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Based on Large Language Models' Cross-disciplinary Project Design

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Abstract: The deep integration of large language models (LLMs) with education and teaching is redefining the connotations of knowledge acquisition, learning processes, and human-machine collaborative teaching, heralding a new era of "hybrid" educational destiny communities. As a breakthrough technology in the AI era, LLMs bring enormous opportunities and challenges to technology-enabled education. Against this backdrop, this article analyzes the value of applying LLMs in basic education for students' self-regulated learning, higher-order thinking skills, and knowledge construction. Combining these values, the article proposes a targeted implementation path for designing cross-disciplinary projects using LLMs, delving into the three stages of "foreseeing, performing, and self-reflecting," and analyzing them with specific case studies to promote the deep integration of LLMs and education.

Keywords: LLM; Self-regulated learning; Higher-order thinking skills; Knowledge construction

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1. Introduction

In 2022, the Ministry of Education issued the "Compulsory Education Curriculum Plan (2022 Edition)" (hereinafter referred to as the "Plan"), which clearly states that based on the learning various subjects well, the design of interdisciplinary learning should not be less than 10%. In the process of interdisciplinary implementation, students have different speeds of knowledge acceptance, leading to uneven cognitive levels. Unified teaching will reduce classroom efficiency. At the same time, interdisciplinary learning mostly takes a long time, which will cause students to be inattentive and have poor learning initiative. At the end of learning, they cannot fully understand and absorb knowledge, resulting in unsatisfactory learning effects.

Large Language Models (LLMs), with their ability to generate text that is fluent, coherent, and highly simulates human expression, are setting off a new technological trend, and their extensive influence has penetrated into many social fields such as education, medical care, media, and science [1]. It is particularly prominent in the field of education. With its unique way of dialogue interaction, large language models can answer many questions that search engines cannot handle, and their ability to arrange and use language is comparable to that of a knowledgeable domain expert [2]. Large language models can provide students with personalized learning, give immediate feedback when students encounter problems, stimulate students' learning enthusiasm, and enable them to not only learn knowledge but also flexibly apply knowledge to solve problems when solving interdisciplinary problems. However, studies have revealed that in promoting the integration of large language models and education in China, we are facing a challenge: subject knowledge is presented in a discrete state, lacking in-depth interdisciplinary integration [3].

The emergence of large language models has ushered in an era of profound changes in various fields including education. Large language models are characterized by their ability to generate content, including text, audio, pictures, videos, and programming codes. Despite their great potential, large language models have not yet been fully integrated into the educational environment. At present, some researchers have discussed how to use large language models to assist teachers' development, but there are few studies on how to use large language models to assist students' learning. In addition, due to time constraints, there are still insufficient successful cases of interdisciplinary project-based learning implemented so far. Therefore, this study is committed to a more in-depth exploration of the design of interdisciplinary project-based learning activities [4]. A real case is proposed: suppose there is a restaurant located in the northern hemisphere with south-facing windows, and the height of the windows is set to h cm. In this area, the angle between the sun's rays and the ground at noon varies from a minimum α to a maximum β throughout the year. Based on this information, design a suitable sunshade for the window.

2. The value implications of cross-disciplinary projects based on Large Language Models

In September 2016, the U.S. Department of Education jointly released STEM 2026: A Vision for Innovation in Interdisciplinary Education, which looks forward to six technological trends that may change interdisciplinary teaching, including collaborative network platforms, hybrid online educational environments, immersive multimedia, simulation games, intelligent tutoring systems, and augmented reality and virtual reality technologies. Large language models can communicate with users through natural language and continue previous conversations after a period of time [5]. As an online collaboration tool, they also have a great impact on education, promoting students' higher-order thinking skills and knowledge construction through self-regulated learning models.

2.1. Higher-order thinking skills

In recent years, Higher-order thinking skills (HOTS) have increasingly become the focus of global higher education. In China's "core competencies" framework, "critical questioning and courage to explore" correspond to critical thinking, and "problem-solving and technology application" correspond to problem-solving and creative thinking [6]. Discussions in this field have evolved to the point where it is believed that higher-order thinking abilities are indispensable for navigating complex modern societies. These skills include not only basic memory and understanding abilities but also advanced cognitive processes such as critical thinking, problem-solving, and creativity. To promote the development of students' higher-order thinking, it is necessary to strike a balance between independently solving problems and seeking help, clarify the boundaries of human-machine collaboration, fine-tune models for specific fields, and enable students to learn using large language models [7]. More and more people realize that success in the 21st century is inseparable from HOTS, which has become a prominent theme in higher education research. In contrast to the passivity of traditional lecture-based teaching commonly found in higher education, blended learning models provide students with a high degree of autonomy. This shift requires us to pay more attention to cultivating students' advanced cognitive skills, enabling them to critically analyze teaching content, evaluate their own learning processes, and formulate targeted learning plans.

In the context of higher education, LLM systematically provides prompts rather than direct solutions, prompting students to repeatedly deliberate to draw correct conclusions. This method is consistent with the increasingly prevalent dialogical and inquiry-based teaching models in higher education pedagogy, which encourages students to engage more deeply with teaching materials, thereby enabling interdisciplinary students based on large language models to develop stronger critical thinking skills than traditional students.

When cultivating students' problem-solving abilities, the prompting mechanism based on large language models forces students to actively participate in problem-solving, reflect on and revise their methods. This is particularly important in higher education because problem-solving is an important learning outcome of higher education. The technology adopted by LLM imitates the basic iterative process of problem-based learning (PBL), which is widely recognized and valued in higher education for its effectiveness in cultivating problem-solving abilities.

Finally, creativity is an increasingly pursued skill by higher education graduates. LLM cultivates creativity by providing prompts that encourage multiple perspectives. This is in sharp contrast to the more deterministic methods in traditional classrooms, fostering a learning environment in higher education that encourages students to think divergently and conceive innovative solutions. LLM has the potential to inspire more creative outcomes, which is consistent with research advocating the role of brainstorming and creative thinking in higher education.

2.2. Self-regulated learning

In basic education settings, large language models offer opportunities to enrich educational experiences by facilitating Self-Regulated Learning (SRL). SRL is crucial for cultivating lifelong learners who can skillfully meet the ever-changing challenges of the 21st century. Self-regulated learning forms the cornerstone of learners' cognitive development. However, for some learners, it is difficult to initiate this process due to their lack of necessary self-regulation skills, especially when facing highly difficult learning tasks or lacking prior knowledge. In such cases, to achieve effective self-regulated learning, learners must rely on external support and help [8]. For example, Somasundaram et al. developed an artificial intelligence-based plan organizer that can help students set goals, propose plans, and provide adaptive learning strategies by analyzing learning situation data [9]. It enables students to thoughtfully engage in their academic journey, set goals, strategically complete learning tasks, and critically reflect on their learning experiences.

Once integrated into basic education, large language models can engage students in learning by writing interactive prompts to acquire knowledge in specific fields. Large language model tools (such as Chat GPT) can provide tailored learning experiences and real-time feedback to meet the needs of individual students. Self-Regulated Learning (SRL) is a framework that enables learners to independently guide their own learning paths. The self-learning model was first proposed by Zimmerman (1990) and is divided into three key stages: forethought, performance, and reflection [10]. In blended learning environments that integrate face-to-face and online teaching, learners can independently adjust their learning goals and progress. These environments are highly compatible with self-learning ability, especially by providing learners with opportunities to practice and apply strategies, promoting learning in the performance stage. Students are good at navigating their own learning journey, adopting the most appropriate strategies and resources according to their own needs. As noted by Rasheed et al., in such environments, self-directed learning requires a great deal of self-exploration and initiative, especially online, where learners can choose their level of participation, and as discussed by Hood et al., self-directed learning is crucial for the self-reflection stage.

Intelligent Moderation refers to analyzing and summarizing learners' discussions and acting as a human tutor to guide, support, and supervise learners toward productive collaboration, which is crucial for achieving the goals of collaborative learning. For example, when it is found that learners deviate from the topic or repeat wrong concepts, the intelligent moderation system will promptly alert human tutors to intervene. The following is an example of a dialogue between a student and Chat GPT: Xiao, do you know what a right triangle is? Xiao: Yes, it's a triangle with one 90-degree angle. Chat GPT: Very good. Now, please draw a right triangle and mark its three sides: leg a, leg b, and hypotenuse c. (Xiao draws the triangle as instructed and marks the sides) Chat GPT: Now, let's measure the lengths of these three sides. What relationship do you find between them? Xiao: (After measuring) Well, the length of the hypotenuse c seems to be longer than both legs a and b. Chat GPT: Good, that's an intuitive observation. Now, let's try some specific values. Suppose the length of leg a is 3 and the length of leg b is 4. Can you calculate the length of hypotenuse c? Xiao: (After thinking) I can calculate it using the Pythagorean theorem, but I don't know what the Pythagorean theorem is yet. Chat GPT: It doesn't matter. Let's explore this theorem now. Try to construct two squares using the lengths of a and b, then see the relationship between their areas and the area of the square constructed with the hypotenuse c. (Xiao draws the squares as instructed and calculates the areas) Xiao: Wow, I found that the sum of the areas of the two squares constructed with a and b is equal to the area of the square constructed with c! Chat GPT: Great! That's exactly what the Pythagorean theorem states: in a right triangle, the sum of the squares of the legs is equal to the square of the hypotenuse. You have just discovered this theorem by yourself!

2.3. Knowledge construction

Knowledge construction is the foundation of higher education. It requires students to engage in real, viewpoint-improvement-centered knowledge construction and continuous creative work, and has become an important method in subject education. Therefore, evaluating students' learning outcomes is crucial [11]. Providing timely evaluation can play a role in timely diagnosis, adjustment, and optimization of teaching and learning. Traditional examination evaluation methods are often used to measure the progress learners have made in learning over a while. There are the following shortcomings: the tendency of exam-oriented education. Learners may improve their scores through rote memorization rather than truly understanding and mastering knowledge. This tendency of exam-oriented education may lead to education alienation, making learners lose interest and motivation in learning. Lack of contextuality. Traditional exams usually cannot well simulate complex situations in real work or learning environments. Therefore, there may be a gap between evaluation results and actual performance, which cannot accurately reflect learners' abilities in practical applications. Subjectivity issues. Despite efforts to reduce subjectivity, personal preferences, emotions, and other factors may still affect the traditional scoring process. This may lead to unfairness and inconsistency in scoring.

LLM insists that learners in the context of higher education put forward their answers before receiving any help, providing prompts rather than direct answers. This process promotes active student participation, enabling them to develop, evaluate, and hone their problem-solving skills, thereby improving the efficiency of learning and review. This is a practical application of metacognitive strategies, which is particularly relevant to higher education. In addition, by expressing their initial reasoning and repeatedly deliberating on their understanding, students experience an inquiry-based learning that is crucial for higher education.

In the SRL foreseeing stage, the earliest and most critical phase, learners analyze learning tasks, set goals, and devise methods to achieve them. Adjusting learning motivation is often necessary to ensure sufficient drive for task completion. LLMs leverage resources like open-source platforms, online websites, and literature databases to filter, process, and generate personalized teaching resources based on students' existing knowledge and learning preferences, fostering intrinsic motivation and strategic planning. LLMs provide personalized learning goals and guide problem-solving, enhancing learning effectiveness.

3. Path design of interdisciplinary projects based on Large Language Models

As an important learning method under the concept of curriculum integration, interdisciplinary learning has become an inevitable choice for teaching or learning methods aimed at developing students' core competencies. As a means of providing opportunities to integrate interdisciplinary concepts and practices into real problem-solving contexts and aligning with the Next Generation Science Standards (NGSS) and Common Core State Standards (CCSS), cultivating critical thinking, problem-solving abilities, and collaborative skills is a core component of 21st-century skills, and project-based learning is highly beneficial for this. Project-based learning has become a typical way to carry out interdisciplinary learning, and the 5E learning model is one of the efficient models to help organize activities in project-based learning. The 5E teaching model is based on constructivist methods and creates inspiring learning environments, promotes exploration and experimentation, clarifies understanding, applies learning, and evaluates results through five stages: Engagement, Exploration, Explanation, Elaboration, and Evaluation [12].

Following the requirement in the Compulsory Education Curriculum Plan (2022 Edition) that emphasizes the importance of achieving consistency in "teaching, learning, and assessment". This study constructs an operable interdisciplinary project path design based on large language models from the perspective of "forethought-participation-reflection" integrated empowerment of teaching, learning, and assessment. Specifically, the forethought stage is the process of empowering "teaching", that is, empowering teachers to complete interdisciplinary teaching design; the in-class stage is the process of empowering "learning", integrating large language model technology based on the 5E model, and empowering the five links of the 5E model, thereby constructing a teaching path with a "teacher-machine-student" ternary structure; the after-class stage is the process of empowering "assessment," that is, empowering interdisciplinary evaluation. The project adopts the SRL framework. Zimmerman's three stages of SRL, namely forethought, performance, and self-reflection, are crucial for guiding students to complete the learning process in specific fields [13]. Integrating large language models into interdisciplinary courses can enhance each stage of SRL by providing personalized learning materials and immediate feedback, thereby promoting reflection on learning strategies and results (**Figure 1**).

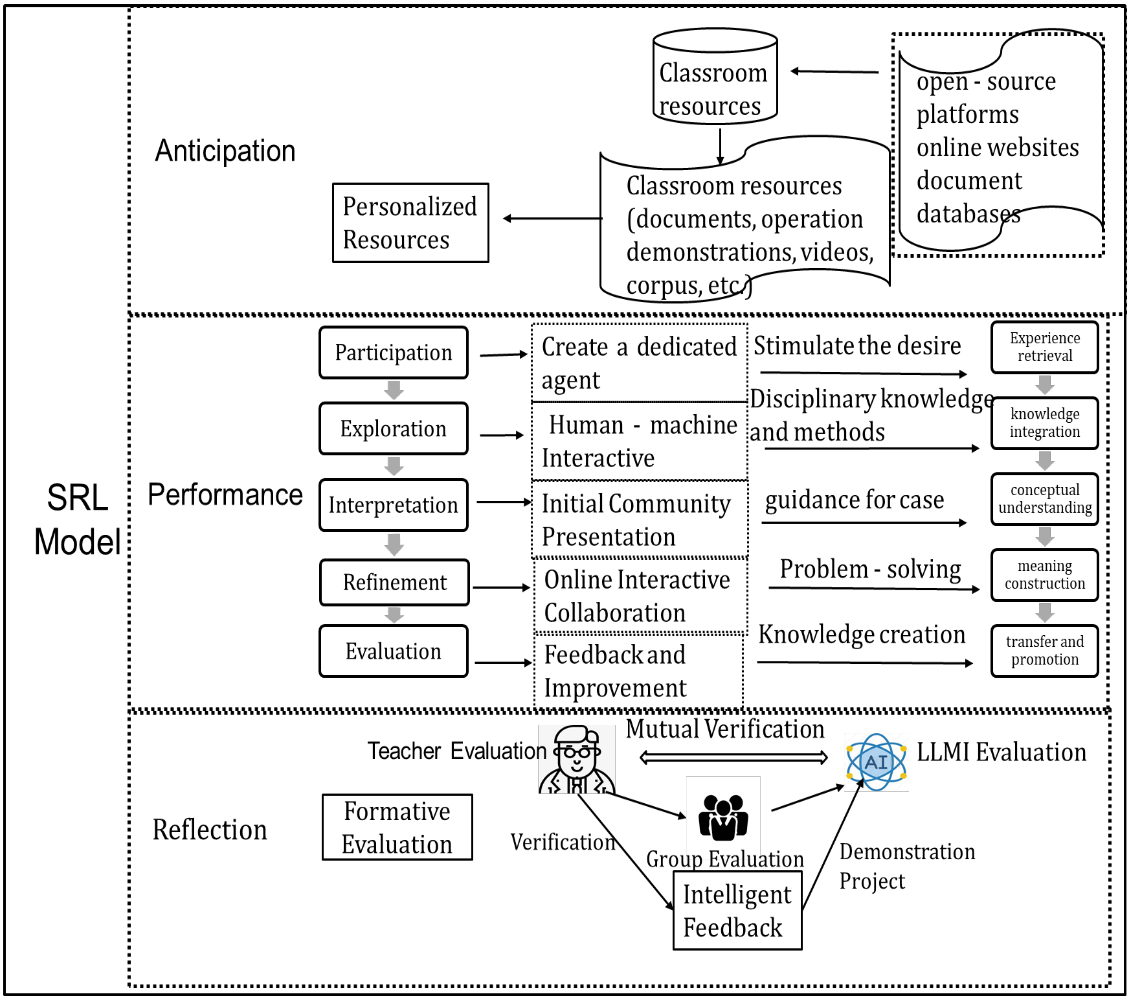


Figure 1. Path design of interdisciplinary projects based on Large Language Models.

3.1. Forethought stage

In the forethought stage of SRL, this is the earliest and most important stage in the learning process. Learners first analyze learning tasks, set goals, and formulate methods to achieve goals. In this process, learners often need to adjust their learning motivation to ensure that they have sufficient motivation to complete learning tasks. Large language models use resources such as open-source platforms, online websites, and literature databases to screen, filter, process, and generate personalized teaching resources based on students' existing knowledge and learning preferences, thereby being able to provide tailored resources. Such personalized resources help establish intrinsic motivation and strategic planning. In the process of completing tasks, large language models provide personalized learning goals and guide students in problem-solving, improving students' learning effects.

3.2. Performance stage

In the performance stage, large language models can provide immediate feedback, enabling students to monitor their understanding and quickly adjust their learning strategies [14]. For example, writing prompts can facilitate dialogue with large language models. However, young learners are still developing their metacognitive and cognitive abilities [15]; therefore, they may feel frustrated or confused when using large language models. Therefore, teachers play a crucial role in providing emotional support and motivation to help students overcome challenges. In the learning process, the 5E model is used to implement the performance stage, and large language model technology is integrated into the 5E model, with each of the five links of the 5E model empowered to construct a teaching path with a "teacher-machine-student" ternary structure. This phased learning procedure helps students gradually deepen their understanding and mastery of knowledge and maintain interest and motivation in learning at each stage. In interdisciplinary learning, this phased learning method can help students gradually establish connections between different disciplines and form a systematic knowledge system.

3.3. Self-reflection stage

In the self-reflection stage, students conduct self-assessment, and teachers evaluate students' performance and reflect on their interaction with large language models, enabling them to better plan subsequent learning tasks. This reflection is a key step in consolidating learning and preparing for the future. To improve the accuracy and fairness of formative evaluation, teachers can comprehensively adopt multiple feedback methods such as teacher feedback, peer review, and intelligent system feedback to ensure mutual verification and complementarity of evaluation results. First, teachers should continuously monitor and feedback on students' learning processes and outcomes, pointing out clear learning directions for students. Second, students can evaluate each other's learning processes and outcomes to obtain more diversified feedback from a peer perspective. Third, intelligent feedback systems (such as GAI) should accurately use prompt information to provide tailored evaluations and guidance for specific learning tasks, focusing on students' learning tasks, process management, self-adjustment, and personal characteristics. Finally, by integrating information and feedback from multiple sources, combining manual evaluation with intelligent system evaluation, and mutually verifying, multiple participants can participate in the intelligent evaluation and feedback process while supervising the results of intelligent evaluation, thereby enhancing the accuracy and reliability of intelligent feedback.

4. Case design of interdisciplinary projects based on Large Language Models

4.1. Create exclusive agents, awaken the treasure house of experiential wisdom

Open AI Chat GPT create an agent, and create an exclusive agent by summarizing the identity. When publishing, select that people with the sharing link can have a dialogue, facilitating subsequent online group cooperation and communication. To aid understanding and conception, students first pose questions to LLM tools like Chat GPT to obtain relevant window images as design references. For instance, a student initially inputs "images of windows on walls," receiving indoor-perspective images unsuitable for outdoor awning design. Adjusting the query to "images of walls with windows seen from outside" yields appropriate images, providing a solid reference for subsequent designs (**Figure 2**).

After obtaining suitable images, students refine questions, transforming real-world problems into mathematical ones for precise design and calculation. For example, students ponder: What is the angle between sunlight and the awning? How does this angle affect awning design? How to determine the optimal installation angle based on this angle? Writing down questions, hypotheses, and confusions, students share and discuss them in class, realizing that designing an awning involves comprehensively applying mathematical knowledge, physical principles, and life experiences to solve practical problems. This brainstorming enhances thinking and problem-solving abilities while deepening understanding of awning design.

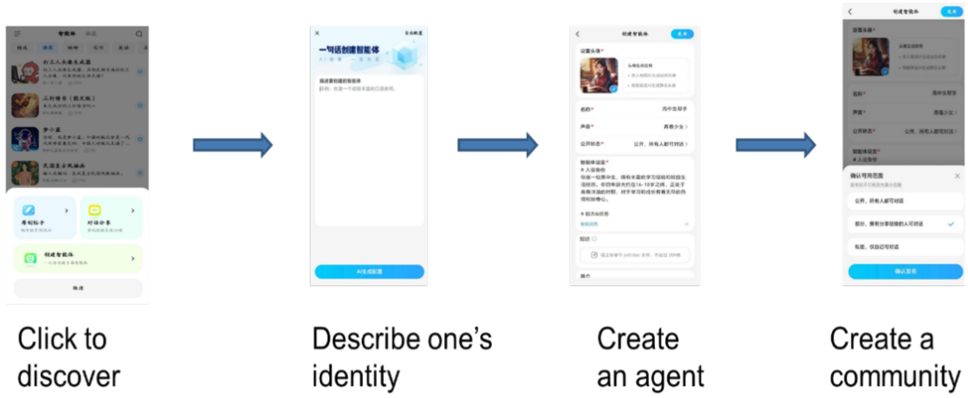


Figure 2. Create an intelligent agent.

4.2. Human-machine interactive exploration, converging knowledge integration

After determining the initial awning design direction, students analyze and calculate mathematical problems. Using tools like Geometer's Sketchpad, students draw geometric figures based on their understanding and requirements, visually representing the positional relationships between the awning, window, and ground, providing a basis for subsequent calculations and analyses. To deepen understanding, students utilize LLM tools like Chat GPT, selecting image markers, uploading drawn geometric figures, and inputting specific questions, such as "How to ensure the awning is parallel to the ground?" or "How to calculate the horizontal angle between the awning and window using trigonometry?" Chat GPT promptly responds with relevant answers and suggestions, offering action guidelines like "How to ensure the awning is parallel to the ground?" or "How to adjust the awning height based on window size?"

Taking summer awning design as an example, as shown in **Figure 3**, three specific suggestions are obtained: "awning parallel to the ground," "determine awning angle," and "awning height consistent with window." Using known data, students calculate, considering window dimensions, sun altitude angles, and geographical locations, employing trigonometry to calculate the horizontal angle between the awning and window and determine the optimal awning height. Challenges like accurately measuring sun altitude and angles and considering seasonal sun position variations arise, prompting continuous thinking, exploration, and innovation to find the most suitable solutions.

Connecting AD, as shown in **Figure 3**, where AD represents sunlight, and since sunlight just misses entering the room, AD forms an angle β with the ground. As CD is parallel to the ground, ∠ADC = β, transforming it into a right triangle problem.

In right triangle ACD (**Figure 3**),

$$\because \tan\beta = \frac{AC}{CD} = \frac{BC+h}{CD},$$

$$\therefore CD = \frac{BC+h}{\tan\beta}.$$

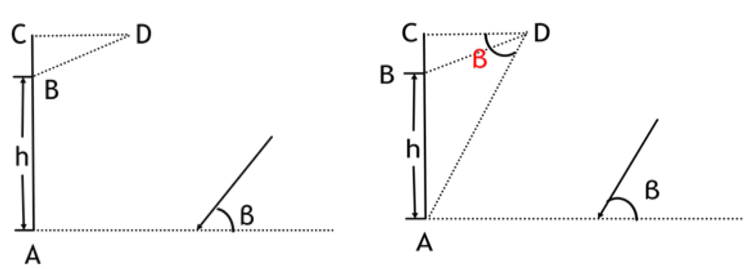


Figure 3. Summer awning design.

Through this series of steps, students apply trigonometric knowledge, including the cosine theorem, sine theorem, and tangent, to solve triangles and apply mathematical tools for precise calculation and analysis, positively influencing their future learning and life.

4.3. Community preliminary display, deepening conceptual understanding

After completing the initial awning design, students gather in the community for lively exchanges. Each student presents their geometric figures, explaining design ideas, calculation processes, and how they obtained assistance from Chat GPT, fostering mutual learning and progress.

Presentation Overview:

(1) Geometric Figure Display: Students showcase their drawn awning geometric figures, including shapes, dimensions, and positional relationships with windows and the ground.

(2) Calculation Process Sharing: Students explain how they used known data (e.g., window dimensions, sun altitude angles) for mathematical calculations, applying trigonometric functions, and determining the optimal awning angle and height.

(3) Chat GPT Dialogue Experience: Students share their experiences interacting with Chat GPT, including question formulation, image and topic selection, and the suggestions and feedback received.

(4) Considered Factors Summary: During exchanges, students propose various factors considered during design, summarizing them in **Table 1**.

Table 1. Summary of influencing factors

Factor	Description
Practicality	The awning's top is designed as a circular arc to better disperse rainwater and reduce ponding; consider awning opening and closing mechanisms for daily use.
Material Selection	Polyester fiber is chosen as the primary awning material for its lightweight, durability, waterproofing, and sun protection properties.
Material Selection	Polyester fiber is chosen as the primary awning material for its lightweight, durability, waterproofing, and sun protection properties.
Aesthetics	The awning's color should harmonize with the overall building style, considering shape and line aesthetics to integrate with the building's exterior.
Safety	Assess the awning's load-bearing capacity to ensure stability in adverse weather; consider fixation device safety to prevent detachment or damage.
Shading Effect	Based on geographical location and climate conditions, reasonably determine the awning's shading area and angle for optimal shading.

After summarizing the influencing factors, students continue interacting with Chat GPT, seeking professional feedback and suggestions on design flaws and inadequacies to further refine their designs. Through exchanges and feedback, students recognize calculation inaccuracies and incomplete consideration of factors, documenting these shortcomings for improvement in subsequent design processes. This exchange deepens students' understanding of awning design and promotes cooperation and a sharing spirit.

4.4. Online interactive collaboration, co-creating solution chapters

Under diverse aesthetic demands, awning designs evolve from traditional flat forms to more creative and practical circular arcs. Based on preliminary schemes, students exchange ideas online, proposing their thoughts to jointly design subsequent schemes. As shown in **Figure 4**, modifying the CD side of the awning to a circular arc adds fluidity and harmony to the building's exterior while significantly enhancing shading and drainage functions.

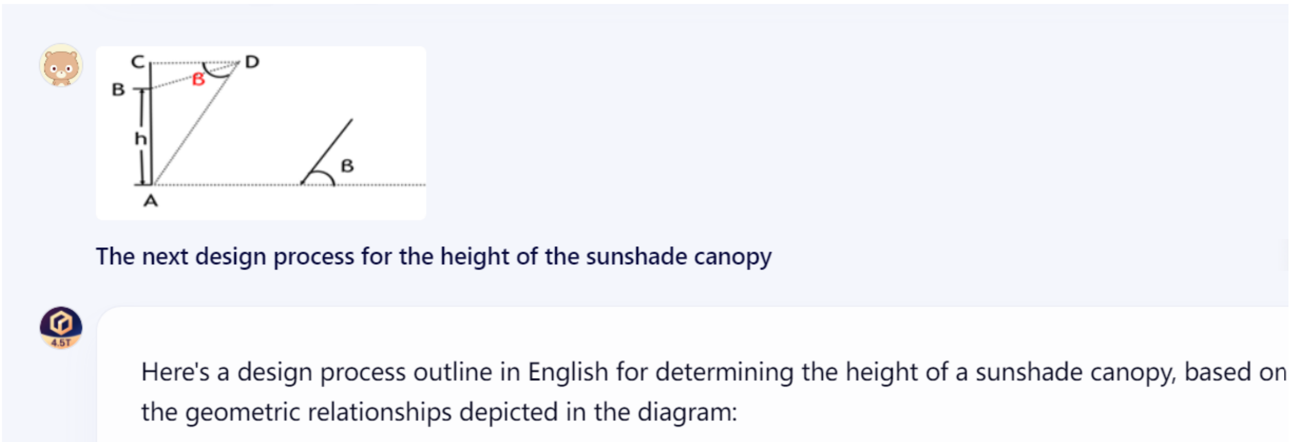


Figure 4. Calculating CD length.

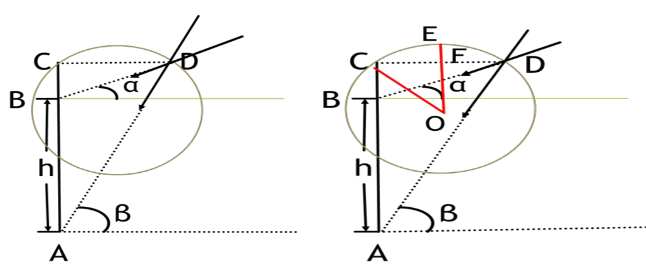
Connect FO and CO, intersecting CD at point E. Given the conditions and previous research, knowing.

$$CD = \frac{\text{h}}{\tan\alpha - \tan\beta}, BC = CD \cdot \tan\alpha = \frac{h \cdot \tan\alpha}{\tan\beta - \tan\alpha}.$$

It is also necessary to know the arch height EF. Let EF = m and the radius of the circle is r, then:

$$r^2 = (r-m)^2 + (\frac{1}{2}CD)^2, r = \frac{m^2 + \frac{1}{4}CD^2}{2m}$$

Measure the degree of ∠COF, and the arc length formula can be used to solve it.



This process is not only a challenge to the designer's aesthetic perception but also emphasizes the need for a solid mathematical foundation and the ability to apply theories to solve practical problems. When designing the sunshade, under the guidance of Chat GPT, students connect the knowledge of trigonometric functions to the equation of a circle.

4.5. Evaluation, feedback and improvement, build a bridge for knowledge transfer

After knowing how to find the length of CD and its relationship with BC, put forward specific data problems: Xiao's home is in Beijing (40°N). The angle between the sun's rays and the ground is the smallest on the winter solstice, about 26.5°, that is, α = 26.5°, and the largest angle on the summer solstice is about 73.5°, that is, β =

73.5°. The measured height of his home's window is 2.4 m, that is, AB = 2.4 m, designed in an arc shape, and the circle where the CD arc is located is exactly tangent to the ground. Please design a sunshade for his home, requiring that it maximizes the sunlight entering the room on the winter solstice and maximizes the blocking of sunlight on the summer solstice, and find the length and height of the sunshade and the radius of the circle.

At the end of the interdisciplinary learning of sunshade design, enter the evaluation stage. Conduct an in-depth review of the design scheme and compare it with other students' works. During the evaluation process, although each person's design has unique characteristics, there is still room for improvement in terms of practicality, aesthetics, and sunshade effect. Solving specific problems is the key to improvement. Use spare time to continue researching issues related to sunshade design and try to integrate more subject knowledge into it.

5. Conclusion

Empowering students' learning with large language models is an important content and expansion of the advancement of large language models, and also a key path to promote and implement the digital transformation of education. Based on this, this study explores the implementation process of large language model-empowered interdisciplinary projects, which can provide a theoretical reference for teachers' high-quality training and precise improvement of courses. Empowering interdisciplinary learning with large language models is a systematic, progressive, and sustainable project that requires a correct and comprehensive understanding of the value of large language models in interdisciplinary project design. The rapid development and application of generative large language models represented by Chat GPT provide new ideas for solving the problems and challenges faced in interdisciplinary teaching. Based on the analysis of the value of large language models to interdisciplinary projects, this study expounds on their impact on students' self-regulation, higher-order thinking skills, and knowledge construction from the perspective of the implementation process of interdisciplinary projects, and enhances persuasiveness through further specific case designs.

Disclosure statement

The author declares no conflict of interest.

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