Ghana. A stratified random sampling technique ensured proportional representation of program levels. Over 400 online self-administered questionnaires were distributed, resulting in 394 valid responses, meeting the minimum sample size recommended for structural equation modelling (Hair et al., 2019: 24) and Krejcie & Morgan (1970: 607) sample size determination. Ethical approval was secured in consonance with the Helsinki 1964 declaration with Ethics ID: RE #122-2025-DRIPPT. The survey link was shared via official class communication channels, reinforcing voluntary participation and confidentiality. The average response time was approximately 12 minutes. All constructs used 5-point Likert scales (1= Strongly Disagree to 5 = Strongly Agree). An expert review panel (3 faculties in design education) confirmed relevance and clarity, supporting the instrument's content validity. The instrument showed strong psychometric properties; Cronbach's alpha and composite reliability exceeded 0.85, AVE surpassed 0.50 and discriminant validity was upheld via Fornell-Larcker (Hair & Alamer, 2022: 4). Data were analyzed using Smart PLS 3.2.9 software. The evaluation proceeded in two stages: testing the measurement model and assessing the structural model. Bootstrapping with 5,000 subsamples was employed to determine the significance of all hypothesized relationships.

FINDINGS AND RESULTS

The PLS-SEM tool was used to analyze data for the current study. According to Hair et al. (2019: 6), two major steps are identified in the literature: the measurement and structural models. While the measurement model estimates construct validity and reliability, the structural model assesses the nature of the relationships, or the paths, between the key constructs of the study, thereby serving as the test for the hypotheses developed for the study.

Demographics

Demographic data on participants' age and gender were collected to contextualize the study and describe the population surveyed. The final dataset comprised 394 valid responses from undergraduate design students in Ghana's technical universities. Participants ranged in age from 16 to over 32 years, categorized into five distinct groups to reflect the typical educational and developmental stages of university students. The largest proportion of respondents (45.4%) fell within the 20-23 age group, followed by 22.1% in the 24-27 range. The remaining participants were distributed among the 16-19 group (15.9%), the 28-31 range (13.4%), and those aged 32 and above (3.3%). This distribution suggests that the sample predominantly comprises students in the early to mid-stages of undergraduate studies, an observation consistent with enrolment trends in creative and design-based tertiary programs in West Africa (Azaglo et al., 2021: 7; Granić, 2022: 9730). With respect to gender, the data revealed a slightly higher representation of females (56.1%) compared to males (43.9%). This finding reflects evolving gender participation patterns in applied arts and design education, where female enrolment in visual communication, fashion design and industrial art disciplines has been steadily rising in Ghanaian technical institutions (Adams & Baddianaah, 2023: 201). Tables 1 and 2 summarize the demographic characteristics of the participants.

Table 1. Frequency distribution of respondents by age and gender

Characteristic	Age	n	% of Total	Cumulative %
Age Group	16-19	63	15.9%	15.9%
	20-23	179	45.3%	61.3%
	24-27	87	22.0%	83.3%
	28-31	53	13.4%	96.7%
	32 years and above	13	3.3%	100.0%
Gender	Male	173	43.9%	43.9%
	Female	221	56.1%	100.0%

Measurement Model Assessment

The assessment of the measurement model was guided by the standard criteria for evaluating reliability and validity within the Partial Least Squares Structural Equation Modelling (PLS-SEM) framework (Hair et al., 2019: 6). Reliability was evaluated using Cronbach's Alpha, Composite Reliability (CR) and rho_A. Convergent validity was assessed via the Average Variance Extracted (AVE), while discriminant validity was examined using the Fornell-Larcker criterion and cross-loadings. Table 2 presents the internal consistency measures for the latent constructs. All construct exceeds the minimum acceptable thresholds of 0.70 for Cronbach's Alpha and Composite Reliability (CR), indicating high internal consistency (Hair et al., 2019: 24; Henseler et al., 2015: 1) The AVE values for all constructs also surpassed the recommended 0.50 level, affirming convergent validity (Fornell & Larcker, 1981: 42). According to Fornell & Larcker (1981: 42), the square root of the AVE for each construct should exceed its highest correlation with any other construct. As shown in Table 3, this criterion is met for all constructs, confirming the discriminant validity of the measurement model. Cross loadings were used to confirm that indicators load higher on their associated constructs than on others, which is another key condition for establishing discriminant validity. As shown in Table 4, all indicators exhibited higher loadings on their respective constructs than others, thus supporting discriminant validity.

Table 2. Construct reliability and validity

	Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)
AI Interaction and Usage	0.880	0.896	0.907	0.585
Creativity	0.906	0.907	0.930	0.726
Critical Thinking	0.887	0.891	0.918	0.690
Overall Perceptions and Challenges	0.621	0.719	0.795	0.579

Table 3. Discriminant validity (Fornell-Larcker criterion)

	AI Interaction and Usage	Creativity	Critical Thinking	Overall Perceptions and Challenges
AI Interaction and Usage	**0.765**			
Creativity	0.712	**0.852**		
Critical Thinking	0.775	0.800	**0.831**	
Overall Perceptions and Challenges	0.630	0.777	0.724	**0.761**

Table 4. Cross Loadings

	AI Interaction and Usage	Creativity	Critical Thinking	Overall Perceptions and Challenges
CR1	0.622	0.849	0.665	0.639
CR2	0.621	0.818	0.660	0.633
CR3	0.543	0.857	0.684	0.657
CR4	0.639	0.882	0.720	0.696
CR5	0.606	0.855	0.679	0.684
CT1	0.682	0.658	0.872	0.608
CT2	0.665	0.689	0.838	0.579
CT3	0.668	0.711	0.860	0.636
CT4	0.554	0.601	0.765	0.532
CT5	0.642	0.661	0.816	0.646
IU1	0.736	0.473	0.508	0.415
IU2	0.770	0.511	0.565	0.477
IU3	0.575	0.318	0.387	0.290
IU4	0.829	0.587	0.642	0.480
IU5	0.813	0.639	0.672	0.561
IU6	0.762	0.560	0.604	0.505
IU7	0.837	0.642	0.699	0.578
OP1	0.525	0.707	0.627	0.869
OP3	0.303	0.334	0.303	0.483
OP4	0.569	0.660	0.651	0.865

Structural Model Assessment

Path Analysis

Following confirmation of construct validity, the next step was to assess the overall model fit to determine its suitability for further structural analysis. Model fit indicators, including the Standardized Root Mean Square Residual (SRMR) and the Normed Fit Index (NFI), were examined to evaluate the degree of fit between the observed data and the hypothesized structural model. As presented in Table 5, the SRMR values for both the saturated model (0.056) and the estimated model (0.063) fall well below the commonly accepted threshold of 0.08, indicating an acceptable level of model fit (Bentler & Bonett, 1980: 590; Henseler et al., 2015: 117). Similarly, the NFI values of 0.883 for the saturated model and 0.875 for the estimated model suggest a reasonably good model-to-data correspondence, considering that NFI values closer to 1 indicate a stronger model fit (Henseler et al., 2015: 117). These indicators collectively suggest that the structural model approximates the empirical data well and meets recommended goodness-of-fit benchmarks for PLS-SEM. In addition to absolute fit indices, the chi-square statistic was also considered. While chi-square values are known to be sensitive to sample size (Hair et al., 2019: 24), the consistency between the chi-square values of the saturated (611.859) and estimated (652.207) models further reinforce the model's adequacy. To further assess the model's explanatory power, R2 values were examined for the two endogenous variables. Constructs: critical thinking and creativity. The R2 coefficient for critical thinking was found to be 0.531, indicating that approximately 53.1% of the variance in this construct can be explained by the exogenous variables (AI interaction and usage; AI perception and challenge). Likewise, the R2 for creativity was 0.582, suggesting that 58.2% of the variance in creativity is attributable to the same set of exogenous predictors. Following the interpretive thresholds proposed by Giao & Vuong (2019: 15), where R2 values obtained in this study reflect substantial explanatory power. These findings imply that the structural model has empirical predictive strength, reinforcing its relevance for explaining cognitive and creative dimensions within AI-enhanced learning contexts.

Table 5. Model fit indices

	Saturated Model	Estimated Model
SRMR	0.056	0.063
d_ULS	0.652	0.830
d_G	0.273	0.299
Chi-Square	611.859	652.207
NFI	0.883	0.875

Having verified the measurement of reliability and validity, the structural model was analyzed to assess the strength and significance of hypothesized relationships among the study constructs. In line with recommendations by Tortosa et al., (2009: 1437), the path coefficients were evaluated using the bootstrapping technique with 5,000 resamples to determine the significance levels of the direct and moderating effects. In addition to the path significance, the model's explanatory adequacy was substantiated by the coefficient of determination (R2), as previously discussed. As reported in Table 6, all four hypothesized direct paths were found to be positive and statistically significant at the $p < 0.001$ level. The relationship between AI integration and usage and critical thinking was significant ($\beta = 0.529$, $p < 0.001$), as was its effect on creativity ($\beta = 0.375$, $p < 0.001$), These results confirm that frequent and meaningful interaction with AI tools is positively associated with higher-order cognitive and creative abilities in design education contexts. Accordingly, H1 and H2 were supported. Similarly, the impact of students' perception of and challenges with AI was also statistically significant for both outcome variables. A strong positive effect was found on creativity ($\beta = 0.547$, $p < 0.001$) and critical thinking ($\beta = 0.391$, $p < 0.001$), thereby confirming H3 and H4. These results strengthen the view that how students interpret AI's role as a support or threat to their intellectual autonomy significantly shapes their engagement with academic tasks requiring creativity and critical reasoning.

Moderation Analysis

The study involved a moderation analysis of students' age and gender in the nexus between AI interaction and usage, critical thinking; AI perception, challenges, and creativity. The study reports non-significant findings. Specifically, age did not significantly moderate the relationships between AI usage and critical thinking (β =

0.010, $p < 0.698$), nor did gender moderate the effect of AI perception on creativity ($\beta = 0.017$, $p < 0.761$). These findings suggest that the influence of AI on student cognition and creative performance is relatively consistent across demographic categories within the sample. Thus, H5 and H6 were not supported. Figure 2 presents the structural model showing path coefficient values.

Table 6. Results of structural model assessment

Hypothesis	Path	Path Coefficient (β)	p value	Result
H1	UI -> CT	0.529	< 0.001	Supported
H2	UI -> CR	0.375	< 0.001	Supported
H3	OP -> CT	0.391	< 0.001	Supported
H4	OP -> CR	0.547	< 0.001	Supported
H5	Age* UI -> CT	-0.010	0.698	Not Supported
H6	Gender* UI -> CR	-0.017	0.761	Not Supported

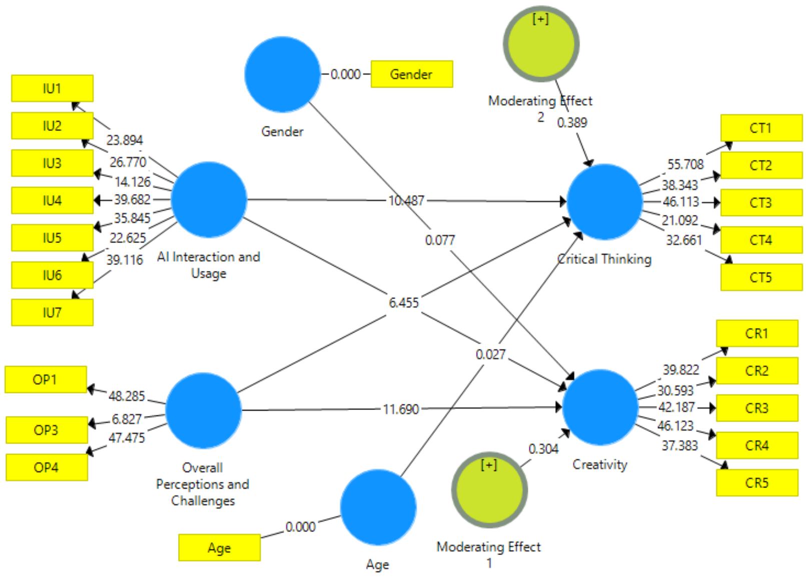

Figure 2. Structural model showing path coefficient values

Note: Standardized path coefficients estimated with 5000 bootstrap samples, R^2 values shown inside endogenous constructs, bootstrapped *t*-statistics shown on measurement paths reflect indicator significance ($t > 1.96 = p < 0.05$).

DISCUSSION

This study examined the influence of artificial intelligence (AI) interaction and perceptions on undergraduate students' cognitive and creative development in design education while also exploring the moderating roles of age and gender. Six hypotheses were tested using structural equation modelling based on partial least square (PLS-SEM). Four hypotheses were supported, while two were not. The implications of each are discussed below.

The first hypothesis proposed a direct relationship between AI interaction and critical thinking. The analysis confirmed this, suggesting that students who frequently and meaningfully engage with AI tools exhibit a more substantial capacity for reflective reasoning and logical judgement. The result aligns with previous studies that indicate AI systems, when used beyond passive consumption, could serve as cognitive catalysts that provoke questioning, comparison, and hypothesis generation. For instance, Vasconcelos & dos Santos (2023: 2296) reported that structured AI dialogues promoted analytical depth in complex STEM problem-solving. This validates the view that AI can serve not merely as an automation tool, but as a framework for developing higher-order thinking when students are guided to reflect on and interrogate its outputs.

The second hypothesis examined whether AI interaction significantly influences student creativity. This relationship was also supported. The creative disciplines, particularly design, thrive on exploration, variation and ideation. The findings imply that students who integrated AI platforms into their iterative design processes were more likely to demonstrate originality in problem-solving. This finding aligns with Shaber et al., (2025: 464), who found that AI-augmented ideation enhanced fluency and novelty in concept development among design students. This implies that AI may act as lateral input, offering divergent examples, triggering associative thinking and expanding the solution space. However, this benefit hinges on active engagement where students do not passively accept AI outputs but adapt, remix, and challenge them.

The third hypothesis tested the influence of students' perceptions and AI-related challenges on their critical thinking. The results strongly support this relationship, indicating that how students interpret AI's role, limits, and potential significantly shapes their analytical behavior. Participants who acknowledged AI's capabilities and shortcomings were more likely to scrutinize its outputs and reflect critically on their design decisions. This confirms the findings of Ibeh et al., (2025: 14) and Zhumagaliyeva et al. (2025:15) who argue that awareness of algorithmic fallibility fosters metacognitive strategies among learners. Students who internalize that AI is fallible and context-sensitive are more likely to evaluate information rigorously, compare alternative viewpoints, and rely on evidence-based reasoning rather than surface-level automation.

The fourth hypothesis focused on whether students' perceptions and challenges regarding AI significantly affect their creativity. This was the strongest supported path in the model, confirming that critical awareness of AI's role can enhance rather than inhibit innovation. Students who approached AI with a balance of curiosity and skepticism appeared better positioned to generate unique ideas. This resonates with Guzik et al. (2023: 100068), who demonstrated that users with greater interpretive awareness of AI-generated suggestions exhibited higher levels of originality.

The fifth hypothesis tested the moderating role of age in the relationship between AI interaction and critical thinking. Contrary to theoretical expectations drawn from prior research, this hypothesis was not supported. Although younger users have often been described as more digitally fluent and more likely to adopt AI tools, our data suggest that in the structured educational setting of Ghanaian technical universities, age difference becomes less predictive of learning outcomes. Kim et al. (2025): 530 noted that in unguided settings, younger users tend to engage more heavily with AI-driven platforms; however, when AI use is framed within pedagogical norms and scaffolding, such generational divides appear to diminish. These results signal that institutional strategies and learning design may play a stronger role in shaping students' AI engagement than age-related preferences alone.

The sixth hypothesis posited that gender would moderate the relationship between AI perceptions and creativity. This hypothesis was also not supported. Previous research, including that of (Asiksoy, 2024: 153; Đerić et al., 2025: 36; Møgelvang et al., 2024: 1363) suggested that female students tend to express more ethical reservations and risk-awareness when engaging with AI tools, which could hypothetically limit their experimental engagement in creative contexts. However, our findings suggest that these differences become statistically irrelevant in environments where both genders are given equitable access, exposure, and instructional guidance. In other words, when AI use is framed within inclusive pedagogical structures, both male and female students appear equally capable of leveraging AI to enhance creativity.

CONCLUSION

The findings from the study provides timely insights and empirical evidence that AI interaction and usage significantly enhance both cortical thinking and creativity among undergraduate design students, reinforcing the view of AI as a cognitive amplifier when engaged reflectively rather than passively. The findings align with prior research demonstrating that AI-mediated learning environments can stimulated reflective reasoning, metacognition and ideational expansion when students actively interrogate and adapt AI-generated outputs (Saritepeci & Yildiz Durak, 2024; Vasconcelos & dos Santos, 2023).

Moreover, the strong influence of students' perceptions and awareness of AI challenges underscores the critical role of AI literacy, supporting evidence that informed skepticism and understanding of AI limitations foster deeper analytical engagement and creative originality (Ibeh et al., 2025; Jose et al., 2025). Importantly, the absence of moderating effects of age and gender suggest that, within structured educational contexts, the cognitive benefits of AI are broadly accessible, echoing arguments that pedagogical design and scaffolding outweigh demographic differences in shaping AI-enabled learning outcomes (Kim et al., 2025). These findings contribute to the ongoing discourse on the cognitive paradox of AI by empirically supporting the position that its educational value depends on guided, reflective integration rather that uncritical reliance (Gerlich, 2025; Jose et al., 2025).

From a practical standpoint, the study highlights the necessity of embedding AI within pedagogical frameworks that promote critical inquiry, ethical awareness and creative reinterpretation. In emerging contexts such as Ghanaian technical universities, where AI adoption remains largely informal, structure curriculum interventions and institutional policies are essential to transform adhoc usage into meaningful cognitive development. Future research should extend this model across disciplines and longitudinal designs to further validate causal mechanisms and long-term impacts of AI-assisted learning.

Authors' Contributions

The authors contributed equally to the study.

Competing Interests

There is no potential conflict of interest.

Ethics Committee Declaration

The Ethics Committee of Accra Technical University reviewed and approved this study on 23rd July, 2025 (Ethics ID RE. #122-2025-DRIPTT). All procedures involving human participants were executed in compliance with the ethical standards established by the institutional research committee and the 1964 Helsinki Declaration, along with its subsequent amendments. All participants provided informed consent prior to the collection of data.

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