

RESEARCH ARTICLE

Open Access



# Exploring students' experiences and perceptions of human-AI collaboration in digital content making

Yohan Hwang<sup>1</sup> and Jang Ho Lee<sup>2\*</sup> 

\*Correspondence:  
jangholee@cau.ac.kr

<sup>1</sup> Department of English  
Language and Literature,  
Jeonbuk National University, 567,  
Baekje-daero, Deokjin-gu, Jeonju,  
South Korea

<sup>2</sup> Department of English  
Education, Chung-Ang  
University, 84 Heukseok-ro,  
Dongjak-gu, Seoul, South Korea

## Abstract

This study investigated university students' experiences and perceptions of collaborating with generative AI for digital content creation. Participants engaged in a digital contest addressing sociocultural issues, using generative AI while emphasizing the modification and refinement of AI outputs, rather than direct submission from AI-generated content. To provide more scientific results, this study included two groups: an experimental group using generative AI (Prompt Literacy; PL) and a comparative group relying solely on conventional digital tools (Digital Literacy; DL). This study compared the groups in terms of their creative problem-solving abilities and curiosity. The findings indicated that the PL group showed significantly enhanced creative problem-solving skills compared to the DL group. Students in the PL group perceived generative AI as a valuable partner that helped in idea creation, increased efficiency, and more dynamic creative exploration, although some expressed concerns about its limitations and ethical issues. The results suggest that prompt literacy plays a critical role in understanding new human-AI interaction and collaboration, which highlights the importance of human agency facilitated by technological support. Based on these findings, this study suggests some pedagogical implications of integrating generative AI into educational tasks and highlights the potential of AI to foster emergent creativity.

**Keywords:** Generative AI, Prompt literacy, Emergent creativity, ChatGPT, Multimodal AI

## Introduction

Engaging students in creative problem-solving tasks is crucial for education (Greenier et al., 2023). Therefore, educators encourage various active learning approaches, such as project-based learning and problem-based learning, which encourage students to participate in their own active knowledge creation (Wijnia et al., 2024). In such environments, using various digital tools and technologies can help students by facilitating the easy collection of new information and fostering creative problem-solving (Bajúzová & Hrmo, 2024). In particular, with generative AI (GenAI), which has recently gained significant attention as a supportive educational tool, the learning process can become more convenient and efficient (Lo et al., 2024). Several studies have highlighted that incorporating GenAI can be beneficial in several ways, such as assisting creative problem-solving

(Chan & Hu, 2023), promoting student engagement (Zha et al., 2024), supporting data analysis and research projects (Batista et al., 2024), and enhancing personalized learning experiences (Sengar et al., 2024).

Creativity was previously believed to be a uniquely human trait (Gabora, 2020). However, given the impressive creative abilities of GenAI in producing new content, it is crucial to consider whether it has a positive or negative influence on cultivating students' creative development. In this regard, there are concerns that using GenAI might lead students to become overly reliant on technology, thereby negatively affecting their cognitive development (Chan & Hu, 2023). It is essential to examine the balance between leveraging GenAI to enhance students' learning experiences and ensuring that it does not hinder their ability to develop independent thinking skills. To address these concerns, educators and researchers have to carefully consider how and to what extent GenAI can be integrated into classrooms (Wood & Moss, 2024).

This study aims to investigate university students' experiences with project-based learning using GenAI and examine their perceptions of the dynamics and potential of AI-human collaboration in achieving creative outcomes. To this end, the study encouraged students to participate in digital content making contest using GenAI, which suggests possible solutions for various sociocultural problems. Given the lack of competitions which allow AI-generated outputs in the target context, this study proposed holding an AI-human collaboration contest within the college for which one of the authors works. For contest participation, students were prohibited from submitting the AI output as it is; instead, they were encouraged to modify and refine the prompts they provided to the AI and edit the AI results provided to them. Through this process, the authors sought to understand how they collaborated with and utilized AI to solve the assigned problems. Furthermore, to scientifically analyze the impacts of human-AI collaboration in digital content making, the study compared the results of the students with those of a comparison group that created contest content by themselves without using GenAI. This study addresses the following research questions:

- (1) Does collaborating with GenAI in a digital content contest lead to a greater enhancement of creative problem-solving skills and curiosity than creating content lacking thereof?
- (2) How do students perceive their experiences of utilizing and collaborating with GenAI in creating digital content?

### **Prompt literacy and multimodal collaboration with generative AI**

Recently, several studies have examined the impact of large language model (LLM)-based GenAI. Much of this work has been conducted in the context of language education. These studies have highlighted how text-generation AI tools, mostly ChatGPT, can help students in tasks such as language production, composition, and critical thinking (Lo et al., 2024). Ngo (2023) surveyed 200 Vietnamese undergraduate students who had some experience using ChatGPT about the benefits and barriers of using GenAI, and interviewed a subset of them. Vietnamese students found that AI technology allowed them to save time, provide different types of information and individualized feedback,

and help them brainstorm ideas for their composition. At the same time, they expressed some concerns about using ChatGPT, including the generation of unreliable information and the inability to evaluate the quality and credibility of sources. Despite such challenges, students expressed their intention to continue using ChatGPT. With academic staff and PhD students from four countries, Firat (2023) explored their perceptions of ChatGPT and AI integration, using the survey as the instrument and thematic content analysis as the method of analysis. Among the emerging themes, the two most frequently mentioned are “Evolution of learning and education systems” and “Changing role of educators.” Under these themes, participants also pointed out the importance of digital literacy as an emerging type of literacy in higher education, as well as creativity and critical thinking as skills that deserve more attention in AI-integrated education.

Some authors discussed the potential of ChatGPT as an AI partner or collaborator for students. For example, in a study that explored the factors contributing to the adoption of an AI model, Jo (2023) suggested that students in higher education should develop the ability to use and evaluate AI-generated information and improve their academic performance when engaged in a target task with this technology. This may also lead them to view AI as a collaborator rather than just a content generator. Jo further noted that such a mindset among students can contribute to the development of “hybrid intelligence systems,” in which AI’s capabilities synergize with students’ abilities. Alqasham (2023) found that ChatGPT could help undergraduate students develop ideas in earlier stages of academic writing, “acting as a guide during the brainstorming phase” (p. 1256). This view aligns with the notion of considering AI as a collaborator in a given task (i.e., composition in Alqasham’s study), beyond being a proofreading tool (e.g., Liu & Ma, 2024).

Although the aforementioned contributions of GenAI are significant, much of the existing literature has tended to focus on narrow applications of GenAI, particularly in language-based tasks. For instance, Ngo’s (2023) findings on Vietnamese students’ perceptions emphasize the utility of AI in language production but lack a critical exploration of how such technologies impact the co-creation process in more diverse tasks. Similarly, while Jo (2023) highlights the potential for AI-human collaboration, the study does not explore how such collaboration could be realized in multimodal contexts. These gaps in research are particularly relevant to the study of creative problem-solving and curiosity, as they suggest that current AI implementations in education may not fully support the exploration of novel ideas across different modes of expression. Creativity often involves combining disparate elements in innovative ways, which requires a broader integration of AI capabilities beyond text-only mode (Lee & Palmer, 2025).

Recently, there is an increasing need to explore the role of multimodal collaboration with AI in education (Hwang et al., 2023). This shift calls for research that explores new forms of collaboration and interactions with GenAI in terms of multimodality. In other words, multimodal AI technologies, such as image and video generators, should be considered as means to facilitate creative tasks in learning and content creation (Zhan et al., 2023). This perspective aligns with the growing emphasis on fostering creative problem-solving in learning environments, where students are encouraged to experiment with AI tools to generate creative ideas and refine them across various fields. Through these interactions, students not only enhance their interaction with AI, but also cultivate the ability to approach problems with flexibility and an exploratory mindset (Hwang et al.,

2023). In fact, most extant research focused on simply employing AI-generated outputs without further modification. This approach limits the potential for truly collaborative efforts between humans and AI because it fails to explore the dynamics of the co-creation process and products.

To explore this issue in depth, this study considered the concept of prompt literacy. Prompt literacy refers to the skill and ability to create prompts for GenAI, interpret the output, and modify the prompts to achieve the desired results (Hwang et al., 2023). It goes beyond merely using AI output as it is; it refers to the ability to combine outputs from diverse AI sources—whether textual, visual, auditory, or otherwise—and more critically, to reimagine and recreate these outputs through human intervention. This iterative process is fundamental to creative problem-solving, as it requires students to engage critically with AI-generated content, refine their ideas, and explore multiple solutions. This holistic approach emphasizes the collaborative potential of AI and human users in creating innovative content and solutions (Hwang et al., 2023). Creativity is no longer solely a human trait but has expanded to include the synergistic outcomes of human-AI collaboration (Sengar et al., 2024). Therefore, the ability to edit, refine, and reimagine AI-generated output plays a crucial role in fostering creative problem-solving abilities and curiosity that merge technological innovation with human effort.

In sum, while the reviewed studies provide valuable insights into the benefits and challenges of integrating GenAI in education, they also reveal several gaps that need to be addressed. Most importantly, there has been limited empirical exploration of the application of AI to multimodal tasks, such as video or image generation, and little analysis of the collaborative processes involved in co-creating digital content with GenAI. Furthermore, the concept of prompt literacy, a critical skill for effective engagement with GenAI, remains underexplored in the existing literature. Given that creativity is closely linked to one's ability to explore, experiment, and iterate on ideas, understanding how students engage in the creative co-construction process with AI is crucial. Research in this area can provide deeper insights into how GenAI influences students' creative problem-solving approaches, their willingness to take intellectual risks, and their ability to generate innovative solutions.

## **Method**

### **Participants and research context**

The participants in this study were students majoring in English Language and Literature at a university in South Korea. The experimental group, consisting of 24 students, was enrolled in a course titled "Prompt Literacy and Humanities," while the comparison group, comprising 47 students, was registered in another course titled "Digital Literacy and Humanities." Both courses were taught by the same instructor (the first author) and studied identical learning content, focusing on the importance of the humanities and the creation of digital content to address sociocultural issues from a humanistic perspective. To ensure homogeneity between the two groups, the study was conducted with students from the same department who had similar academic backgrounds and were admitted based on comparable academic performance and abilities.

As both courses were taught by the same instructor who organized and evaluated the activities, many efforts were made to minimize potential instructor bias. First, the

evaluation criteria were standardized and pre-determined for both groups, ensuring that all submissions were evaluated based on objective measures such as creativity, coherence and relevance to the competition themes. Second, an additional reviewer (i.e. the course TA) was involved in reviewing the evaluation process and ensuring consistency across both groups. This reviewer, who was not involved in the teaching process, independently assessed 30% of a randomly selected subset of submissions. Finally, students in both groups were encouraged to anonymously evaluate their learning experience and provide feedback on the lecturer's teaching methods. These evaluations were reviewed to identify and address any potential biases that may have influenced the learning environment or outcomes, but no significant biases were found.

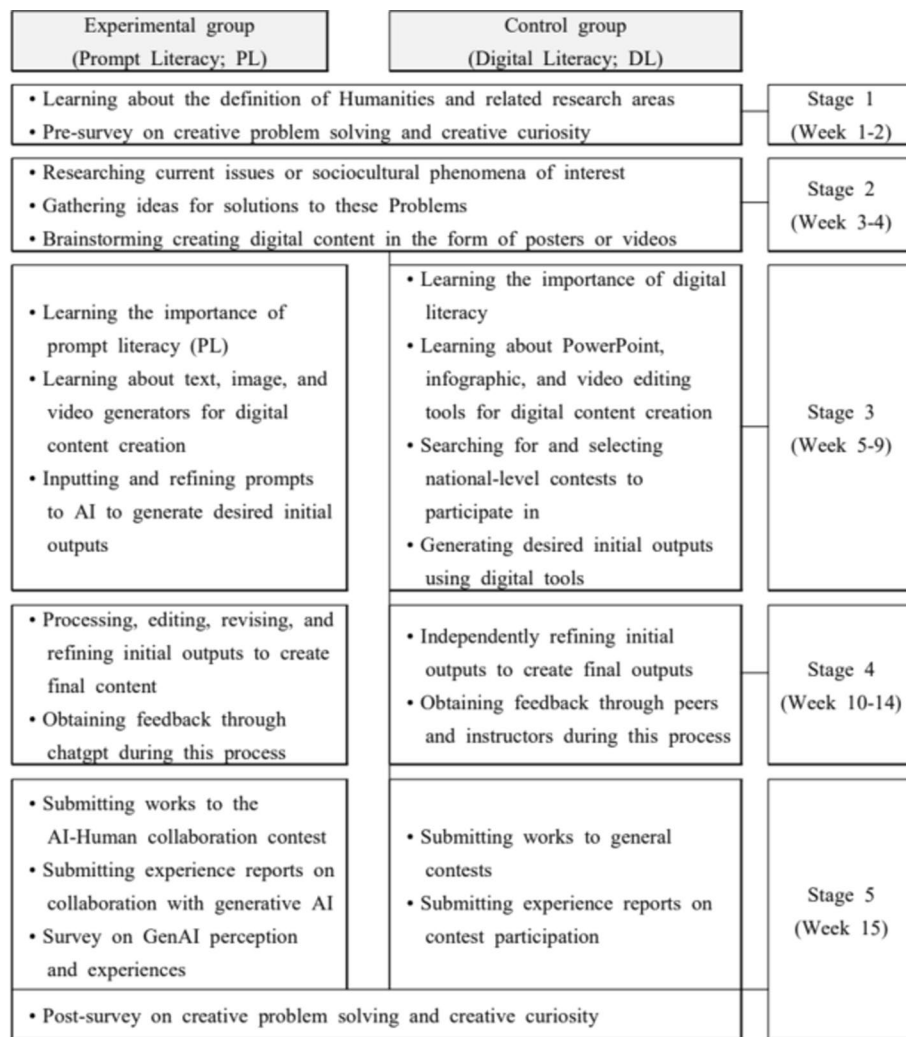
The experimental group, referred to as the Prompt Literacy (PL) group, engaged in content creation using GenAI technologies. By contrast, the comparison group, referred to as the Digital Literacy (DL) group, was introduced to more traditional digital literacy skill development without the use of GenAI. None of the students in the experimental group had prior experience using GenAI technologies. The only difference between the two groups was their approach to content creation for contest participation (see *Contest participation and submission* for details). The experimental group used GenAI technologies such as text-to-image or text-to-video tools to create digital content. Conversely, the comparison group relied on conventional digital literacy skills, such as PowerPoint, infographics, or videos, to independently develop their content. The step-by-step process for both groups is presented in Fig. 1.

The study followed strict ethical standards. At the beginning of the courses, each group of students was given detailed information about the objectives of the study, the use of their data (i.e., the final results of their digital content), and assurances of confidentiality. They were explicitly informed that their participation was voluntary and that they could withdraw from the study at any time. All participants signed an informed consent form, which outlined their rights and the scope of the study.

To ensure a comprehensive approach to ethical considerations, the study not only adhered to strict ethical standards but also took careful steps to address potential ethical risks associated with the use of GenAI in creative tasks. First, all participants in the PL group were explicitly informed about the ethical implications of using GenAI, including issues related to intellectual property and misinformation. Second, all AI-generated outputs used by students in the PL group were thoroughly reviewed by the first author to ensure adherence to ethical guidelines. For instance, students were required to document the specific prompts used to generate AI outputs and to detail how they modified or enhanced these outputs in their final submissions. The application forms submitted with their work included a section on ethical considerations, such as identifying the AI tools employed and explaining how the AI was used to complement rather than replace their (human) creativity.

### **Contest participation and submission**

As part of their course requirements, two groups of students registered for each course participated individually in the digital content contest. Students were asked to choose a topic of their own interest to investigate various sociocultural phenomena and create digital content that conveyed problem-solving messages. For contest participation and



**Fig. 1** The outline of a study procedure

submissions, the presented formats included images and videos. For images, participants could create posters, infographics, digital artworks, and webtoons with a recommended resolution of at least 300 dpi and an A3 size for posters. Submissions had to be made in 'jpg' or 'png' file formats. Videos could be video clips, shorts, advertising campaigns, animations, or documentaries with a minimum resolution of 1920×1080 pixels (HD) and a 16:9 horizontal aspect ratio. For shorts, a 9:16 vertical aspect ratio was required.

The PL group participated in contests that required the use of GenAI to create content, whereas the DL group participated in a general contest that created content without this technology. As mentioned in Introduction, given the lack of contests in the target context allowing the use of GenAI by the time of data collection, the first author organized an internal contest at the college level. Conversely, the students in DL group searched for and decided to participate in one of the national-level contests. Finally, students in the DL group chose to participate in either the "Disability Awareness Improvement Contest" or "Marine Pollution Prevention Contest" (see the images on the right in Fig. 2). Figure 2 shows the posters on which each group of students participated.



**Fig. 2** The posters of the contests in which the students participated

In the PL group, a crucial requirement for contest participation was that all submissions be created using GenAI. However, simply submitting an unmodified AI-generated output was not permitted. Specifically, the participants were required to edit, modify, enhance, combine, and develop the AI output to complete their final work. For example, they could create a video based on a scenario generated by ChatGPT or use images generated by AI image generators to create their own content. The selection of AI tools was guided by specific inclusion and exclusion criteria that were validated for the experiment. Specifically, the tools were selected based on their accessibility, multimodal functionality, reliability, and compliance with ethical AI guidelines, while excluding those with high technical barriers or insufficient user support. In addition, a pilot test was conducted prior to the study to validate the selected tools. This involved a group of undergraduate students who tested the tools on tasks similar to those in the main study. Their feedback on usability, effectiveness, and potential challenges was used in the final selection of tools.

In addition to their final product, the PL group had to submit an application form that provided detailed explanations of the prompts given to the AI and how the AI-generated outputs were developed to complete the final work. The first author verified that the participants did not submit unmodified AI-generated outputs by thoroughly reviewing the application forms and ensuring that the explanations demonstrated meaningful modifications and enhancements to the AI-generated content.

### Contest result

This section introduces some examples of student work, focusing primarily on award-winning pieces in contests. As mentioned previously, the students in the DL group participated in one of the following two contests: the “Disability Awareness Improvement Contest” and “Marine Pollution Prevention Contest.” The students created and submitted posters and videos expressing their ideas and problem-solving strategies through digital content; one of the students received the grand prize for the video creation in the first contest (Fig. 3), while the other two students received the encouragement award in the second contest (Fig. 4).

Compared with the DL group, as the PL group was allowed to choose their own topics, a wide variety of content covering diverse subjects was produced, including low birth rates, environmental protection, racial discrimination, deepfake technology, gender equality, nuclear war, regional development, competition in college admissions, and drunk driving, to list a few. Among these submissions, the video that won the grand prize and the two posters that received excellence awards are presented in Figs. 5 and 6, respectively, along with the GenAI programs used by the students and the final prompts they entered.

To create a video of the dangers of drinking and driving, as shown in Fig. 5, the students developed a scenario in collaboration with ChatGPT (<https://www.openai.com/chatgpt>) utilizing Vimeo (<https://vimeo.com>) and InVideo (<https://invideo.io>) to produce short video clips and edit the videos by themselves.

To create the poster shown in Fig. 6A (image on the left), the student first determined the direction of content creation through conversations with ChatGPT. Specifically, he collected the content and specific examples that needed to be included in the poster to deliver a message on preventing low birth rates in South Korea. Subsequently, using Adobe Firefly (<https://firefly.adobe.com/>), he entered the following prompt to generate the desired image: *Please draw a picture of a child and parents together. Illustrate the background and overall atmosphere in warm tones. Position the child among the parents and depict everyone smiling happily. Write the word “family”*



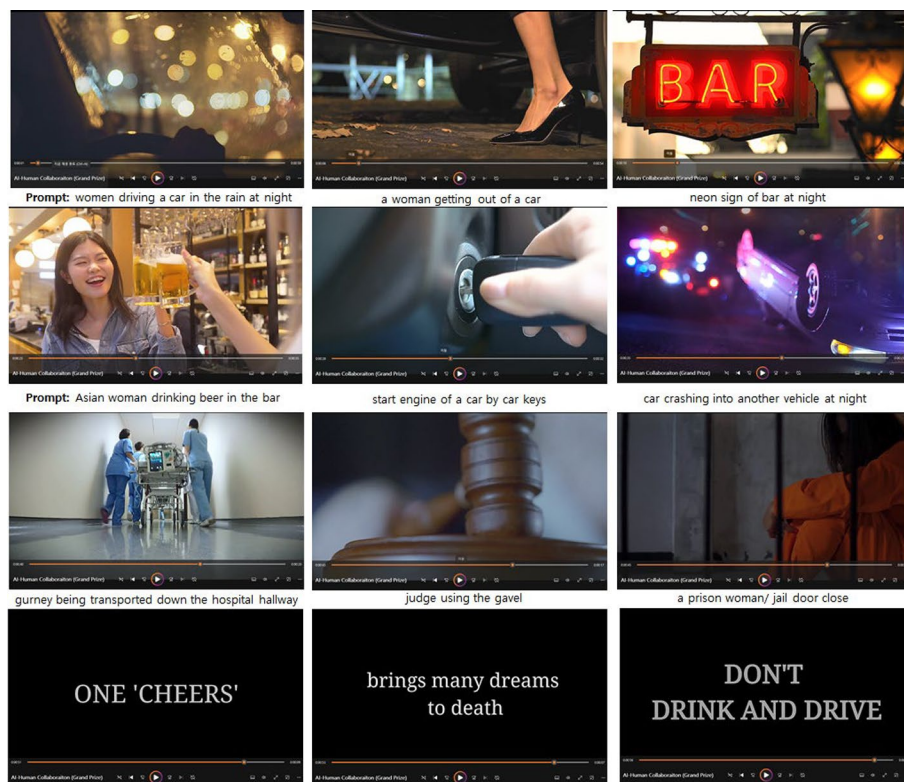
**Fig. 3** Video for disability awareness improvement contest by DL group student



CAPTION:  
The sea is trembling with fear because of grenades that could fall at any time.

CAPTION: Masks take 500 years to decompose, plastics take hundreds of years to break down, and we must not turn the sea—the home of marine animals—into a garbage dump.

**Fig. 4** Posters submitted to marine pollution prevention contest by DL group



**Fig. 5** Video created by PL group participant collaborated with GenAI



**Fig. 6** Posters created by PL group participants collaborated with GenAI

in black letters on a white background. Use white for the letter “I” and black for the other letters. PowerPoint was used to manually insert the desired text.

Similarly, the student who created Fig. 6B (image on the right) also collected information on current environmental issues through conversations with ChatGPT by asking the following prompt: *I am planning to create a poster on global warming; what kind of images should be included in the poster to effectively convey the message?* She then gathered ideas for phrases or sentences that could be incorporated into the poster to raise awareness about global warming: *What phrases should be included in a poster on global warming?* To visualize this, with the copilot image generator (<https://copilot.microsoft.com/images/create>), she entered the following prompt: *Global warming is causing the Earth's temperature to rise, melting all the glaciers in the Arctic and leaving only a few really small glaciers, so polar bears have nowhere to live and are barely able to stand on the few remaining glaciers.* After creating the background of the poster, she manually inserted the desired text to deliver an environmental protection message.

Thus, both groups demonstrated the ability to integrate humanistic perspectives with technological tools, resulting in impactful digital content that addressed various socio-cultural issues. Whereas the DL group created content only through their own efforts, along with digital tools, the PL group collaborated with GenAI during all processes, from content planning to production.

### Instruments

As the dependent variables with which to compare the creative dimensions of the PL and DL groups, we selected creative problem-solving and creative curiosity as the dependent

variables of the study, given the nature of the target task. Specifically, this task, unlike traditional classroom tasks, did not impose strict restrictions on the output format or specific theme, allowing participants to draw on digital resources of their choice in their own original ways. This whole process was therefore expected to encourage students' inquisitive thinking and to promote engagement with the target task in a creative way.

To assess the levels of creative problem-solving and curiosity in both groups, a survey consisting of relevant items was developed. Creative problem-solving was defined in terms of students' ability to identify problems, generate innovative ideas, and implement effective solutions, measured using 12 items adapted from Lee et al.'s (2017) "Creativity Indicators for University Students." Creative curiosity was defined in terms of the willingness to explore new ideas, persevere through challenges, and engage deeply with tasks, measured using 10 items from the same source (see supplementary material for the full list of survey items). Regarding reliability, the questionnaire items associated with each construct were found to be overall reliable:  $\alpha=0.77$  for Creative Problem-solving (Pre-intervention),  $\alpha=0.87$  for Creative Problem-solving (Post-intervention),  $\alpha=0.74$  for Creative Curiosity (Pre-intervention),  $\alpha=0.85$  for Creative Curiosity (Post-intervention).

Another set of questionnaire items was developed to explore the PL group's perceptions of GenAI. To this end, the survey items of Chan and Zhou (2023) and Wang and Zhang (2023) were adapted to this study's research context and aims. The survey consisted of three sub-constructs: (1) usefulness of GenAI for academic performance (six items), (2) perception of GenAI when engaged in the target task (four items), (3) ethical concerns and limitations when using GenAI (three items), and (4) intention to use GenAI in the future (three items). Regarding reliability, the sub-constructs included in the questionnaire were found to be moderately reliable:  $\alpha=0.76$  for the usefulness of GenAI for one's academic performance,  $\alpha=0.74$  for the perception of GenAI when engaged in the target task,  $\alpha=0.71$  for ethical concerns and limitations when using GenAI, and  $\alpha=0.84$  for intention to use GenAI in the future.

Next, the PL group was asked to write reflective reports based on the following two topics: (1) "Please describe your experience of creating humanities content using generative AI." (2) "Please explain how the experience of creating humanities content using generative AI has influenced the development of your creative ability." This data was used to provide a richer and more in-depth explanation of the quantitative data collected for the first and second research questions.

### Data analysis

We conducted two paired *t*-tests for each group to test whether the mean scores of each group on the target constructs changed significantly after the intervention. Given the parametric nature of the paired *t*-test, we first checked the normality of each variable using the Shapiro–Wilk test, which showed that the distribution of the target variables for two groups did not deviate significantly from normality (see Table 1), except for the DL group's post-intervention scores on Creative problem-solving. On closer inspection, this non-normality may have been due to its skewness (skewness=0.77, standard error of skewness=0.35). Given that the skewness *z*-score is 2.2 (0.77/0.35), it can be suggested that the DL group's post-intervention scores on Creative Problem-solving are significantly deviant at  $p < 0.05$  (*z*-score when greater than 1.96), but not at  $p < 0.01$  (*z*-score

**Table 1** The results of Shapiro–Wilk test on the target variables

| Construct                | Group    | Intervention point | Statistics ( <i>W</i> ) | <i>p</i> value |
|--------------------------|----------|--------------------|-------------------------|----------------|
| Creative problem-solving | PL group | Pre-intervention   | 0.95                    | 0.32           |
|                          |          | Post-intervention  | 0.97                    | 0.72           |
|                          | DL group | Pre-intervention   | 0.96                    | 0.13           |
|                          |          | Post-intervention  | 0.93                    | 0.006**        |
| Creative curiosity       | PL group | Pre-intervention   | 0.98                    | 0.89           |
|                          |          | Post-intervention  | 0.98                    | 0.87           |
|                          | DL group | Pre-intervention   | 0.96                    | 0.13           |
|                          |          | Post-intervention  | 0.96                    | 0.12           |

\*\* $p < 0.01$ 

when greater than 2.58) (Field, 2017). Therefore, the normality assumption was overall met for these variables.

After examining the changes in each group's scores across the intervention, we employed analysis of covariance (ANCOVA) to accurately estimate the effects of the condition (i.e. PL vs. DL), given its value in reducing within-group error variance and reducing the effects of confounds (i.e. pre-intervention differences in the target variable in our context) (Field, 2017). We used two statistical models (i.e., one for Creative Problem-solving and the other for Creative Curiosity), with the mean responses of the two groups at pre-intervention as the covariate and condition (i.e., PL and DL) as the between-group variable. In addition to the normality assumption examined above, we also tested other statistical assumptions for the use of ANCOVA: homogeneity of variances and linearity of covariate relationships. The results of Levene's test showed that overall the assumption of homogeneity of variances was not violated:  $F(1, 69) = 2.21$ ,  $p = 0.14$  for Creative Problem-solving before the intervention,  $F(1, 69) = 0.02$ ,  $p = 0.90$  for Creative Curiosity before the intervention,  $F(1, 69) = 1.78$ ,  $p = 0.19$  for Creative Problem-solving after the intervention,  $F(1, 69) = 0.03$ ,  $p = 0.86$  for Creative Curiosity after the intervention. To test the linearity of the covariate relationships, the examination of the scatterplots showed the linear relationships between covariates (i.e. pre-intervention scores) and the dependent variables (i.e. post-intervention scores) for both Creative Problem-solving and Creative Curiosity. Therefore, the statistical assumptions for ANCOVA were considered to be met in the current dataset.

Participants' responses to the items related to the perceptions of GenAI were analyzed descriptively to investigate participants' perceptions of their development of creative problem-solving and curiosity, as well as engagement in the target task in collaboration with GenAI. Participants' responses in the reflective reports were analyzed using an inductive coding process which allows for the identification of patterns and themes directly rooted in the participants' interactions with GenAI (Chandra & Shang, 2019).

## Result

This section presents findings related to three different types of data: (1) the quantitative responses of the PL and DL groups on creative problem-solving and creative curiosity; (2) the quantitative responses of the PL group to questionnaire items related to GenAI; and (3) qualitative analyses of their reflections. Specifically, (1) and those related

to creative problem-solving and curiosity in (2) and (3) addressed the first research question. Those related to the PL group's perceptions of GenAI in (2) and (3) are presented together to address the second research question.

#### Development in creative problem-solving and creative curiosity

Table 2 shows the mean responses of the two groups to the two target constructs at two different time points (pre- and post-intervention). The results of the paired *t*-test further revealed that the PL group's mean responses to the target constructs increased significantly because of the intervention ( $t=3.75$ ,  $p<0.001$  for Creative problem-solving and  $t=2.31$ ,  $p=0.02$  for Creative curiosity). Similarly, the DL group's mean responses on the target constructs increased significantly at post-intervention in comparison with their responses at pre-intervention ( $t=3.30$ ,  $p<0.001$  for Creative problem-solving and  $t=3.43$ ,  $p<0.001$  for Creative curiosity).

We further employed ANCOVA to estimate the effects of the target intervention. For creative problem-solving, a one-way ANCOVA indicated that there was a significant effect in favor of the PL condition,  $F(1, 68)=6.48$ ,  $p=0.013$ , after controlling for mean responses at pre-intervention. In other words, the PL condition was more effective than the DL condition in enhancing students' creative problem-solving skills. Meanwhile, for creative curiosity, there was no significant effect of condition,  $F(1, 68)=1.47$ ,  $p=0.23$ , after controlling for mean responses at pre-intervention.

These findings not only highlight the comparative effectiveness of the PL condition for fostering creative problem-solving but also raise interesting considerations regarding participants' experiences with the target task. Shifting the focus from the first data set, we examined the data from another survey—the responses of the PL group to questionnaire items related to engagement with the target task using GenAI. Specifically, the participants were largely positive about engaging in the target task in collaboration with GenAI (see Table 3). For example, when engaging in the target task, participants believed that GenAI helped them connect their ideas better ( $M=4.19$ ) and be more creative than lack thereof ( $M=4.12$ ). More importantly, the participants realized the importance of prompt literacy in producing the intended output ( $M=4.65$ ) and enhanced their emergent creativity by engaging in the target task in collaboration with GenAI ( $M=4.35$ ).

To further understand the comparative effectiveness of the PL condition in terms of creative problem-solving, selected reflection data was examined in relation to the survey results. Students in the PL group reported an extensive incorporation of AI-generated

**Table 2** Descriptive statistics of PL and DL groups' responses on two target constructs at two different time points

| Construct                | Group    | Pre-intervention<br><i>M</i> ( <i>SD</i> ) | Post-intervention<br><i>M</i> ( <i>SD</i> ) | <i>t</i> value<br>(paired<br><i>t</i> -test) |
|--------------------------|----------|--------------------------------------------|---------------------------------------------|----------------------------------------------|
| Creative problem-solving | PL group | 4.09 (0.61)                                | 4.65 (0.72)                                 | 3.75***                                      |
|                          | DL group | 4.18 (0.45)                                | 4.39 (0.53)                                 | 3.30***                                      |
| Creative curiosity       | PL group | 3.73 (0.64)                                | 4.09 (0.80)                                 | 2.31*                                        |
|                          | DL group | 3.57 (0.60)                                | 3.79 (0.70)                                 | 3.43***                                      |

\* $p<0.05$ , \*\*\* $p<0.001$

**Table 3** Descriptive statistics of participants' perception of GenAI (PL group only)

| Sub-construct                                       | Statement (questionnaire item)                                                                                                       | M (SD)      |
|-----------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------|-------------|
| Perception of GenAI when engaged in the target task | I've been able to better connect my various ideas by using GenAI to create content                                                   | 4.19 (0.94) |
|                                                     | I was able to be more creative than I would have been in the past by using GenAI to create content                                   | 4.12 (0.77) |
|                                                     | I realized the importance of typing in prompts by using GenAI to create content                                                      | 4.65 (0.56) |
|                                                     | I developed the ability to be creative (connecting results to create something new) through the task of creating content using GenAI | 4.35 (0.63) |

ideas into their creative processes, highlighting AI's function as an idea generator and refiner. For example, students with strong creative problem-solving skills produced work that demonstrated exploratory ways of working, such as mixing tools and/or addressing unusual socio-cultural issues. Some students used AI as a brainstorming partner, leveraging it to generate a variety of ideas to polish and refine, while others employed it to overcome creative blocks or enhance the visual impact of their work. Such iterative refinement highlights the dynamic interplay in AI-assisted ideation, with AI acting as a collaborator that enhances rather than replaces human creativity.

Building on these observations, an in-depth analysis of participants' reflections further underscores how generative AI has impacted on their creative problem-solving abilities. First, enhanced creative problem-solving ability emerged as a prominent theme. Many participants reported that the GenAI helped them generate new ideas and expand their creative problem-solving abilities. For some, AI acted as a catalyst, stimulating creativity by providing unexpected suggestions or refining initial concepts. One participant noted: *At first, the idea I thought of was boring, but thanks to AI, I learned how to solve problems in a more fun and creative way* (Participant #9). Another shared: *Generative AI was a great help in solving problems in ways I hadn't thought of before* (Participant #3). This illustrates how AI can serve as a collaborative partner in creative problem-solving tasks and help students develop their own ideas.

Similarly, many indicated that their ability to connect different ideas and elements into new creative forms was significantly enhanced by the use of AI. One participant shared: *The process itself was fascinating, as generative AI helped with parts of the drawing that I couldn't express well, and in the end, it seemed to make me more creative* (Participant #1). Another remarked: *The unexpected keywords or perspectives provided by AI acted as a catalyst for new ways of thinking* (Participant #6), reflecting how the AI could prompt her novel thinking in the target task. Many viewed AI as a collaborator requiring human input and refinement to produce the desired outcomes. One participant even emphasized the importance of collaboration and interaction with GenAI in the future society, noting that: *Collaboration with generative AI was not just about using a tool; it was an opportunity to reflect on the interaction between technology, humans, and society* (Participant #5).

While GenAI proved useful in many respects, participants acknowledged its limitations in creative problem-solving tasks based on their experience of engaging in the

target task. One participant commented: *The innovative ideas I came up with couldn't be fully realized by AI, so it wasn't 100% helpful for the development of creativity* (Participant #4). This suggests that, while AI can assist the creative process, it still does not fully replicate the depth of human creativity, particularly when nuanced or highly original ideas are concerned. Similarly, critical reflections on creativity and the role of AI emerged as students considered the broader implications of AI in creative tasks. One respondent reflected: *I realized that AI combines and reuses existing information, which made me wonder whether that can really be considered a genuinely creative outcome* (Participant #12). This reflection raises important questions about the boundaries of human-AI co-creativity, suggesting that while AI can facilitate creativity, it may also challenge traditional definitions of creative work.

### PL group's perception of GenAI

Table 4 presents the descriptive statistics of the questionnaire items regarding participants' general perceptions of GenAI.

First, regarding their perception of the usefulness of GenAI for academic performance, the participants responded positively, with the mean responses for all items associated with this sub-construct being over 4.0, indicating a general agreement regarding GenAI's benefits in this regard.

This was also confirmed by the participants' reflection papers. One of the significant themes among the responses to the first question (i.e., general perception of using GenAI in digital content making) was the increased efficiency in content creation offered by GenAI. Many participants found that tasks such as image creation, video production, and editing were easily performed with AI assistance, which was less time-consuming. For instance, one participant noted: *It might take lots of time if I did it alone, but with AI, it was so easy and fast to create content* (Participant #11). In addition, it was found

**Table 4** Descriptive statistics of participants' perception of GenAI (PL group only)

| Sub-construct                                      | Statement (questionnaire item)                                                                                     | M (SD)      |
|----------------------------------------------------|--------------------------------------------------------------------------------------------------------------------|-------------|
| Usefulness of GenAI for one's academic performance | I believe generative AI technologies can improve my digital literacy skills                                        | 4.00 (0.94) |
|                                                    | I believe generative AI technologies can improve my overall academic performance                                   | 4.19 (0.80) |
|                                                    | I think generative AI technologies can help me become a better writer                                              | 4.08 (0.81) |
|                                                    | I think generative AI technologies can help me become a better content-maker                                       | 4.38 (0.70) |
|                                                    | I think AI technologies can provide me with personalized and immediate feedback and suggestions for my assignments | 4.12 (0.82) |
|                                                    | I believe generative AI technologies can help me save time                                                         | 4.46 (0.71) |
| Ethical consideration and limitations              | I understand generative AI technologies have limitations in their ability to handle complex tasks                  | 3.81 (0.98) |
|                                                    | I understand generative AI technologies can generate output that is factually inaccurate                           | 4.08 (0.74) |
|                                                    | I understand generative AI technologies can generate output that is out of context or inappropriate                | 4.04 (0.74) |
| Intention to use GenAI in the future               | I intend to continue using GenAI in the future                                                                     | 3.96 (0.87) |
|                                                    | I will always try to use GenAI in my daily life                                                                    | 4.31 (0.68) |
|                                                    | I plan to use generative AI in my academic study in the future                                                     | 4.27 (0.72) |

that the GenAI served as a guide, helping participants to be more creative in the content-making process. One participant stated: *Having generative AI as part of the content creation process allowed me to be more creative than if I were creating the content by myself* (Participant #2). These reflections indicate that GenAI provides a structural framework, making it easier for students to work efficiently through the ideation and creation processes.

Despite the challenges of working with AI (particularly in generating detailed and refined prompts), some participants expressed satisfaction with and pride in their final products. As one participant reflected: *At first, it was a bit challenging to get the right prompts for the generative AI, but as I refined the prompts, I was proud of myself not giving up and finishing the job* (Participant #8). Another participant highlighted the direct impact of using GenAI to create digital content in his academic work, stating that: *I think the experience of creating digital content using generative AI has been very beneficial to my academic achievement and has really helped me* (Participant #14). This sense of accomplishment was a common feeling among participants, highlighting the supportive role played by AI in their creative endeavors.

While participants generally recognized the benefits of using GenAI, several raised concerns about ethical issues and its limitations. These results demonstrate that the participants were aware of limitations of AI in handling complex tasks ( $M=3.81$ ), inaccuracies ( $M=4.08$ ), and context-related issues ( $M=4.04$ ). In their reflections, some even expressed fears about the potential misuse of AI and its over-reliance on technology. For example, one participant stated: *It's fascinating and remarkable that AI has developed to this extent, but at the same time, I felt a bit scared, wondering if it might be misused* (Participant #3). Others raised questions about how AI could impact customs and agreements that have been held in society until now. With other students commenting: *I felt that ethical considerations about how to effectively utilize technology are necessary* (Participant #5), and *Issues like copyright and determining whose work it is when collaborating with generative AI need to be discussed first* (Participant #17).

Despite such concerns presenting both opportunities and challenges, another set of questionnaire items concerning participants' intention to use GenAI in the future was mostly positive, showing a high level of willingness to continue employing GenAI in both their daily lives ( $M=4.31$ ) and academic studies ( $M=4.27$ ). Participants found that it was difficult to use GenAI initially because of challenges such as selecting appropriate programs, creating and referring prompts, and sizing AI outputs to meet their expectations. However, once they produced the desired results, they felt a great sense of accomplishment, which led to increased future intention to use GenAI in their work. One participant recalled: *At first, it felt extremely difficult, and I thought I wouldn't be able to do it, but as I kept going, it became fun, and now I want to use it even more in the future* (Participant #11). Another participant noted the difficulty of refining prompts: *I felt disappointed when the results didn't initially match what I wanted, but as I adjusted the prompts and saw the images that matched with my intention, I felt proud and wanted to keep using it* (Participant #7).

Similarly, working with GenAI appeared to increase participants' confidence in their creative endeavors. The role of AI as a supportive tool allowed them to take risks and try new approaches, which they might have been hesitant to do previously on their own.

One participant stated that *Using AI helped me overcome the fear of creating something, and it made me want to try to make more creative works* (Participant #18). This growing confidence was frequently observed in the students' reflections, suggesting that AI can serve as a valuable tool to encourage students to engage in more complex creative problem-solving tasks. One student mentioned: *If given the chance, I would like to fully utilize the capabilities of generative AI to create much more complex works* (Participant #6).

In conclusion, the participants' experiences with GenAI revealed its potential and limitations in the context of digital content creation. Although many recognized the significant advantages of increased efficiency, creativity, and a sense of accomplishment, they also expressed concerns about ethical issues and the limitations of AI in replicating human creativity. Despite initial challenges such as generating appropriate prompts, participants reported a strong willingness to continue using GenAI in future academic and personal endeavors.

## Discussion

This study revealed that collaborating with GenAI positively affected students' creative problem-solving abilities. That is, the PL group demonstrated significant improvement in creative problem-solving skills compared to the DL group. It was further revealed that many students in the PL group perceived AI as a means to help their idea creation and creative exploration, and that most expressed positive perceptions of AI as a collaborative partner, highlighting its ability to support creative endeavors and increase efficiency. This finding aligns with the results of previous studies (e.g., Han, 2023; Kim & Han, 2021; Singh et al., 2023; Zou et al., 2020) which collectively suggest the value of AI tools (including ChatGPT) for more customized learning than their traditional counterparts.

Most participants in the PL group acknowledged the need for and importance of AI technology for their studies in higher education and careers as a result of engaging in the target task administered in the study. Such positive perceptions among the participants echoed those of Hamid et al.'s (2023) study with university students majoring in pharmacy who used GenAI during process-driven problem-based learning. Hamid et al. (2023) highlighted the value of this tool in increasing the sampled students' levels of engagement in the target activity, which we also observed in the process of our students' content creation. Participants generally found that GenAI supported their creative problem-solving tasks by helping them connect ideas, accelerate their creative processes, and increase their confidence in content-making.

Traditionally, creativity has been regarded as a uniquely human trait (Gabora, 2020), but the findings of this study suggest that creativity can now be redefined within the context of human-AI collaboration. AI tools act not merely as instruments but also as catalysts for emergent creativity, helping students explore ideas and approaches in a new way. For example, participants in the PL group noted that AI provided unexpected suggestions or helped refine initial concepts into more innovative solutions. By fostering collaborative thinking and a multidimensional approach to problem-solving, AI encourages students to develop new ways of connecting and integrating ideas. These findings provide empirical evidence supporting previous studies underscoring the importance of embracing AI as a partner in education (Alqasham, 2023; Jo, 2023).

However, despite the overall positive perceptions, some participants raised concerns about the limitations and ethical implications of GenAI. These reactions included issues related to accuracy, originality, and potential misuse. This finding is consistent with those of previous studies that highlighted the importance of AI ethics (Mbiazi et al., 2023). The ethical considerations expressed by students in this study raised some concerns about over-reliance on AI, the risk of diminishing originality, and the potential for plagiarism. This finding suggests the importance of integrating prompt literacy as a core component of curricula, which is another important implication of this study. As mentioned above, prompt literacy goes beyond the technical skill of using AI; it reflects a broader ability to direct, modify, and co-create with AI, ensuring that human agency remains at the center of the creative process (Hemment et al., 2023; Hwang et al., 2023). In educational contexts, this emphasizes the need to integrate prompt literacy into the classroom as a critical skill for hybrid intelligence systems, in which humans and AI collaborate to solve problems and create content in tandem. For example, students should be encouraged to critically evaluate the outputs of AI, recognizing when and how these outputs align with their independent goals and creative intentions.

Based on the results of the present study, we provide the following two pedagogical implications for educational practitioners: First, because creativity is at the heart of modern education and GenAI is increasingly being used in the curriculum, teachers and curriculum designers are strongly encouraged to consider ways to incorporate student collaboration with GenAI as an element of the course. From a theoretical perspective, collaboration in this study is rooted in socio-constructivist learning theories, which emphasize shared meaning-making and mutual engagement in problem-solving tasks (Vygotsky, 1978). Collaboration in the context of human-AI interaction refers to a hybrid intelligence model in which students actively co-create with the AI, using its capabilities while maintaining autonomy, critical oversight, and ethical awareness. Effective pedagogical design supports this model by providing structured opportunities for students to direct, refine, and reflect on their interactions with AI, ensuring that human agency remains central. Educators, therefore, should focus on developing students' ability to collaborate with AI as a tool while maintaining critical and ethical judgement. These findings underscore the importance of recognizing and promoting learner agency in AI-assisted education (Darvishi et al., 2024; Lee et al., 2025). More importantly, to ensure that the integration of GenAI does not hinder the development of students' independent thinking skills, pedagogical designs should foster critical engagement with AI outputs. Specifically, educators should guide students in questioning the validity, biases, and sources of information provided by AI tools. By designing tasks that require students to iteratively refine AI outputs, justify their modifications, and reflect on the creative process, educators can ensure that students remain active and thoughtful participants in their learning journey.

Second, given the feasibility of content creation using GenAI technology in higher education and its pedagogical value in terms of developing creative problem-solving skills, content creation can be included as part of assessment and grading in higher education courses. The integration of content creation with generative AI technologies seems to fit well with Gardner's (1983, 2006) theory of multiple intelligences and would be beneficial for students who may have been disadvantaged in higher education

assessments (particularly in the creativity dimension) because of its heavy reliance on the verbal and written aspects of assessment. Such students are expected to demonstrate their creativity and other aspects related to learning outcomes better if they are given access to content creation using generative AI technologies.

## Conclusion

This study explored the potential of GenAI as a useful tool in education, particularly in helping students to cultivate their creative problem-solving skills in new ways. The group of students who used GenAI (PL group) showed significant improvements in their ability to connect ideas, think innovatively, and refine their work. These findings highlight the importance of prompt literacy as a critical skill that helps students effectively direct and co-create with AI while retaining their human agency. At the same time, the study highlights some important challenges. Participants in the PL group reported technical challenges such as difficulties in crafting precise prompts to achieve desired outcomes, issues with consistently generating high-quality visual content, and occasional inaccuracies or biases in AI-generated output. Incorporating AI into the classroom can open up new possibilities for blending human creativity with technology. This study suggests that by focusing on both the benefits and the challenges of AI, educators can help students learn to use it responsibly while still fostering their own creativity and independent thinking.

While our findings provide practical insights, some limitations of the present study warrant some discussion. First, the study's theoretical implications for pedagogy and the psychology of learning remain underexplored. The findings underscore the importance of human-AI collaboration as a model of hybrid intelligence, where students actively engage with AI to enhance their creative problem-solving skills. Future research should delve deeper into how this hybrid model influences cognitive and metacognitive processes, particularly in fostering critical thinking, self-regulation, and ethical decision-making in educational contexts. Furthermore, to extend the findings of this study, future research should explore other types of tasks beyond digital content creation, such as collaborative research projects, simulations, or interdisciplinary problem-solving activities. Methodological approaches such as longitudinal studies or experimental designs could provide more robust insights into the long-term effects of GenAI on creativity and curiosity. Finally, this study recognizes that the sample size of the present study ( $N=71$ ) is relatively small, particularly for conducting inferential statistical tests. To address this limitation, we rigorously checked the statistical assumptions required for these tests and found that our dataset largely met these assumptions. However, we recognize that a larger sample size would strengthen the validity and generalizability of the findings reported in this study.

## Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s41239-025-00542-0>.

Additional file 1.

## Acknowledgements

We sincerely appreciate the anonymous reviewers for their constructive feedback and valuable comments on this manuscript.

**Author contributions**

Yohan Hwang: Conceptualization, Methodology, Formal Analysis, Investigation, Resources, Data Curation, Writing – Original Draft, Writing – Review & Editing, Visualization, Supervision. Jang Ho Lee: Conceptualization, Methodology, Validation, Formal Analysis, Investigation, Data Curation, Writing – Original Draft, Writing – Review & Editing, Supervision.

**Funding**

Not applicable.

**Data availability**

Data will be made available on reasonable request.

**Declarations****Competing interests**

No potential conflict of interest was reported by the authors.

Received: 9 December 2024 Accepted: 28 May 2025

Published online: 01 July 2025

**References**

- Alqasham, F. H. (2023). ChatGPT in the Saudi EFL classroom: A study of learner usage patterns and possibilities in learning optimization. *Migration Letters*, 20(7), 1251–1263.
- Bajúzová, M., & Hrmo, R. (2024). Digital tools in education: The impact of digital tools in education on students' creativity. *R&E-SOURCE*, 1(s1), 4–18. <https://doi.org/10.53349/resource.2024.is1.a1236>
- Batista, J., Mesquita, A., & Carnaz, G. (2024). Generative AI and higher education: Trends, challenges, and future directions from a systematic literature review. *Information*, 15(11), 676. <https://doi.org/10.3390/info15110676>
- Chan, C. K. Y., & Hu, W. (2023). Students' voices on generative AI: Perceptions, benefits, and challenges in higher education. *International Journal of Educational Technology in Higher Education*, 20, 43. <https://doi.org/10.1186/s41239-023-00411-8>
- Chan, C. K. Y., & Zhou, W. (2023). Deconstructing student perceptions of generative AI (GenAI) through an expectancy value theory (EVT)-based instrument. *arXiv*. <https://doi.org/10.48550/arXiv.2305.01186>
- Chandra, Y., & Shang, L. (2019). Qualitative research using R: A systematic approach. *Springer*. [https://doi.org/10.1007/978-981-13-3170-1\\_8](https://doi.org/10.1007/978-981-13-3170-1_8)
- Darvishi, A., Khosravi, H., Sadiq, S., Gašević, D., & Siemens, G. (2024). Impact of AI assistance on student agency. *Computers & Education*, 210, 104967. <https://doi.org/10.1016/j.compedu.2023.104967>
- Field, A. (2017). *Discovering statistics using IBM SPSS statistics* (5th ed.). SAGE Publications.
- Firat, M. (2023). What ChatGPT means for universities: Perceptions of scholars and students. *Journal of Applied Learning and Teaching*, 6(1), 57–63. <https://doi.org/10.37074/jalt.2023.6.1.22>
- Gabora, L. (2020). Research on creativity. In E. G. Carayannis (Ed.), *Encyclopedia of creativity, invention, innovation and entrepreneurship* (pp. 1974–1983). Springer. [https://doi.org/10.1007/978-3-319-15347-6\\_387](https://doi.org/10.1007/978-3-319-15347-6_387)
- Gardner, H. (1983). *Frames of mind: The theory of multiple intelligences*. Basic Books.
- Gardner, H. (2006). *Multiple intelligences: New horizons*. Basic Books.
- Greenier, V., Fathi, J., & Behzadpoor, S.-F. (2023). Teaching for creativity in an EFL context: The predictive roles of school climate, teaching enthusiasm, and metacognition. *Thinking Skills and Creativity*, 50, Article 101419. <https://doi.org/10.1016/j.tsc.2023.101419>
- Hamid, H., Zulkifli, K., Naimat, F., Yaacob, N. L. C., & Ng, K. W. (2023). Exploratory study on student perception on the use of chat AI in process-driven problem-based learning. *Currents in Pharmacy Teaching and Learning*, 15(12), 1017–1025. <https://doi.org/10.1016/j.cptl.2023.10.001>
- Han, H. J. (2023). Learner perception for artificial intelligence technology based educational tools. *Journal of Digital Contents Society*, 24(10), 2363–2372. <https://doi.org/10.9728/dcs.2023.24.10.2363>
- Hemment, D., Vidmar, M., Panas, D., Murray-Rust, D., Belle, V., & Aylett, R. (2023). Agency and legibility for artists through experiential AI. *arXiv*. <https://arxiv.org/abs/2306.02327>
- Hwang, Y., Lee, J. H., & Shin, D. (2023). What is prompt literacy? An exploratory study of language learners' development of new literacy skill using generative AI. *arXiv*. <https://doi.org/10.48550/arXiv.2311.05373>
- Jo, H. (2023). Decoding the ChatGPT mystery: A comprehensive exploration of factors driving AI language model adoption. *Information Development*. <https://doi.org/10.1177/02666669231202764>
- Kim, H.-K., & Han, S. (2021). College students' perceptions of AI-based writing learning tools: With a focus on Google Translate, Naver Papago, and Grammarly. *Modern English Education*, 22(4), 90–100. <https://doi.org/10.18095/meeso.2021.22.4.90>
- Lee, D., & Palmer, E. (2025). Prompt engineering in higher education: A systematic review to help inform curricula. *International Journal of Educational Technology in Higher Education*, 22, 7. <https://doi.org/10.1186/s41239-025-00503-7>
- Lee, M., Yi, T. R. J., Der-Thanq, C., Song, H. J., & David, H. W. L. (2025). Exploring interactions between learners and ChatGPT from a learner agency perspective: A multiple case study on historical Inquiry. *Education and Information Technologies*, 30, 7167–7189. <https://doi.org/10.1007/s10639-024-13114-y>
- Lee, Y., Byun, H., Kim, M., & Lee, S. (2017). A study of development and validation of the creativity index. *The Journal of Creativity Education*, 17(4), 1–18.

- Liu, G., & Ma, C. (2024). Measuring EFL learners' use of ChatGPT in informal digital learning of English based on the technology acceptance model. *Innovation in Language Learning and Teaching*, 18(2), 125–138. <https://doi.org/10.1080/17501229.2023.2240316>
- Lo, C. K., Yu, P. L. H., Xu, S., Ng, D. T. K., & Jong, M. S.-Y. (2024). Exploring the application of ChatGPT in ESL/EFL education and related research issues: A systematic review of empirical studies. *Smart Learning Environments*, 11, 50. <https://doi.org/10.1186/s40561-024-00342-5>
- Mbiazi, D., Bhange, M., Babaei, M., Sheth, I., & Kenfack, P. J. (2023). Survey on AI ethics: A socio-technical perspective. *arXiv*. <https://arxiv.org/abs/2311.17228>
- Ngo, T. T. A. (2023). The perception by university students of the use of ChatGPT in education. *International Journal of Emerging Technologies in Learning*, 18(17), 4–19. <https://doi.org/10.3991/ijet.v18i17.39019>
- Sengar, S. S., Hasan, A. B., Kumar, S., & Carroll, F. (2024). Generative artificial intelligence: A systematic review and applications. *Multimedia Tools and Applications*. <https://doi.org/10.1007/s11042-024-20016-1>
- Singh, P., Phutela, N., Grover, P., Sinha, D., & Sinha, S. (2023). Student's perception of ChatGPT. In *2023 International Conference on Electrical, Communication and Computer Engineering (ICECCE)* (pp. 1–6). IEEE. <https://doi.org/10.1109/ICECCE61019.2023.10442033>
- Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.
- Wang, Y., & Zhang, W. (2023). Factors influencing the adoption of generative AI for art designing among Chinese Generation Z: A structural equation modeling approach. *IEEE Access*, 11, 143272–143284. <https://doi.org/10.1109/ACCESS.2023.3342055>
- Wijnia, L., Noordzij, G., Arends, L. R., Rikers, R. M. J. P., & Loyens, S. M. M. (2024). The effects of problem-based, project-based, and case-based learning on students' motivation: A meta-analysis. *Educational Psychology Review*, 36, 29. <https://doi.org/10.1007/s10648-024-09864-3>
- Wood, D., & Moss, S. H. (2024). Evaluating the impact of students' generative AI use in educational contexts. *Journal of Research in Innovative Teaching & Learning*, 17(2), 152–167. <https://doi.org/10.1108/jrit-06-2024-0151>
- Zha, S., Qiao, Y., Hu, Q., Li, Z., Gong, J., & Xu, Y. (2024). Designing child-centric AI learning environments: Insights from LLM-enhanced creative project-based learning. *arXiv*. <https://doi.org/10.48550/arXiv.2403.16159>
- Zhan, F., Yu, Y., Wu, R., Zhang, J., Lu, S., & Liu, L. (2023). Multimodal image synthesis and editing: The generative AI era. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 45(12), 15098–15119. <https://doi.org/10.1109/TPAMI.2023.3305243>
- Zou, B., Liviero, S., Hao, M., & Wei, C. (2020). Artificial intelligence technology for EAP speaking skills: Student perceptions of opportunities and challenges. In M. R. Freiermuth & N. Zarrinabadi (Eds.), *Technology and the psychology of second language learners and users* (pp. 433–463). Palgrave Macmillan. <https://doi.org/10.1007/978-3-030-34212-8>

## Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.