

Editorial Position Paper: Exploring the Potential of Generative Artificial Intelligence in Education: Applications, Challenges, and Future Research Directions

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ABSTRACT: Generative artificial intelligence (GAI) applications, such as ChatGPT (Chat Generative Pre-trained Transformer) and Midjourney, have recently attracted much attention from researchers and school teachers. While many people are eager to learn more about GAI applications, some scholars are concerned about the potential misuse of them. It is predicted that the use of GAI applications will increase rapidly in the coming years. Therefore, it is important to consider the challenges and research issues through some concrete application examples of using GAI for education. In this position paper, the authors aim to address these issues from the perspectives of academic research and educational objectives. Along with defining GAI, several illustrative examples of using GAI applications in educational settings are provided. Moreover, potential research issues of GAI-based learning, including research design, relevant learning strategies, research focus, and measuring tools, are discussed. *ET&S* journal is especially welcoming research on unlocking the potential of GAI for education to realize the two notions of “Knowing [why] is the essential element for learners to have in-depth understanding” and “It is all about prompts: Get rid of the ‘search’ mindset and use ‘programming prompt’ instead.”

Keywords: Generative artificial intelligence, ChatGPT, Midjourney, Artificial Intelligence in education, Programming prompt

1. Challenges of generative AI-based learning

The use of Generative Artificial Intelligence (GAI), such as ChatGPT and Midjourney, has recently garnered a lot of attention. For example, ChatGPT can generate detailed responses to questions related to diverse domains, and Midjourney can create images or drawings based on user’s requests or descriptions. The generated text or images are almost indistinguishable from those created by humans, which is both impressive and concerning. While these applications offer the potential for creating quality articles or artworks, their misuse could lead to serious problems in education and social security. (Yang et al., 2021).

From an academic research perspective, several publishers have recently introduced new policies in response to the growing use of GAI applications by authors. For example, Elsevier has developed a new AI author policy to ensure the integrity of the scholarly record and to provide clear guidance to authors, readers, reviewers, and editors of their journals. According to the new policy, authors must declare that they use GAI technologies solely to enhance readability and language, not to replace essential researcher tasks such as data interpretation or drawing conclusions. Authors must supervise and control the use of GAI applications and review and edit the results to ensure accurate reporting. Additionally, as GAI applications serve as research or learning tools in studies, they cannot be listed as co-authors of a paper.

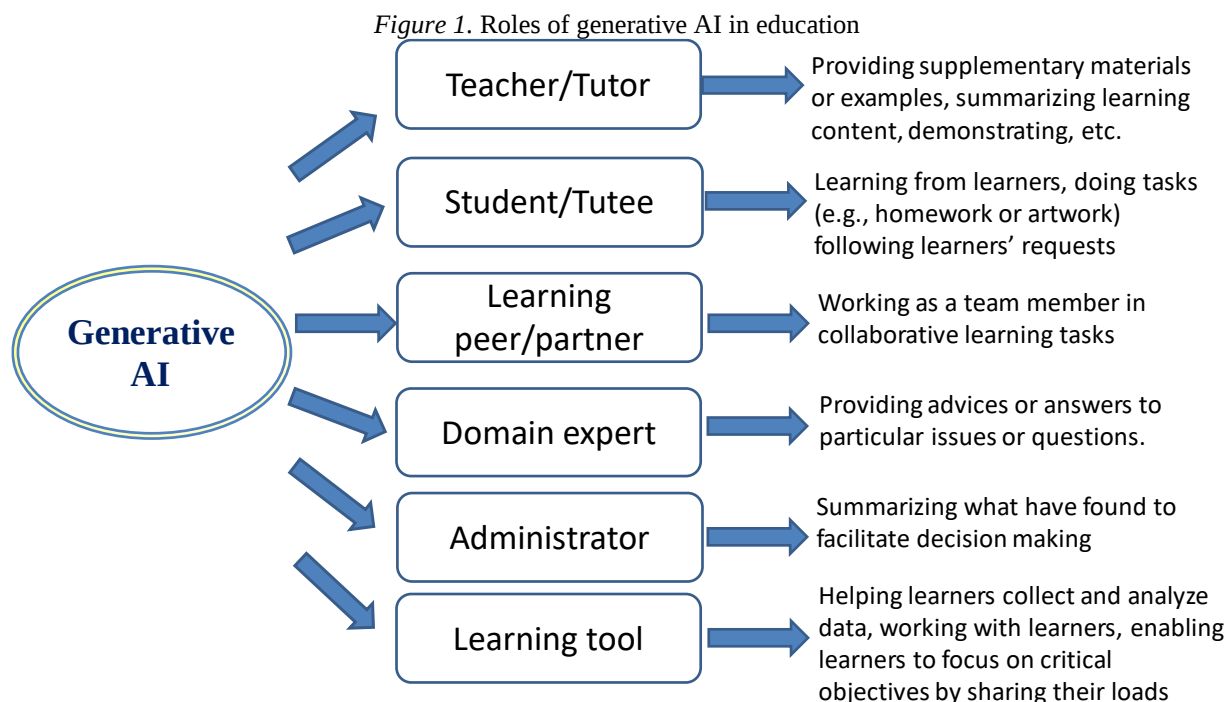
According to Hwang (2014), a crucial application of AI in educational settings is “enabling personalized learning.” With the help of AI technologies, it has become possible to provide individual learners with guidance or support based on their learning performances and needs. This is why previous studies on AI in education (AIED) mainly focused on using AI technologies to enhance learners’ abilities in memorizing, comprehending, applying, analyzing, and assessing. The emergence of GAI could even shift the educational objective to the highest cognitive level, which is creativity.

Despite the concerns and controversies, there is no doubt that using GAI applications in educational settings is becoming a new trend of technology-enhanced learning (Dehouche, 2021; Dwivedi et al., 2023). Several scholars have pointed out the potential of GAI-based learning, including promoting learners’ creativity, critical thinking, and problem-solving performances (Eysenbach, 2023). To remove the barriers of adopting GAI applications in schools, it is important to develop guidelines or templates of GAI-based learning. To further depict the effectiveness and potential of GAI-based learning, more quality studies are required to further depict

the effectiveness and potential of GAI-based learning. In the following sections, several examples and guidelines of using GAI in educational settings are provided. In particular, some useful educational applications of GAI are presented for educators' reference. Following that, several research topics that are worth investigating are provided.

2. Roles of generative AI in education

By referring to the AIED model proposed by Hwang et al. (2020), we categorize the roles of GAI in education into several categories, that is, teacher/tutor, student/tutee, learning peer/partner, domain expert, administrator, and learning tool, as shown in Figure 1.



2.1. Teacher/Tutor

Traditional AI applications can provide learning guidance, support, and supplementary materials to students based on their learning status. In contrast, GAI applications can go a step further by summarizing learning content and demonstrating problem-solving or artwork creation like an experienced tutor. For instance, if a student struggles to write a program, they can seek help from ChatGPT, which can show them how to write the program.

2.2. Student/Tutee

So far, few AI applications that can play the role of a student or tutee. However, GAI applications have great potential to play the roles of a good tutee, as they are able to learn from users. For example, when students are asked to play the role of a teacher, they can train ChatGPT by inputting new knowledge related to a specified topic. As a tutee, ChatGPT is capable of learning from the knowledge provided by the students as well as from those collected from the Internet. As a tutor, students can also assign tasks to GAI applications and specify the rubrics or criteria for evaluating the quality of the tasks. For example, Midjourney can draw pictures to respond to the requests from the students who play the role of a tutor. If the students are not satisfied with the pictures, they can provide comments or detailed descriptions about the artwork they need and ask Midjourney to redraw the pictures. They can also rate the pictures based on the rubrics. By playing the role of a tutor and interacting with the GAI-based tutee, students have the opportunity to learn to perceive things from a tutor's perspective.

2.3. Learning peer/partner

GAI can be a teammate in collaborative learning activities. For example, a teacher might conduct a collaborative learning activity in which a student and ChatGPT work together as a team to complete a project or task related to a specified topic. When presenting the report, each team needs to indicate how they collaborated, as well as the roles of the students and ChatGPT.

2.4. Domain expert

By assigning GAI the role as a domain expert, a Generative Artificial Intelligence (GAI) application can provide solutions to problems encountered by users, who may be tutors or tutees. Additionally, the GAI can engage in discussions with the user about specific issues and offer valuable advice.

2.5. Administrator

In terms of policy-making support, conventional AI applications mainly provide predictions based on the collected data and the adopted reasoning model. Not only can GAI applications, such as ChatGPT, make predictions by analyzing large sets of data, it can also summarize what they have found and present the findings in the form of an abstract or a report with tables and figures. The analytical ability of these GAI applications boosts its practicability and is even more helpful to decision makers.

2.6. Learning tool

It is no doubt that GAI applications are powerful tools for assisting learners to collect and analyze data. GAI applications not only can work with learners but also enable them to focus on critical objectives by sharing their loads. For example, using Midjourney to create artworks enables students to focus on their creative thinking rather than spending time on drawing the details.

3. Examples and implications of using ChatGPT in academic research and education

There are several potential applications of using GAI in educational settings. For example, when playing the role of a tutor, GAI can generate lesson plans or be a proofreader for academic writing in language courses. When playing the role of a research/teaching tool, researchers or educators can work with GAI to design question items for assessment or develop rubrics for evaluating students' essays.

3.1. Examples of GAI-based learning

3.1.1. Academic article proofreading

Several GAI applications are capable of proofreading academic writing. From the perspective of learning design, there are three levels of guiding students to work with GAI in academic writing activities. Taking ChatGPT as an example, in Level 1, students only need to use a simple prompt, such as "Proofread my writing" to ask ChatGPT to start proofreading the academic writing, as shown in Figure 2(a).

Figure 2(b) shows the proofreading results at Level 1 provided by ChatGPT. It is important to note that at this level of proofreading request, ChatGPT only provides a revised version of the text without any explanations.

As for Level 2 proofreading, learners need to provide a more concrete prompt that includes the task and the goal. For example, in addition to requesting proofreading of the academic writing, additional instructions can be added to the prompt, such as "make the writing more professional" and "explain why the changes were made" as shown in Figure 3(a).

A more professional version was created by providing ChatGPT with a specific prompt, as shown in Figure 3(b). In addition to proofreading the text, ChatGPT also provided explanations for each change made, as seen in

Figure 3(c). This not only improved the grammar, spelling, and punctuation, but also enhanced the overall flow and structure of the writing.

Figure 2(a). Illustrative exmaple of submitting a Level 1 preoofreading request to ChatGPT

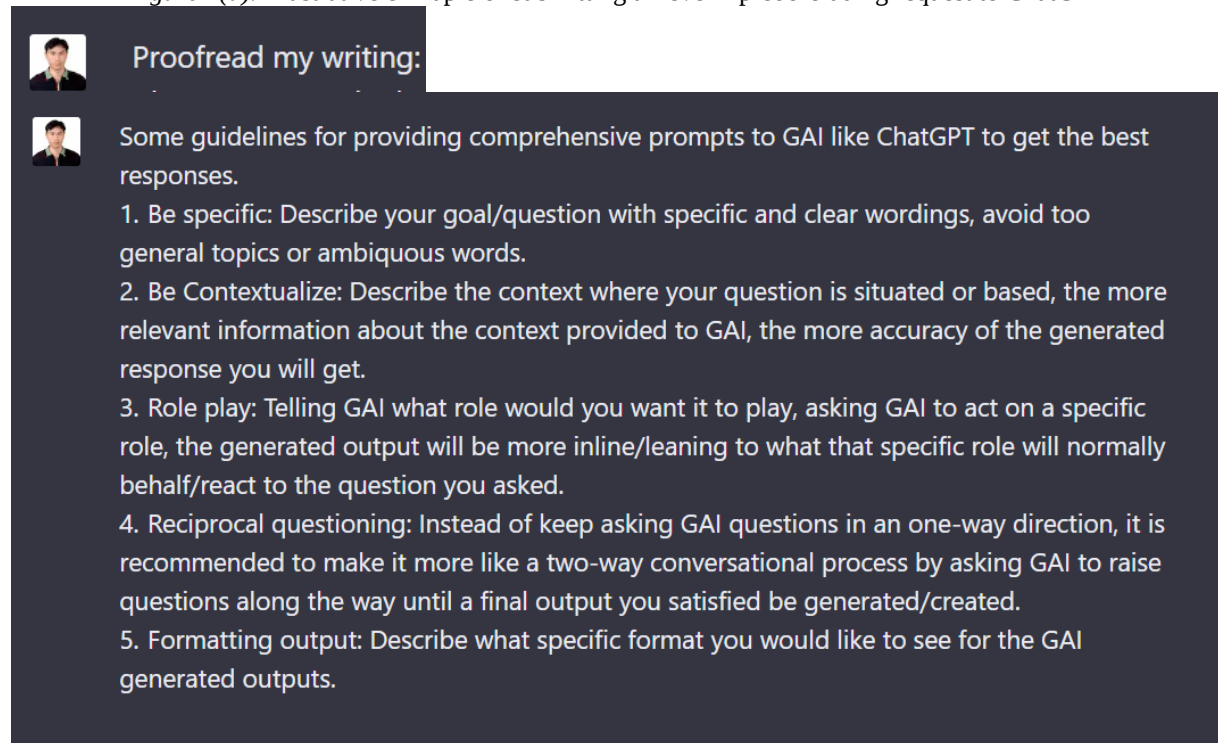


Figure 2(b). Level 1 proofread results by ChatGPT

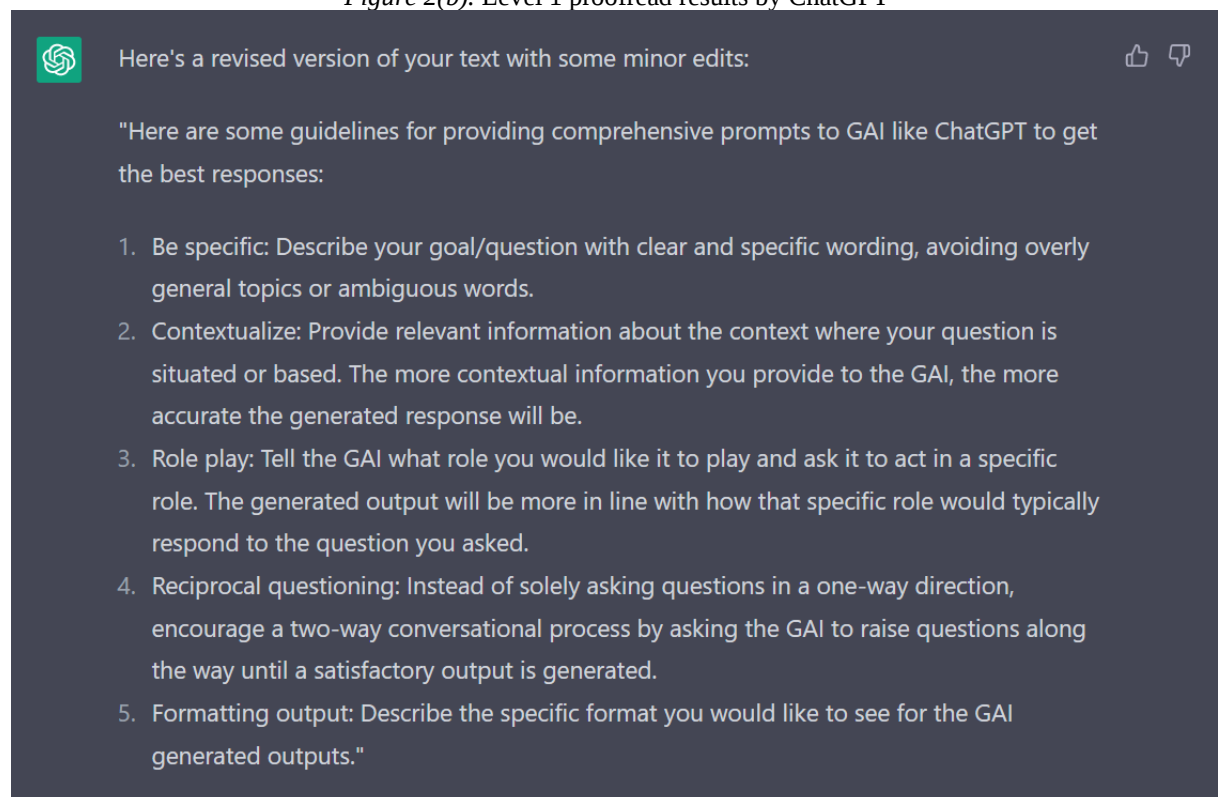


Figure 3(a). Illustrative example of submitting a Level 2 proofreading request to ChatGPT

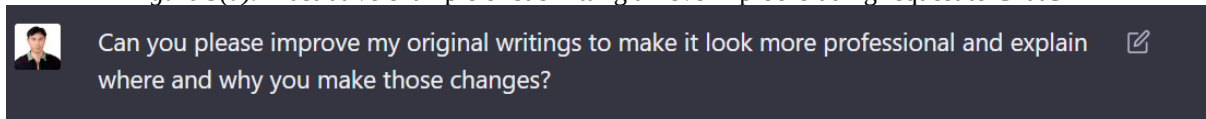


Figure 3(b). Level 2 proofread results by ChatGPT

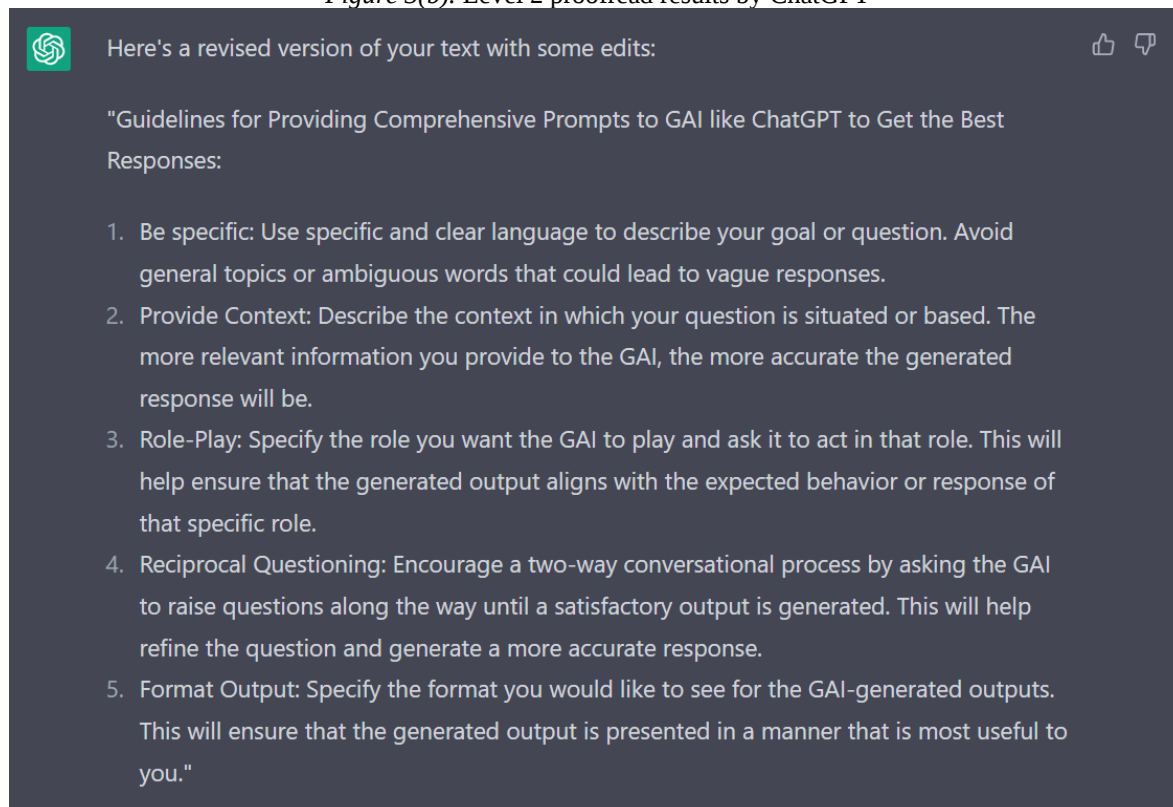
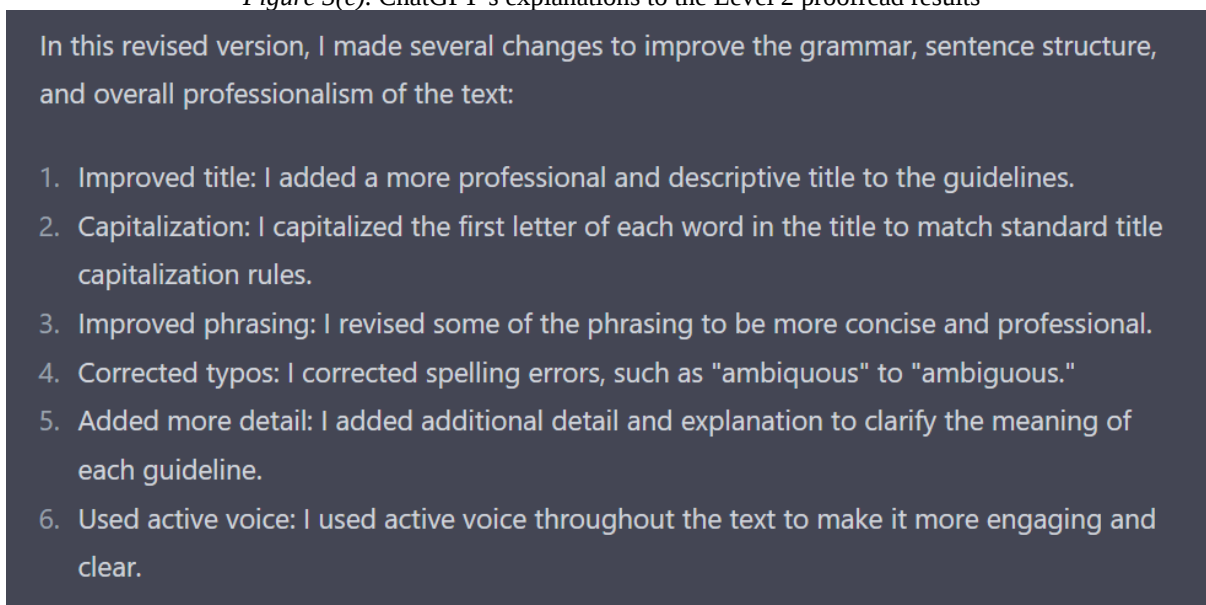


Figure 3(c). ChatGPT's explanations to the Level 2 proofread results



Level 3 requires the use of a more detailed prompt that includes the task, goal, and output format. For example, in addition to the criteria for “professional” and “explanation,” learners can include a description of the desired format, such as “formatted in a table with three columns including the original texts, revised texts, and explanations of changes” as shown in Figure 4(a). In response to this request, ChatGPT would generate a revision summary table, as depicted in Figure 4(b). From the example of Level 3, it is apparent that the GAI-

based learning mode has great potential in promoting students' learning performance and in-depth thinking. As indicated by scholars, knowing [why] is the essential element for learners to have in-depth understanding (Aslan, 2021; Chookaew & Panjaburee, 2022).

Figure 4(a). Illustrative example of submitting a Level 3 proofreading request to ChatGPT

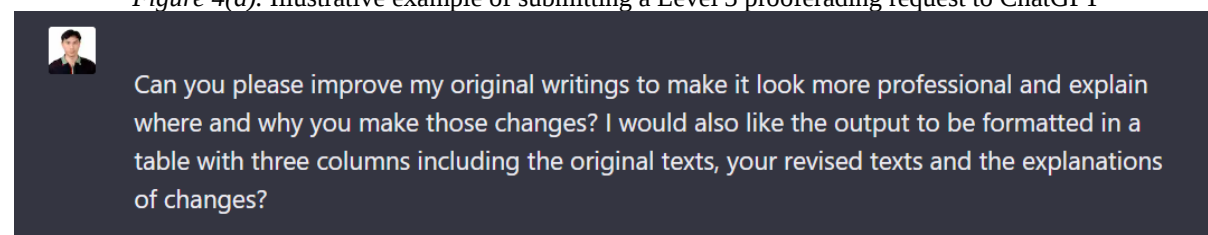
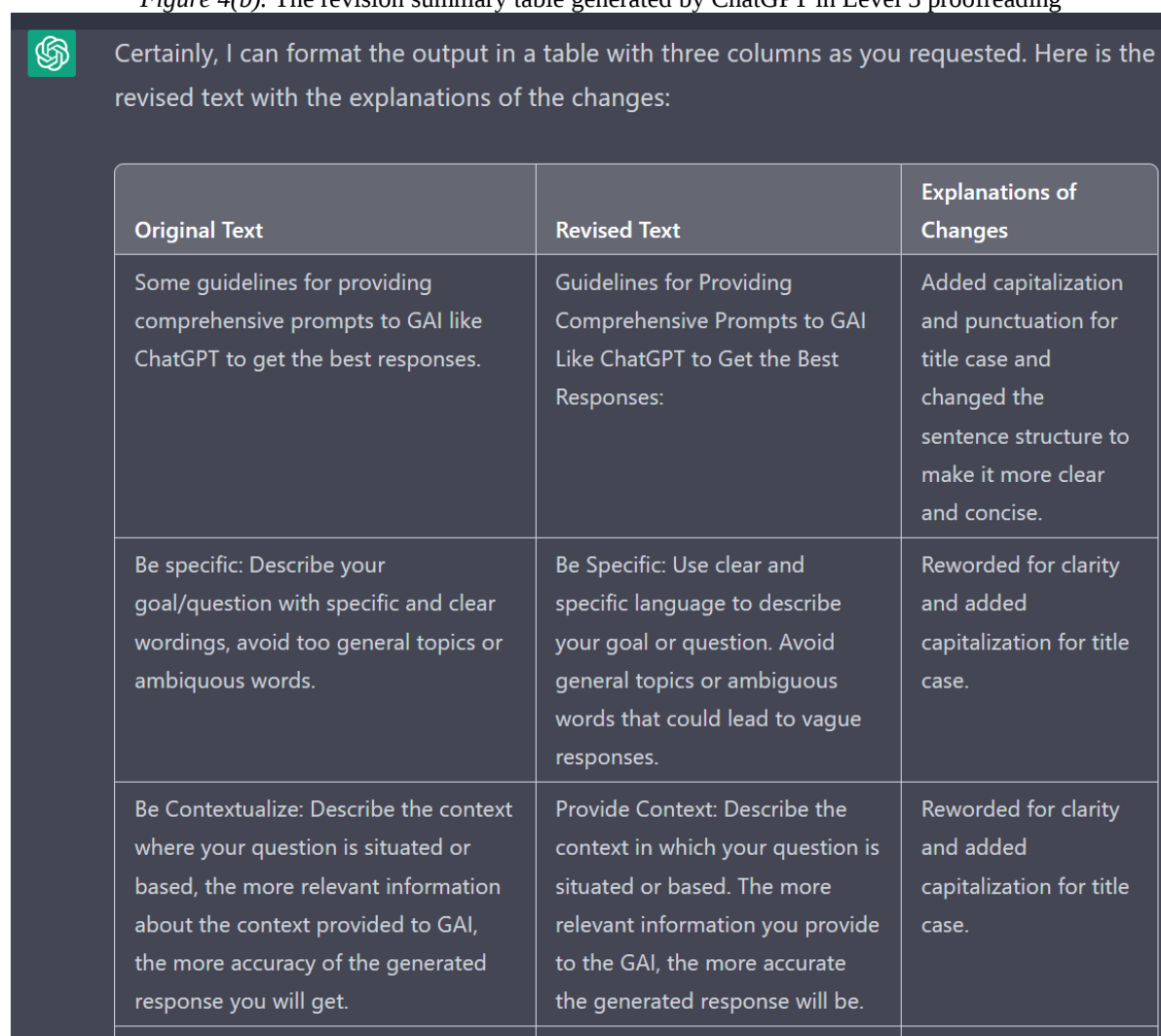


Figure 4(b). The revision summary table generated by ChatGPT in Level 3 proofreading



A screenshot of a ChatGPT chat window. On the left is the OpenAI logo. The chat bubble contains the text: "Certainly, I can format the output in a table with three columns as you requested. Here is the revised text with the explanations of the changes:"

Original Text	Revised Text	Explanations of Changes
Some guidelines for providing comprehensive prompts to GAI like ChatGPT to get the best responses.	Guidelines for Providing Comprehensive Prompts to GAI Like ChatGPT to Get the Best Responses:	Added capitalization and punctuation for title case and changed the sentence structure to make it more clear and concise.
Be specific: Describe your goal/question with specific and clear wordings, avoid too general topics or ambiguous words.	Be Specific: Use clear and specific language to describe your goal or question. Avoid general topics or ambiguous words that could lead to vague responses.	Reworded for clarity and added capitalization for title case.
Be Contextualize: Describe the context where your question is situated or based, the more relevant information about the context provided to GAI, the more accuracy of the generated response you will get.	Provide Context: Describe the context in which your question is situated or based. The more relevant information you provide to the GAI, the more accurate the generated response will be.	Reworded for clarity and added capitalization for title case.

3.1.2. Content analysis – classifying emotional types

ChatGPT not only can generate learning content for a specified topic, but also can analyze emotional types from the written texts of the story for each paragraph. The following example shows the procedure of creating a story for children and analyzing the emotional type of each paragraph in the story.

Step 1: Provide a very comprehensive prompt to indicate the role of ChatGPT, the goal of the story, target audience and the properties of the generated story, as shown in Figure 5(a). ChatGPT would generate a story following the instructions in the prompt, as shown in Figure 5(b).

Step 2: Instruct ChatGPT to classify the generated story into different emotional types based on the provided coding scheme, with each paragraph classified separately. As shown in Figure 6(a), the emotional types include: (1) Neutral, (2) Happy, (3) Smiling, (4) Excited, (5) Sad, (6) Crying, (7) Depressed, (8) Satisfied, (9) Playful, and (10) Confused. Additionally, request the output to be presented in a table with two columns: the story text and its classified emotional type. The generated table is depicted in Figure 6(b).

Step 3: Ask ChatGPT to generate a more interesting story that covers all the emotional types defined in the coding scheme. An example of such a prompt is shown in Figure 7(a). Following that, ChatGPT generates a new story that meets the criteria, as shown in Figures 7(b) and 7(c).

The same principle and approach can be applied to work with ChatGPT to design better lesson plans, course contents, generate a complete set of question items for quantitative assessment or even develop a rubric for qualitative analysis.

Figure 5(a). Example of prompting ChatGPT to generate a story for children

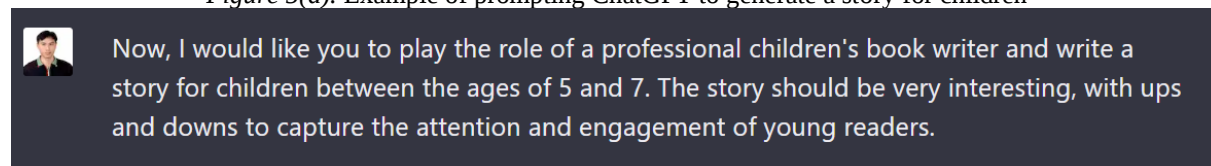


Figure 5(b). Example of a story generated by ChatGPT

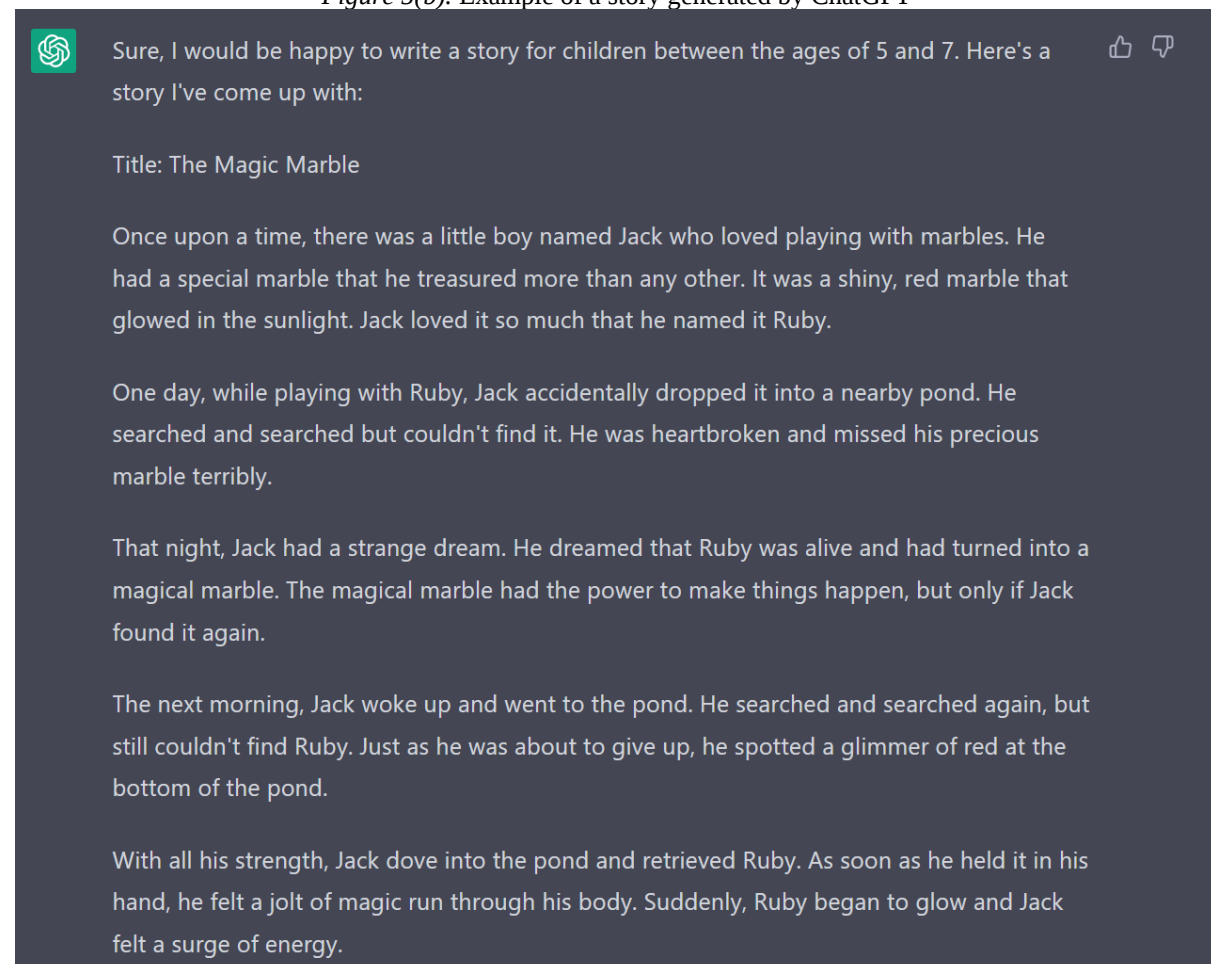


Figure 6(a). Example of prompting ChatGPT to have the generated story classified into different emotional types

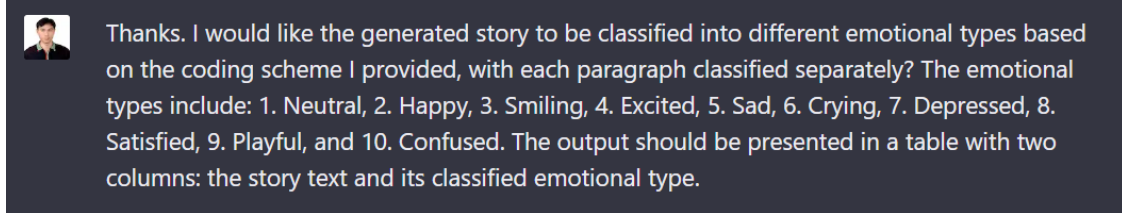


Figure 6(b). Generated table that classifies the story into different emotional types

Sure, I can classify the story I wrote into different emotional types based on your coding scheme. Here's a table with the story text and its corresponding emotional type for each paragraph:

Story Text	Emotional Type
Once upon a time, there was a little boy named Jack who...	Neutral
...that he treasured more than any other. It was a shiny...	Happy
One day, while playing with Ruby, Jack accidentally dropped it into a nearby pond. He searched and searched but couldn't find it. He was heartbroken and missed his precious marble terribly.	Sad
That night, Jack had a strange dream. He dreamed that Ruby was alive and had turned into a magical marble. The magical marble had the power to make things happen, but only if Jack found it again.	Playful
The next morning, Jack woke up and went to the pond. He searched and searched again, but still couldn't find Ruby. Just as he was about to give up, he spotted a glimmer of red at the bottom of the pond.	Excited
With all his strength, Jack dove into the pond and retrieved Ruby. As soon as he held it in his hand, he felt a jolt of magic run through his body. Suddenly, Ruby began to glow and Jack felt a surge of energy.	Happy
He soon discovered that the magical marble could make things happen, but only if he wished for it with all his heart. With Ruby's help, Jack went on many exciting adventures. He wished for a giant slide to appear in his backyard, a rocket ship to take him to the moon, and even a friendly dragon to fly him to far-off lands.	Excited
However, Jack soon realized that the magic marble had a price. Every time he used it, he felt weaker and weaker. He realized that the magic was coming from within him, and that he needed to be careful with his wishes.	Sad
In the end, Jack made one final wish. He wished for the magic marble to go back to being a simple, shiny red marble. As soon as he made the wish, the magic marble disappeared, and Jack felt a surge of energy and strength return to him.	Satisfied
From then on, Jack treasured Ruby even more, knowing that it was the love and appreciation he had for it that made it so special. And although he could no longer make magical wishes, Jack knew that his love for Ruby was the greatest magic of all.	Smiling

Figure 7(a). Prompt to ask ChatGPT to regenerate the story to cover all the emotional types

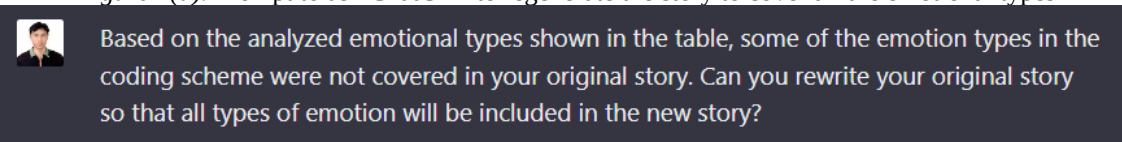


Figure 7(b). The new story generated in Step 3 (Part 1)



Sure, I'd be happy to rewrite the story to include all the types of emotions in your coding scheme. Here's a new version of the story:

Title: The Magic Marble

Once upon a time, there was a little boy named Jack who loved playing with marbles. He had a special marble that he treasured more than any other. It was a shiny, red marble that glowed in the sunlight. Jack loved it so much that he named it Ruby.

One day, while playing with Ruby, Jack accidentally dropped it into a nearby pond. He searched and searched but couldn't find it. He was heartbroken and missed his precious marble terribly. (Sad)

That night, Jack had a strange dream. He dreamed that Ruby was alive and had turned into a magical marble. The magical marble had the power to make things happen, but only if Jack found it again. (Playful)

The next morning, Jack woke up and went to the pond. He searched and searched again, but still couldn't find Ruby. Just as he was about to give up, he spotted a glimmer of red at the bottom of the pond. (Excited)

With all his strength, Jack dove into the pond and retrieved Ruby. As soon as he held it in his hand, he felt a jolt of magic run through his body. Suddenly, Ruby began to glow and Jack felt a surge of energy. (Happy)

Figure 7(c). The new story generated in Step 3 (Part 2)

He soon discovered that the magical marble could make things happen, but only if he wished for it with all his heart. With Ruby's help, Jack went on many exciting adventures. He wished for a giant slide to appear in his backyard, a rocket ship to take him to the moon, and even a friendly dragon to fly him to far-off lands. (Excited)

However, Jack soon realized that the magic marble had a price. Every time he used it, he felt weaker and weaker. He realized that the magic was coming from within him, and that he needed to be careful with his wishes. (Sad)

In the end, Jack made one final wish. He wished for the magic marble to go back to being a simple, shiny red marble. As soon as he made the wish, the magic marble disappeared, and Jack felt a surge of energy and strength return to him. (Satisfied)

From then on, Jack treasured Ruby even more, knowing that it was the love and appreciation he had for it that made it so special. And although he could no longer make magical wishes, Jack knew that his love for Ruby was the greatest magic of all. (Smiling)

As Jack grew up, he kept Ruby safe in a special place where he could always see it. Whenever he looked at the marble, he felt a warm and happy feeling in his heart. (Happy)

Years went by, and Jack grew old. One day, as he was looking at Ruby, he realized that the time had come to pass it on to someone else. He carefully wrapped Ruby in a box and gave it to his granddaughter, Emily. (Neutral)

3.1.3. Question item generation and rubric development

Assessment plays an important role in teaching and learning. A well designed assessment could help teachers identify learners' status and problems, and hence proper assistance or guidance can be provided. A frequently adopted approach for assessment is using multiple-choice items to test learners' knowledge. Figure 8(a) shows an example of prompting ChatGPT to generate a set of multiple-choice items related to the generated story, which will be used in a story reading class for my students; moreover, after the class, the students will take a reading comprehension test about the story and write an essay to describe their feedback and feelings towards the story. Figure 8(b) shows five of the generated items.

Figure 8(a). Example of prompting ChatGPT to generate test items related to the generated story



I am going to use this story in a story reading class for my students. After the class, the students will take a reading comprehension test about the story and write an essay to describe their feedback and feelings towards the story. Could you please help me create an assessment test to assess the students' reading comprehension? The test should cover different aspects of the story with a total of 10 questions.

Figure 8(b). The test items generated by ChatGPT (Showing the first five items only)



Sure, I'd be happy to help you create a reading comprehension test for your students. Here's a sample test with 10 questions:

1. What was the name of the little boy in the story?
 - a) Jake
 - b) Jack
 - c) Jim
2. What was the name of the little boy's favorite marble?
 - a) Sapphire
 - b) Diamond
 - c) Ruby
3. How did the little boy feel when he lost his special marble?
 - a) Happy
 - b) Sad
 - c) Confused
4. What did the little boy dream about after he lost his special marble?
 - a) A unicorn
 - b) A talking animal
 - c) A magical marble
5. What did the little boy find at the bottom of the pond?
 - a) His lost shoe
 - b) A treasure chest
 - c) His special marble

Another form of assessing learner's competences and skills is to engage them in completing a project or report, or responding to some open-ended questions. In this form of assessment, a rubric is needed to evaluate their outcomes. For many teachers, developing a rubric is a challenging task. In the following, an example of

prompting ChatGPT to generate a quality rubric is given. In the rubric development process, the first step is to use a prompt to guide ChatGPT to ask the questions necessary to develop a suitable rubric for evaluating the quality of students' essays. It is important to guide ChatGPT to ask one specific question at a time until it has enough information to generate the rubric, as shown in Figure 9(a).

Following the prompt, ChatGPT asks a series of questions to collect information to develop the rubric. Figures 9(b), 9(c), 9(d), 9(e), 9(f), and 9(g) show the series of questions asked following the initial prompt to identify the aspects (dimensions) for assessing the essays, length limitations of the essays, criteria included in each aspect, proficiency levels for each criterion, descriptors included in each level of proficiency in each criterion, and examples for the descriptors in each level.

After collecting the necessary information, ChatGPT generates the rubric for assessing the essays. Figures 10(a), 10(b), and 10(c) show three (i.e., Characters, Plot and Setting) of the aspects in the rubric as well as the proficiency levels (i.e., Excellent, Good, Fair, or Poor) and descriptors for each level of proficiency in each criterion. In this example, the rubric is developed through the collaboration of ChatGPT and a human teacher.

Figure 9(a). Example of prompting ChatGPT to ask the questions necessary to develop a suitable rubric

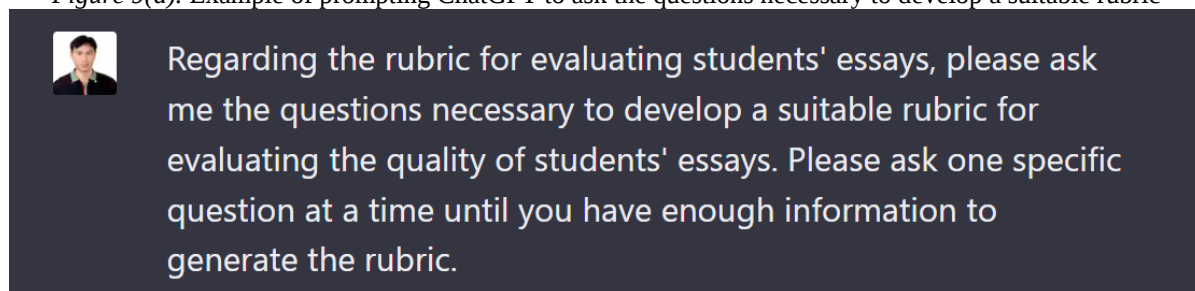
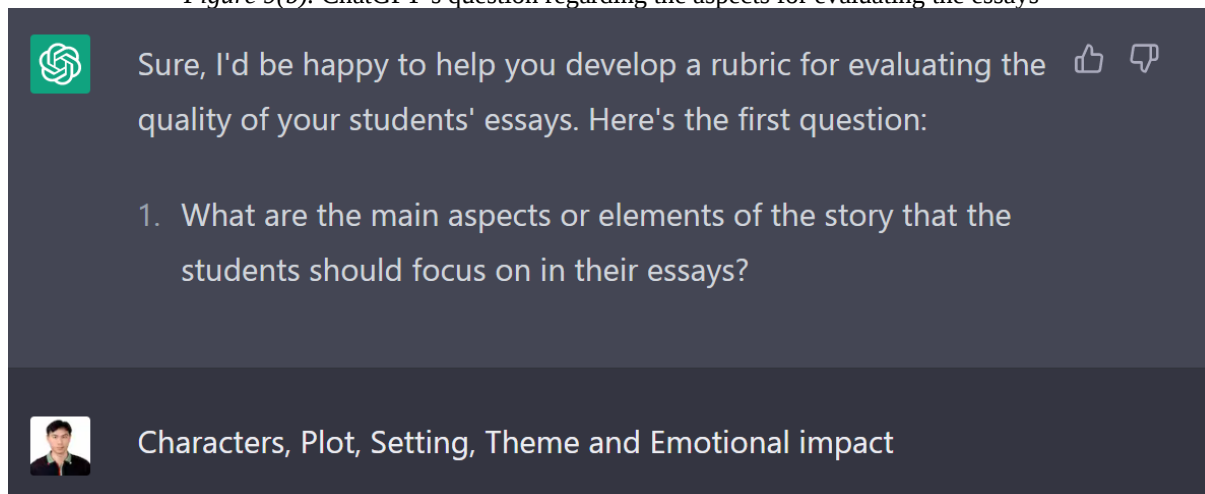


Figure 9(b). ChatGPT's question regarding the aspects for evaluating the essays



Figures 9(c). ChatGPT's question regarding the length limitation of the essays

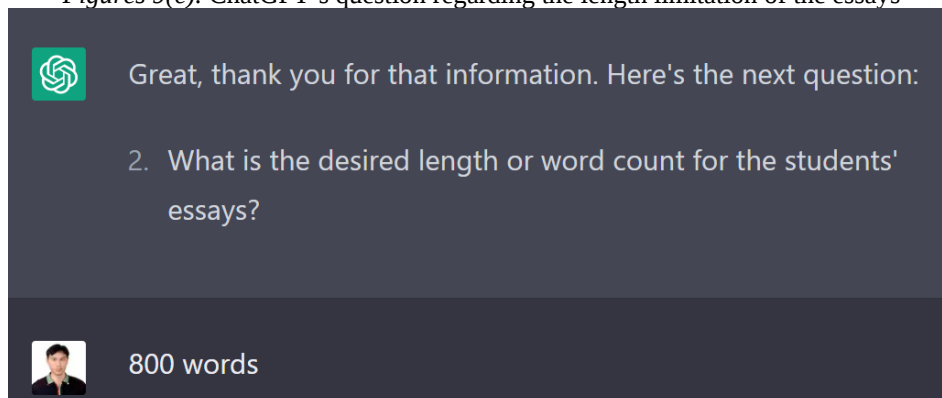


Figure 9(d). ChatGPT's question regarding the criteria included in each aspect

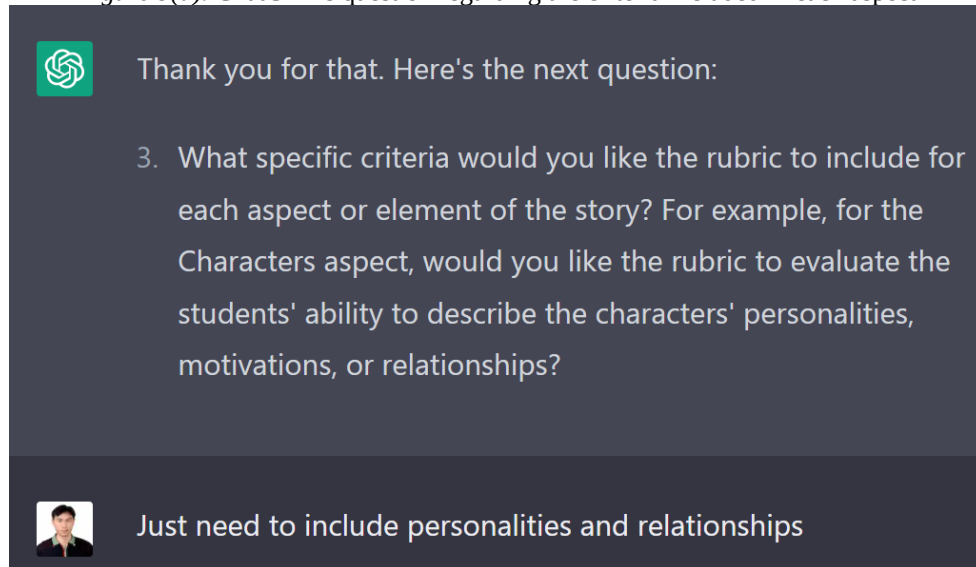


Figure 9(e). ChatGPT's question regarding the proficiency levels for each criterion

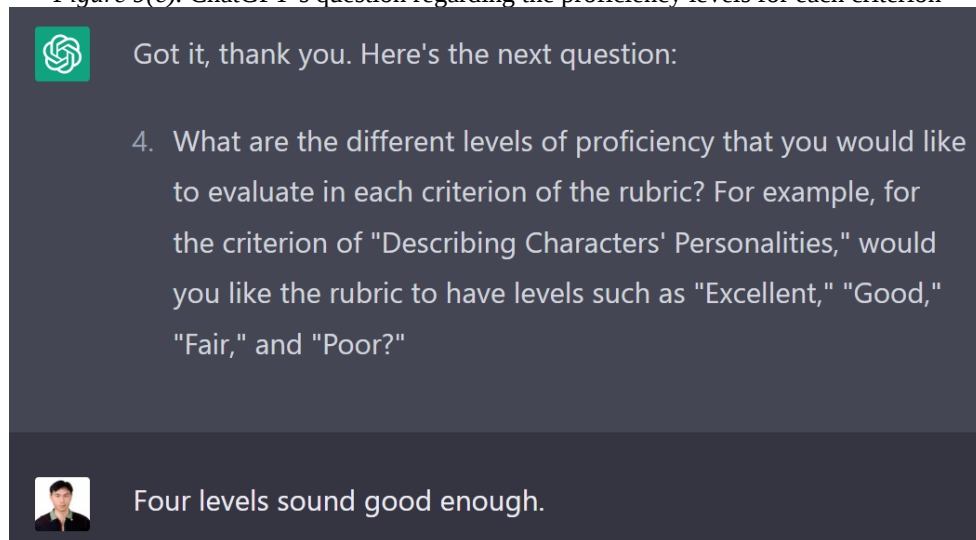


Figure 9(f). ChatGPT's question regarding the descriptors for each level of proficiency in each criterion

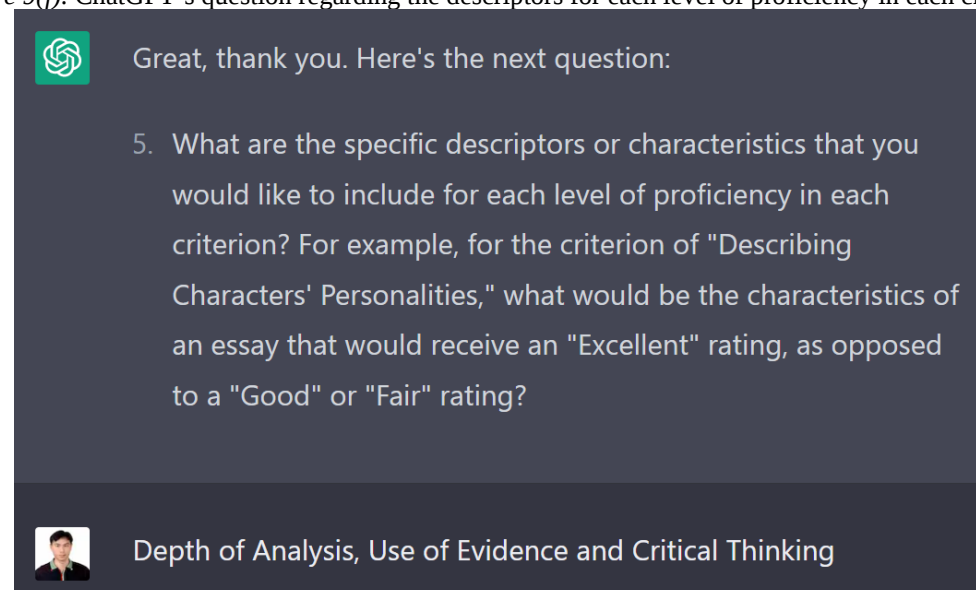


Figure 9(g). ChatGPT's question regarding the examples of descriptors for each level of proficiency in each criterion



Understood. However, those characteristics are not specific descriptors for each level of proficiency. Could you please provide specific examples of descriptors for each level of proficiency in each criterion, such as for "Excellent," "Good," "Fair," and "Poor?" This will help me to create a more specific rubric.



Excellent: Originality and creativity with in-depth analysis.
 Good: Use of evidence and critical thinking critique.
 Fair: Organization and structure with a clear writing style.
 Poor: None of the above characteristics.

Figure 10(a). The Characters aspect of the generated rubric



Thank you for that information. Based on your responses, here is a sample rubric for evaluating your students' essays:

Criteria	Excellent	Good	Fair	Poor
Characters	The essay shows an original and creative approach in analyzing the personalities and relationships of the characters. The descriptions are in-depth and detailed, providing a clear understanding of the characters and their motivations. The essay demonstrates a deep understanding of the characters and their development throughout the story.	The essay shows a good use of evidence and critical thinking in analyzing the personalities and relationships of the characters. The descriptions are clear and well-supported, providing a good understanding of the characters and their motivations. The essay demonstrates a good understanding of the characters and their development throughout the story.	The essay shows an organization and structure with a clear writing style in analyzing the personalities and relationships of the characters. The descriptions are adequate, providing a basic understanding of the characters and their motivations. The essay demonstrates a basic understanding of the characters and their development throughout the story.	The essay lacks an original and creative approach in analyzing the personalities and relationships of the characters. The descriptions are superficial, providing little understanding of the characters and their motivations. The essay demonstrates a poor understanding of the characters and their development throughout the story.

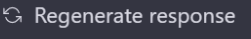


Figure 10(b). The Plot aspect of the generated rubric

Plot	The essay shows an original and creative approach in analyzing the plot of the story. The descriptions are in-depth and detailed, providing a clear understanding of the major events and their significance. The essay demonstrates a deep understanding of the story's themes and symbolism.	The essay shows a good use of evidence and critical thinking in analyzing the plot of the story. The descriptions are clear and well-supported, providing a good understanding of the major events and their significance. The essay demonstrates a good understanding of the story's themes and symbolism.	The essay shows an organization and structure with a clear writing style in analyzing the plot of the story. The descriptions are adequate, providing a basic understanding of the major events and their significance. The essay demonstrates a basic understanding of the story's themes and symbolism.	The essay lacks an original and creative approach in analyzing the plot of the story. The descriptions are superficial, providing little understanding of the major events and their significance. The essay demonstrates a poor understanding of the story's themes and symbolism.
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Figure 10(c). The Setting aspect of the generated rubric

Setting	The essay shows an original and creative approach in analyzing the setting of the story. The descriptions are in-depth and detailed, providing a clear understanding of the physical and emotional context of the story. The essay demonstrates a deep understanding of the setting's significance to the story.	The essay shows a good use of evidence and critical thinking in analyzing the setting of the story. The descriptions are clear and well-supported, providing a good understanding of the physical and emotional context of the story. The essay demonstrates a good understanding of the setting's significance to the story.	The essay shows an organization and structure with a clear writing style in analyzing the setting of the story. The descriptions are adequate, providing a basic understanding of the physical and emotional context of the story. The essay demonstrates a basic understanding of the setting's significance to the story.	The essay lacks an original and creative approach in analyzing the setting of the story. The descriptions are superficial, providing little understanding of the physical and emotional context of the
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3.2. Implications and suggestions

The above examples deliver an important message that learning higher level GAI usage would generally benefit the learners more. The examples also imply that learners benefit from ChatGPT based on the way they interact with it. Five learner-GAI interactive levels are listed as follows:

- Level 1 - None: The learner always waits for the teacher or others' commands or instructions.
- Level 2 - A little: The learner always asks wrong questions.
- Level 3 - Average: The learner knows how to ask the right questions.
- Level 4 - A lot: The learner knows how to ask the right questions in logical sequences using a conversational approach.
- Level 5 - Super: The learner treats ChatGPT as a teammate and always works together as a good teammate with ChatGPT.

Accordingly, here are some guidelines for providing comprehensive prompts to GAI like ChatGPT to get the best responses:

- Be specific: Describe your goal/question with specific and clear wording. Avoid using too general topics or ambiguous words.
- Provide context: Describe the context where your question is situated or based. The more relevant information about the context provided to GAI, the more accurate the generated response will be.
- Role-play: Tell GAI what role you want it to play, and ask it to act as a specific role. The generated output will align with how that specific role would typically react to the question you asked.
- Reciprocal questioning: Instead of asking GAI questions in a one-way direction, it is recommended to make it more like a two-way conversational process by asking GAI to raise questions along the way until a final output that you are satisfied with is generated.
- Output formatting: Describe the specific format you would like to see for the GAI-generated outputs.

4. Potential research topics of generative AI in education

The diverse roles that GAI can play in educational settings have attracted attention from researchers in both the fields of computer science and educational technology. On the other hand, scholars and school teachers raise several concerns regarding the use of GAI in school settings. That is, GAI in education is not only an interesting issue, but also a challenging one. This implies that GAI in education research has great potential in the coming years since people are eager to know how to use it and what could happen. To this end, the present study proposes the following potential research issues of GAI in education:

(1) *Proposing GAI-based educational models or frameworks.* Individual roles of GAI in education, as addressed in Figure 1, could be further extended by taking into account different educational objectives, computer technologies or devices, research foci, and pedagogical theories to establish GAI-based educational models or frameworks. The models or frameworks could be a good reference for guiding researchers or instructors to implement GAI-based learning strategies, teaching plans or research designs.

(2) *Investigating the effects of GAI-based learning on students' learning performance and behavioral patterns.* Despite the fact that some researchers and educators worry about the possible misuse of GAI applications by students, the powerful GAI functions are likely to engage students in totally different learning modes, in particular, in creative learning tasks. That is, properly adopting GAI applications in learning designs could shift technology-enhanced learning to a different level, in which students can fully exploit their creativity and application capabilities to create artworks, solve problems, or complete projects with the assistance from GAI. Therefore, it is important and challenging to explore the effective ways of using GAI in educational settings by conducting experimental studies to address this issue.

(3) *Exploring the effectiveness of GAI-based learning from diverse angles.* In addition to comparing the performances of the students learning with GAI and those with the conventional approach, it is also important to probe the effectiveness of GAI-based learning by taking different factors or issues into considerations. For example, it is interesting to investigate the impacts of GAI-based learning on the performances of learners with different cognitive styles or knowledge levels. It is also interesting to reconsider several application domains in which researchers seldom take into account when trying to applying conventional technologies for educational purposes, such as arts, music, and design courses. It is also worth investigating whether the use of GAI could improve students' creative thinking and performances. With the new functions provided by GAI, it is possible to conduct those learning designs that cannot be implemented using conventional AI technologies.

(4) *Revisiting the roles of pedagogical theories by taking the use of GAI in education into account.* It is obvious that GAI provides people with a totally different perspective of what technologies can do. As addressed by Hwang et al. (2020), different educational technologies generally imply angles of perceiving pedagogies. The new features and functions of GAI reveal that educational contexts and objectives need to be perceived from a totally different perspective. By taking the features of GAI into account, it is possible that those well-known pedagogical theories can be interpreted in a different and innovative way.

(5) *Incorporating effective learning strategies into GAI-based learning activities.* The effectiveness of GAI-based learning heavily depends on how learners use this new technology to complete their learning tasks. Without proper guidance, bad ways of applying GAI could happen. For example, students could completely rely on ChatGPT to write a report by sending a request to it. To engage students in learning with GAI in a good way, incorporating effective learning strategies into the learning design is very important. In the above example of asking students to write a report using ChatGPT, a possible strategy could be “video sharing,” which requires students to record and share how they work with ChatGPT to write their report. Using the peer-assessment strategy, which requests the students to provide ratings and comments to peers’ reports based on the rubrics provided by the teacher, could be a good follow-up task of the video sharing activity. Other learning strategies or tools, such as concept mapping and gamification, could also be good choices to facilitate GAI-based learning.

(6) *Examining the effects of different roles played by GAI on students’ learning performances.* As mentioned above, GAI applications could play the role of a tutor, tutee or learning partner. It is interesting to investigate the best way of using GAI in different applications domain by comparing the different roles played by GAI.

(7) *Constructing ethical guidelines and examples for applying GAI applications to educational settings.* From the concerns raised by researchers and school teachers, it is apparent that the issues of using GAI in education is relevant not only to the effectiveness of this approach in promoting learners’ performances, but also to the possible ethical problems caused by implementing it in educational settings (Zohny et al., 2023). Without clear guidelines, improper use of GAI could lead to plagiarism or authorship problems. Allowing students to use GAI to complete learning tasks could deliver the wrong messages to them that asking others (e.g., ChatGPT) to do homework or projects for them is acceptable. Therefore, it is essential to take the ethical issues into account when prompting the use of GAI in educational settings.

(8) *Investigating the impacts of diverse Human-GAI collaborative modes.* As mentioned above, GAI could play the role of a tutor, tutee or partner. This implies that the role of treating AI as an intelligent tutor in traditional AIED research could now be very different owing to the presence of GAI. That is, the relationships between learners/instructor and GAI need to be reconsidered. It is possible that, in educational settings, GAI is more like a partner rather than a tutor. In addition, how to use GAI as a tutee to benefit human learners, who play the role of a tutor, remains an open issue.

(9) *Exploring the effective ways of employing and evaluating the effectiveness of multimodal GAI applications in education.* GAI technologies have advanced from version 1.0 to 4.0. During the process, the functions of a GAI application have significantly changed. For example, GAI 1.0 applications generate text outputs based on users’ text inputs (e.g., ChatGPT 3.5), GAI 2.0 applications generate text outputs based on users’ text and image inputs (e.g., ChatGPT 4.0), GAI 3.0 applications generate text and image outputs based on users’ text and image inputs, while GAI 4.0 applications are able to generate any combinations of text, image, and video outputs based on the text and video inputs provided by the users. This raises an interesting question: what are the potential applications and research issues of multimodal GAI applications?

(10) *The fusion of various GAI tools together for personalized learning.* Investigating the integration of AI-generated learning content, AI-driven pedagogical and learning strategies, and AI-simulated educational avatars to create adaptive learning systems that cater to individualized learning experiences. For example, the guidance and support designed in previous studies (Chu et al., 2021) for helping individual learners based on their learning obstacles and special needs, those design mechanisms can be empowered by integrating pedagogical GAI tools.

(11) *Integrating embodiment features into GAI by combining GAI with educational robots to promote active social learning.* Based on embodied cognition theory and active social learning theory, effective learning requires learners to immerse themselves in a contextually meaningful learning environment and engage in learning activities that involve social interactions using both the brain and body. It is recommended that researchers who have developed learning applications using educational robots (Cheng et al., 2021; Cheng et al., 2023) could explore the possibility of integrating GAI tools using their APIs to make the educational robots behave smarter and more human-like.

6. Conclusions

The presence of GAI has shifted the paradigm of AI in education. It is crucial for researchers and educators to perceive GAI from a completely different angle from conventional AI, chatbots, and information systems: (1) GAI is not just an intelligent system that provides personalized guidance or support; (2) GAI is not just a chatbot that can interact with learners via a natural language interface; (3) GAI is not just an application enabling users to search for information. From the examples given in this paper, it is suggested that researchers and educators get rid of the “search” mindset and use “programming prompt” instead to work with GAI applications. The “programming prompt” refers to the ability to guide GAI applications to complete tasks following a sequence of logical instructions. A well-designed set of prompts will guide ChatGPT to perform a quality task. This implies that, from the perspective of education, fostering teachers’ and students’ competences of “programming prompts” would significantly affect the quality of GAI-based teaching and learning, including the quality of learning content, learning designs, and assessment designs for teachers, and the learning outcomes of students.

Under the notion of programming prompt, there are four categories of programming prompts including (1) Conversational prompts, (2) Content analysis prompts, (3) Coding prompts, and (4) Multimodal prompts. The application examples shown in this paper are examples of conversational prompts. Researchers are encouraged to further explore the design principles and development guidelines to help learners master the knowledge and skills about these four programming prompts to better utilize the benefits that GAI can offer for education.

Although ChatGPT is used to demonstrate various strategies of using GAI in educational settings, the concepts and strategies introduced in this paper can be applied to other GAI applications. It is believed that, in the coming years, more and more GAI applications will be developed and introduced to people and will replace most of the existing computer applications. Therefore, the authors of this paper would like to advise researchers and educators to seriously perceive this new trend of technology-supported education and learn how to correctly and wisely use this new form of computer applications in promoting the educational quality.

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