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Research on the Effectiveness of Project-Based Learning Promoted by the Integration of Chat GPT and Argument Mapping

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Abstract: This article aims to explore the impact of integrating Chat GPT with Argument mapping on the effectiveness of project-based learning (PBL). As a teaching method that promotes the development of students' higher-order thinking, PBL faces many challenges in practice, such as difficulties in student communication, lack of innovative thinking, and teacher dominance. Argument mapping, as a tool, help address the fragmentation of knowledge and team collaboration issues, but they also have their limitations. This study proposes that combining generative artificial intelligence (such as Chat GPT) with Argument mapping can overcome these challenges and enhance the effectiveness of PBL.The study hypothesizes that science argumentation maps empowered by Chat GPT can positively affect students' learning engagement, interest, critical thinking, and academic performance. Through experimental research, two senior high school classes from School X in City L were selected as research subjects. The experimental group used Chat GPT empowered argumentation maps to support PBL, while the control group did not use this tool. The study used both quantitative and qualitative analysis methods, measuring critical thinking with the CTDI-CV scale, and designed questionnaires to survey learning engagement and interest.

1. Introduction

Project-Based Learning (PBL), as an important way to cultivate higher-order thinking, still faces issues in its teaching practice. Kizkapan, through quasi-experimental research methods, identified problems such as students' disagreement with peers' views, lack of communication skills with peers, fear of not completing all tasks and objectives, and difficulty adapting to new models [1]. According to Bicer, some students in the course design project implementation study failed to generate ideas that can solve problems [2]. Additionally, Quint stated that some students find it hard to communicate when facing very complex project processes [3]. This only turns problem-solving into a ritual without affecting students' thinking, creativity, confidence, and effective working methods. Project activities become pseudo-project-based learning under the guise of student-centeredness but

actually teacher-centered. Moreover, communication breakdowns and conflicts often occur in the process of project team collaboration [4]. Wang Shujuan discussed issues such as "evolving into project-oriented activities," "evolving into product-driven rather than problem-driven," and "teachers leading the project process while giving students too few choices" [5]. In the practice of chemistry PBL, it was found that focusing on the quantity of projects while neglecting their purpose leads to students' inability to delve into inquiries, and the long project cycle and slow progress make it difficult to achieve classroom teaching goals [6]. Although Argument mapping can help PBL solve the problem of focusing on scattered knowledge points and assist in team collaboration and communication as well as problem-solving, they still have their own limitations, such as not being able to solve the understanding of unfamiliar concepts and generating additional cognitive empowerment. Faced with the empowerment and upgrading of generative artificial intelligence across all industries, this study hopes to solve the dilemma of PBL and enhance the effectiveness of PBL by combining Chat GPT with Argument mapping. Therefore, this study makes the following four hypotheses.

H1: Project-based learning activities empowered by Chat GPT and Argument mapping will have a positive impact on students' learning engagement.

H2: Project-based learning activities empowered by Chat GPT and Argument mapping will have a positive impact on students' learning interest.

H3: Project-based learning activities empowered by Chat GPT and Argument mapping will have a positive impact on learners' critical thinking.

H4: Project-based learning activities empowered by Chat GPT and Argument mapping will have a positive impact on students' learning achievements.

2. Literature Review

2.1. The Positive Impact of Chat GPT on Project-Based Learning

Generative AI, especially language models like Chat GPT, has started a revolution in the field of education. Project-Based Learning (PBL), as a student-centered teaching method, emphasizes the promotion of students' knowledge and skill learning through real-world projects. Integrating generative AI into PBL can not only meet the personalized learning needs of students but also improve the teaching efficiency of teachers. The following is a review of the role of generative AI in project-based teaching. Generative AI can generate customized content based on the specific needs of students. In PBL, this means that each student or group can obtain unique learning materials and activity suggestions from AI according to their interests and learning objectives[7]. For example, Chat GPT can provide reading materials, discussion questions, and writing prompts related to the students' research topics, thereby supporting students' exploratory learning[8]. In PBL, students need timely feedback at different stages of the project to improve their work. Generative AI can quickly respond to students' questions and requests, providing preliminary feedback to help students adjust their research directions and methods in a timely manner[9]. This instant feedback mechanism reduces the workload of teachers, allowing them to devote more time to in-depth guidance and individual tutoring. Generative AI tools are good at creating and suggesting teaching content[10]. Teachers can use this feature to design course frameworks, learning activities, and assessment criteria. AI can assist teachers in generating course plans, teaching materials, exercises, and tests, thereby improving the efficiency of teaching preparation. Generative AI can simulate real-world situations, providing cases and challenges related to students' life experiences and interests. This contextualized learning can increase student engagement and motivation. In PBL projects, AI can assist in creating engaging situations, allowing students to learn and apply knowledge in the process of solving real problems.

Although generative AI has great potential in PBL, there are also challenges and limitations. First, the content generated by AI may have biases and inaccuracies, which need to be verified by teachers and students. Second, over-reliance on technology may weaken students' critical thinking and independent problem-solving abilities. In addition, dependence on technology may also exacerbate educational inequality, as some students may not have access to these advanced AI tools. The application prospect of generative AI in project-based teaching is broad and can provide students with a more personalized and efficient learning experience. However, to ensure the best learning outcomes, educators need to carefully consider how to integrate AI tools while paying attention to cultivating students' critical thinking and technology use ethics. By using generative AI responsibly and creatively, we can expect it to bring positive changes in the field of education. the aforementioned margins will not be printed.

2.2. The Positive Impact of Argument mapping on Project-Based Learning

Argument and evidence diagrams were first proposed by J. H. Wigmore in the early 20th century to help teach and analyze court cases. The purpose was to reveal the structure of debates, especially how evidence is used to clarify the state of the debate [11]. The practical aspect was pioneered by the logician Richard Whately in his book "Elements of Logic," where Whately proposed a hierarchical chain of argumentation, attempting to reduce the structure of an argument to the necessary and relevant propositions so that readers can apply logic and reasoning [12]. By the late 1950s, with the spread of Toulmin's ideas in the field of debate, the value of debate diagrams was quickly recognized, leading to their frequent appearance in textbooks. In the early 21st century, their form became that of computer software, which is much more convenient than paper and pen Argument mapping in terms of drawing, editing, and saving, promoting the exploration and application of Argument mapping in teaching [13]. The following are related studies on the application of Argument mapping in education.

2.2.1. Argument mapping empowered by Chat GPT promote the development of critical thinking skills

Davies believes that having good critical thinking skills can help them understand or acquire more complex knowledge beyond their own cognitive level, and Argument mapping will play a certain value and role in this process. Nancy Shontz [14], Dwyer [15]all use Argument mapping as tools in the teaching process of critical thinking and have come to a consistent conclusion that the use of Argument mapping has a statistically significant effect on the improvement of critical thinking. Among them, Tim van Gelder and others tested the impact of students using Chat GPT and Argument mapping on critical thinking, and the results showed that the weighted average benefit was as high as 0.85, thus proving that the application of Argument mapping in the teaching process combined with good teaching methods of teachers can effectively improve students' critical thinking [16]. Davies analyzed the reasons for this, stating that in the process of learning with Argument mapping, re-depicting the structure of arguments in the mind makes it easier to criticize the results of arguments [17]. Hogan and Broome described the method of drawing Argument mapping in "Integrating Argument Mapping with Systems Thinking Tools to Advance Systems Science," which attempts to overcome the problem of poor critical thinking skills[18]. Therefore, these studies collectively prove the value of Argument mapping empowered by Chat GPT in teaching, which can combine with teachers' teaching guidance to help learners promote the comprehensive improvement of critical thinking levels.

2.2.2. Argument mapping empowered by Chat GPT help with memory and cognitive construction

Dwyer divided learners into three memory methods: using colored Argument mapping, text, and monochrome Argument mapping. The results showed that the memory methods of color and monochrome Argument mapping were significantly better than the text memory learners. He believes that using boxes, arrows, and connection lines can make it clearer for learners to understand, and by combining them to express the relationships between contents, it can simplify the effort to understand [19]. Compared with mind maps, Argument mapping can more clearly indicate the relationships between certain special materials through arrows, thus helping learners in the process of memorizing and understanding these special materials[20]. In addition, Kuang-Hung Chiang also believes that Argument mapping can help students read articles more easily and improve their reading comprehension ability. His experimental results show that compared with traditional and conceptual mapping methods, using Argument mapping can improve students' argumentative article reading comprehension ability [21]. Daniel D. Suthers' research results confirm that using Argument mapping can significantly improve participants' understanding of problems. Especially in specialized critical thinking courses, through a large number of argument mapping exercises, students can gain more cognitive and teaching benefits, thereby better understanding problems [22]. Karaku's experimental class using Argument mapping showed significant results in academic achievement, indicating that teachers and students believe that Argument mapping are more helpful for their learning and memory [23].

2.2.3. Argument mapping Empowered by Chat GPT Aid in the Organization and Expression of Language

Berty Nsolly Ngajie, Ali Malmir, and others have reached a consistent conclusion in their research results analysis that Argument mapping have a significant improvement effect on expository and descriptive writing tasks. Specifically, they can improve participants' writing in terms of grammar, coherence, cohesion, and task achievement, but also indicate limitations, that is, there is almost no improvement in writing vocabulary [24][25]. The completed argumentation diagram plays an obvious role in guiding the writing process, resulting in significant improvement in learners' writing coherence and cohesion. Snmez's research found that learners also improved in writing ability through the use of scientific argumentation diagram tools. Argument mapping can effectively help students improve their oral and written expression abilities. The research believes that the use of Argument mapping can help students better organize and express their ideas, making their arguments more persuasive and logical. This also helps students to express their thoughts more clearly and accurately in oral and written communication [26].

3. Experimental Design

3.1. Participants

The subjects of this study are selected from the students of Grade 1, Class 3 (Experimental Class) and Class 5 (Control Class) of X Middle School in City L. The subjects are finally selected based on the comprehensive judgment of the number of students in the class, academic performance, learning progress, etc., with 48 people in each class as the subjects of the study. In the experimental design of this study, the experimental group adopts project-based learning activities supported by Chat GPT empowered Argument mapping, while the control class adopts the same activity process of project-based learning activities without the support of Chat GPT empowered scientific

argumentation diagram tools. One week before the official start of the course, this experiment first selects two classes with similar levels as the experimental class and the control class through critical thinking test papers, learning attitude survey questionnaires, and pre-tests of academic performance. Before the official start of the course, it is necessary to first train the students in the experimental class on the drawing tools and related application knowledge of Chat GPT empowered Argument mapping. After the course experiment is over, a post-test is conducted to analyze the changes in the experimental subjects. The specific details are shown in Table 1.

Table 1: Experimental Procedure.

Stage	time	Activities	Class Hours
Questionnaire Pre-test	2023.3.8	Conducting pre-tests for the experimental and control classes	2
Training on the Application of Chat GPT and Argument mapping and Logical Foundations	2023.3.9	Learning to use digital argumentation diagram software tools and basic argumentation knowledge in the computer lab	2
Implementation of Project Teaching Activities	2023.3.13-6.7	Using project-based learning activities for parts of the required courses in high school biology, physics, and chemistry	48
Questionnaire Post-test	2023.6.9	Conducting post-tests for the experimental and control classes after learning is completed	2

3.2. Measurement

This study uses a combination of quantitative and qualitative analysis methods to analyze and process data, mainly through the comprehensive application of software such as Excel and SPSS to process the collected data. This study chooses to use the Chinese version of the California Critical Thinking Disposition Inventory (CCTDI-CV) to measure critical thinking ability. The measurement scale includes seven categories: truth-seeking, open-mindedness, analytical ability, systematic ability, confidence in critical thinking, curiosity, and cognitive maturity, with ten test questions under each item, totaling 70 questions (30 positive questions and 40 negative questions, see Appendix A for details)[27]. In addition, the content validity (CVI) of CCTDI-CV is 0.89, and the alpha value is 0.90. The trait alpha values are between 0.54 and 0.77, showing high internal consistency[28]. In addition, the learning investment and learning interest before and after are measured through improved questionnaires. After the pre-release of the questionnaire, the Cronbach's alpha coefficient α of the improved questionnaire is greater than 0.7, indicating that the reliability of the evaluation tools applied in this study is relatively good.

4. Experimental Results

4.1. Analysis of the Effect of Project-Based Learning Empowered by Chat GPT and Argument mapping on Critical Thinking

From the pre-and post-test results in Table 2, the paired sample t-test results of the control class and the experimental class show that Sig (=0.281) > 0.05, indicating that there is no significant difference in critical thinking levels between the experimental class and the control class.

Table 2: Paired Sample T-Test Results for Critical Thinking Total Score.

Paired Sample Test								
	Paired Difference					t	Df	Sig.
	Mean	Std.Deviation	Std. Error of Mean	95% Confidence Interval for the Difference				
				Lower	Upper			
Total score of control class pre-test - Total score of experimental class pre-test	-.167	2.612	.377	-.925	.592	-1.442	47	.660
Total score of control class post-test - Total score of experimental class post-test	-3.146	4.785	.691	-4.535	-1.757	-4.555	47	.000

After the project-based learning activities empowered by Chat GPT and Argument mapping, the experimental class and the control class were retested, and the paired sample t-test results showed that Sig (=0.001) < 0.05, thereby verifying the original hypothesis that project-based learning activities empowered by Chat GPT and Argument mapping have a positive impact on students' critical thinking.

4.1.1. Analysis of the Effect on the Truth-Seeking Dimension

The dimension of seeking truth mainly measures the sincere and objective attitude towards seeking knowledge. If the answers found are inconsistent with personal views, even contrary to personal beliefs, or affect one's own interests, it is also disregarded. The pre-and post-test results of the experimental class and the control class in this dimension are shown in Table 3.

The paired sample t-test analysis of the pre-test data of the experimental class and the control class shows that Sig (=0.660) > 0.05, indicating that there is no significant difference between the two classes in the truth-seeking dimension. At the same time, the paired sample t-test analysis of the post-test data of the experimental class and the control class shows that Sig (=0.000) < 0.05, and the mean of the experimental class increased by 3.146 compared to the control class, indicating a significant difference between the two classes. In the teacher interview, it was found that the teacher believes that "the past communication and answering questions only needed to state the views, while the project-based learning activities based on Argument mapping added the requirement to supplement reasons or evidence, making students express their views more objectively and reasonably." Overall, after the project-based teaching activities empowered by Chat GPT and Argument mapping, students have a positive improvement in the dimension of seeking truth.

Table 3: Paired Sample T-Test Results for the Truth-Seeking Dimension.

Paired Sample Test								
	Paired Difference					t	Df	Sig.
	Mean	Std.Deviation	Std. Error of Mean	95% Confidence Interval for the Difference				
				Lower	Upper			
Truth-seeking of control class pre-test - Truth-seeking of experimental class pre-test	-.521	3.209	.463	-1.453	.611	-1.124	47	.267
Truth-seeking of control class post-test - Truth seeking of experimental class post-test	-2.896	5.439	.785	-4.475	-1.316	-3.689	47	.001

4.1.2. Analysis of the Effect on Open-Mindedness

Open-mindedness is the dimension of being tolerant of different opinions and guarding against the possibility of personal bias. The statistical results of the experimental class and the control class in the dimension of open-mindedness in critical thinking are shown in Table 4. The paired sample t-test analysis of the pre-test data of the experimental class and the control class shows that Sig (=0.267) > 0.05, indicating that there is no significant difference between the two classes in the pre-test of the open-mindedness dimension.

Table 4: Paired T-Test of Open-Mindedness Before and After

Paired Sample Test								
	Paired Difference					t	Df	Sig.
	Mean	Std.Deviation	Std. Error of Mean	95% Confidence Interval for the Difference				
				Lower	Upper			
Open-mindedness of control class pre-test - Open-mindedness of experimental class pre-test	-.750	3.938	.568	-1.893	1.394	-1.319	47	.193
Open-mindedness of control class post-test - Open-mindedness of experimental class post-test	-4.521	4.980	.719	-5.967	-3.074	-6.288	47	.000

At the same time, the paired sample t-test analysis of the post-test data of the experimental classand the control class shows that Sig (=0.001) < 0.05, and the mean of the experimental class increased by 2.896 compared to the control class, indicating a significant difference between the two classes. According to the interview with teachers and students, teachers believe that "the Argument mapping empowered by Chat GPT can record multiple viewpoints, which will cause students to think about and analyze different viewpoints." Students believe that "there are more opportunities to think about other people's viewpoints and communicate with others during the learning activity process." Therefore, the results from both qualitative and quantitative aspects indicate that project-based learning activities empowered by Chat GPT and Argument mapping have a positive effect on open-mindedness.

4.1.3. Analysis of the Effect on Analytical Skills

Analytical skills refer to the ability to identify problems, understand the crux with reasons and evidence, and anticipate consequences. The statistical results of the experimental class and the control class in the dimension of analytical skills in critical thinking are shown in Table 5. The paired sample t-test analysis of the pre-test data of the experimental class and the control class shows that Sig (=0.193) > 0.05, indicating that there is no significant difference between the two classes in the dimension of analytical skills.

Table 5: Paired T-Test of Analytical skills before and after

Paired Sample Test								
	Paired Difference					t	Df	Sig.
	Mean	Std.Deviation	Std. Error of Mean	95% Confidence Interval for the Difference				
				Lower	Upper			
Analytical skills of control class pre-test - Analytical skills of experimental class pre-test	-2.354	14.946	2.157	-6.694	1.986	-1.091	47	.281
Analytical skills of control class post-test - Analytical skills of experimental class post-test	-15.229	28.275	4.081	-23.439	-7.019	-3.732	47	.001

The paired sample t-test analysis of the post-test data of the experimental class and the control class shows that Sig (=0.000) < 0.05, and the mean of the experimental class increased by 4.521 compared to the control class, indicating a significant difference between the two classes. The overall results indicate that after the project-based teaching activities empowered by Chat GPT and Argument mapping, students have a positive impact on the dimension of analytical skills. Through separate interviews with teachers and students, teachers believe that "the exercise of analytical skills in the environment of project-based learning based on complex problem situations, Chat GPT empowered Argument mapping have certain help in analyzing data and problems, and their promotion has improved analytical skills." Students believe that "the drawing requirements force us to think more clearly and reasonably during the learning process." Therefore, both quantitative and qualitative results indicate that project-based learning activities empowered by Chat GPT and

Argument mapping have certain effects on learners' analytical skills.

4.1.4. Analysis of the Effect on Systematic Skills

Systematic skills mainly measure the ability to organize and purposefully deal with problems. The statistical results of the experimental class and the control class in the dimension of systematic skills in critical thinking are shown in Table 6. The paired sample t-test analysis of the pre-test data of the experimental class and the control class shows that Sig (=0.288) > 0.05, indicating that there is no significant difference between the two classes in the dimension of systematic skills.

Table 6: Paired T-Test of Systematic Skills before and After

Paired Sample Test								
	Paired Difference					t	Df	Sig.
	Mean	Std.Deviation	Std. Error of Mean	95% Confidence Interval for the Difference				
				Lower	Upper			
Systematic skills of control class pre-test - Systematic skills of experimental class pre-test	-.229	1.477	.213	-.658	.200	-1.075	47	.288
Systematic skills of control class post-test - Systematic skills of experimental class post-test	-2.417	6.273	.905	-4.238	-.595	-2.669	47	.010

At the same time, the paired sample t-test analysis of the post-test data of the experimental class and the control class shows that Sig (=0.010) < 0.05, and the mean of the experimental class increased by 2.417 compared to the control class, indicating a significant difference between the two classes. The overall results indicate that after the project-based teaching activities empowered by Chat GPT and Argument mapping, students have a positive impact on the dimension of systematic skills. In the interview with teachers, it was found that teachers believe that "collaborating in groups and drawing Chat GPT empowered Argument mapping can help clarify goals and solve problems." Therefore, the comprehensive analysis of qualitative and quantitative results shows that project-based learning activities empowered by Chat GPT and Argument mapping have certain effects on systematic skills.

4.1.5. Analysis of the Effect on Critical Thinking Confidence

Critical thinking confidence mainly measures the confidence in one's rational analysis ability. The statistical results of the experimental class and the control class in the dimension of critical thinking confidence are shown in Table 7. The paired sample t-test analysis of the pre-test data of the experimental class and the control class shows that Sig (=0.502) > 0.05, indicating that there is no significant difference between the two classes in the dimension of critical thinking confidence.

At the same time, the paired sample t-test analysis of the post-test data of the experimental class and the control class shows that Sig (=0.117) > 0.05, indicating that there is no significant

difference between the two classes. This indicates that after the project-based teaching activities empowered by Chat GPT and Argument mapping, there is no positive impact on the dimension of critical thinking confidence. Through separate interviews with students and teachers, students believe that "after experiencing project-based learning empowered by Chat GPT and Argument mapping, they do not have much confidence in the accuracy of their own views." Teachers believe that "through classroom observation, project-based learning activities empowered by Chat GPT and Argument mapping should have a positive effect on students' critical thinking confidence. Students are quite loud when expressing their views and can provide reasons, showing more confidence." This study believes that the virtue of modesty may affect students' choices, causing them not to fully express their actual level. Therefore, in this study, from the quantitative data, there is no significant impact, but from the qualitative interview results, there may be certain effects.

Table 7: Paired T-Test of Critical Thinking Confidence before and After

Paired Sample Test								
	Paired Difference					t	Df	Sig.
	Mean	Std.Deviation	Std. Error of Mean	95% Confidence Interval for the Difference				
				Lower	Upper			
Critical thinking confidence of control class pre-test - Critical thinking confidence of experimental class pre-test	-.313	3.197	.461	-1.241	.616	-.677	47	.502
Critical thinking confidence of control class post-test - Critical thinking confidence of experimental class post-test	-.938	4.065	.587	-2.118	.243	-1.598	47	.117

4.1.6. Analysis of the Effect on Curiosity

Curiosity refers to being curious and enthusiastic about knowledge, and trying to learn and understand, even if the practical value of this knowledge is not directly obvious. The statistical results of the experimental class and the control class in the dimension of curiosity in critical thinking are shown in Table 8. The paired sample t-test analysis of the pre-test data of the experimental class and the control class shows that Sig (=0.666) > 0.05, indicating that there is no significant difference between the two classes in the pre-test of the curiosity dimension. At the same time, the paired sample t-test analysis of the post-test data of the experimental class and the control class shows that Sig (=0.091) > 0.05, indicating that there is no significant difference between the two classes from the data.

This indicates that after the project-based teaching activities empowered by Chat GPT and Argument mapping, there is no positive impact on the dimension of curiosity. Through the analysis

of the interview results with teachers and students, it is possible that students are in the high school stage of learning, facing the pressure of thecollege entrance examination, and have always maintained a high level of curiosity. In addition, Chat GPT empowered Argument mapping themselves may not have an impact on curiosity, but are more related to the content of learning, organizational form, teaching methods, and strategies. Secondly, the factors affecting students' individual curiosity are more complex. Therefore, project learning activities empowered by Chat GPT and Argument mapping did not produce a significant impact on curiosity.

Table 8: Paired T-Test of Curiosity Before and After

Paired Sample Test								
	Paired Difference					t	Df	Sig.
	Mean	Std.Deviation	Std. Error of Mean	95% Confidence Interval for the Difference				
				Lower	Upper			
Curiosity of control class pre-test - Curiosity of experimental class pre-test	.250	3.981	.575	-.906	1.406	.435	47	.666
Curiosity of control class post-test - Curiosity of experimental class post-test	-.375	7.142	1.031	-2.449	1.699	-.364	47	.091

4.1.7. Analysis of the Effect on Cognitive Maturity

Cognitive maturity mainly measures whether learners can make judgments prudently or refrain from making judgments or modify existing judgments, be alert to accepting various problem-solving methods, and even in the case of lacking comprehensive knowledge, understand that a temporary decision is sometimes necessary. The pre-and post-test results of the experimental class and the control class in this dimension are shown in Table 9: the paired sample t-test analysis of the pre-test data of the experimental class and the control class shows that Sig (=0.175) > 0.05, indicating that there is no significant difference between the two classes in the dimension of cognitive maturity at the pre-test.

The paired sample t-test analysis of the post-test data of the experimental class and the control class shows that Sig (=0.289) < 0.05, indicating that there is no significant difference between the two classes. Students, after the project-based teaching activities empowered by Chat GPT and Argument mapping, did not have a significant impact on the dimension of cognitive maturity. Through discussions and analyses with teachers and experts, combined with existing literature on cognitive maturity, it is found that there may be two main reasons: "the teaching process lacks effective strategies and methods for cultivating cognitive maturity" and "cognitive maturity itself may require long-term intervention, and short-term education and training cannot bring significant improvement." Therefore, no significant effect was produced.

Table 9: Paired T-Test of Cognitive Maturity before and After

Paired Sample Test								
	Paired Difference					t	Df	Sig.
	Mean	Std.Deviation	Std. Error of Mean	95% Confidence Interval for the Difference				
				Lower	Upper			
Maturity of control class pre-test - Maturity of experimental class pre-test	-.625	3.146	.454	-1.539	.289	-1.376	47	.175
Maturity of control class post-test - Maturity of experimental class post-test	-.937	6.061	.875	-2.698	.823	-1.072	47	.289

4.2. Analysis of the Effect of Project-Based Learning Empowered by Chat GPT and Argument mapping on Learning Engagement

Table 10: Paired T-Test of Learning Engagement before and After

Paired Sample Test								
	Paired Difference					t	Df	Sig.
	Mean	Std.Deviation	Std. Error of Mean	95% Confidence Interval for the Difference				
				Lower	Upper			
Learning engagement of control class pre-test - Learning engagement of experimental class pre-test	-.667	8.866	1.280	-3.241	1.907	-1.521	47	.605
Learning engagement of control class post-test - Learning engagement of experimental class post-test	-3.604	8.759	1.183	-6.147	-1.060	-2.851	47	.006

The pre-test statistical results of learning engagement of the experimental class and the control class show Sig (=0.605) > 0.05, indicating that there is no significant difference between the control class and the experimental class in learning engagement before the experiment, as shown in Table

10.

The paired sample t-test analysis of the post-test data of the experimental class and the control class shows that Sig (=0.006) < 0.05, indicating a significant difference between the two classes in the post-test results, and the mean increased by 3.604, verifying the original hypothesis. The main reasons found through interviews with teachers and students are twofold. First, "the continuous nature of problems in project-based learning activities has a certain effect on maintaining learning engagement," and second, "the task setting in project-based learning activities empowered by Chat GPT and Argument mapping has increased the requirement to draw Argument mapping, which in turn requires more engagement from learners."

4.3. Analysis of the Effect of Project-Based Learning Empowered by Chat GPT and Argument mapping on Learning Interest

The pre-and post-test results of learning interest of the control class and the experimental class are shown in Table 11. The pre-test statistical results of learning interest of the control class and the experimental class show Sig (=0.712) > 0.05, indicating no significant difference between the control class and the experimental class in learning interest before the experiment. The post-test data of the experimental class and the control class were analyzed by independent sample t-test, and the results show that Sig (=0.044) < 0.05, with the mean increasing by 1.958 compared to the control class, indicating a significant difference between the two classes and verifying the original hypothesis that project-based learning activities empowered by Chat GPT and Argument mapping have a positive impact on learners' learning interest.

Table 11: Paired T-Test of Learning Interest before and After

Paired Sample Test								
	Paired Difference					t	Df	Sig.
	Mean	Std.Deviation	Std. Error of Mean	95% Confidence Interval for the Difference				
				Lower	Upper			
Learning interest of control class pre-test - Learning interest of experimental class pre-test	-.271	5.060	.730	-1.740	1.199	-.371	47	.712
Learning interest of control class post-test - Learning interest of experimental class post-test	-1.958	6.552	.946	-3.861	-.056	-2.071	47	.044

The analysis of the interview content with teachers and students found that this interest mainly stems from changes in the environment and tools. The change in the environment is mainly due to the shift from traditional classrooms for teaching chemistry, physics, and biology to computer classrooms, which has increased students' interest; learners are more interested in the application of new learning tools such as Chat GPT empowered Argument mapping. Therefore, the comprehensive analysis of qualitative and quantitative results shows that project-based learning

activities empowered by Chat GPT and Argument mapping have a positive impact on learners' learning interest.

5. Discussion and Conclusions

This study aims to design project-based activities empowered by Chat GPT and Argument mapping and conduct empirical research to verify the feasibility of Chat GPT empowered Argument mapping in classroom teaching. The study adopted the design of experimental and control classes, with the experimental class using Chat GPT empowered Argument mapping for project-based learning activities, while the control class used the same activity framework of project-based learning activities without Chat GPT empowered Argument mapping. The results show that Chat GPT empowered Argument mapping are feasible in classroom teaching and project-based teaching, and have a positive impact on students' learning outcomes in many aspects, as follows.

5.1. Project-based learning empowered by Chat GPT and Argument mapping can have a positive impact on learners' critical thinking

The overall results of critical thinking analysis show that Chat GPT empowered Argument mapping have a significant impact on critical thinking. There is a significant impact on the four dimensions of truth-seeking, open-mindedness, analytical ability, and systematic ability, while the three dimensions of critical thinking confidence, curiosity, and cognitive maturity did not show significant improvement due to certain reasons. Overall, project-based learning empowered by Chat GPT and Argument mapping can have a positive impact on learners' critical thinking, which is consistent with foreign research results on Argument mapping. According to Paul's critical thinking cultivation methods, project-based learning activities empowered by Chat GPT and Argument mapping just meet the opportunity for learners to think. Looking at the activity process, the collaborative learning process supported by Chat GPT empowered Argument mapping requires learners to provide evidence and reasons when they have different views, which may be why the overall effect is more significant.

5.2. Project-based learning empowered by Chat GPT and Argument mapping can have a positive impact on learners' learning engagement

Combining quantitative and qualitative analysis results shows that project-based learning empowered by Chat GPT and Argument mapping has a positive impact on learners' learning engagement. Chat GPT empowered Argument mapping provide students with a clear learning framework and visual support, which can promote learners to actively participate in the learning process. The project-based learning activities empowered by Chat GPT and Argument mapping have a continuous characteristic in problems, and learners themselves will mobilize more engagement in this problem-based and project-based learning process compared to traditional learning activities in order to complete learning tasks. Secondly, the task setting in project-based learning activities empowered by Chat GPT and Argument mapping has increased the requirement to draw Argument mapping, which in turn requires more engagement from learners themselves.

5.3. Project-based learning empowered by Chat GPT and Argument mapping can have a positive impact on learners' learning interest

The analysis of the experimental results shows that project-based learning activities empowered

by Chat GPT and Argument mapping can enhance learners' learning interest. However, through the analysis of the conclusions of the interviews, it is found that the change in interest is mainly caused by the use of new tools such as the environment and Argument mapping. However, it is worth emphasizing that as time changes and learners' freshness for new tools disappears, whether Chat GPT empowered Argument mapping still have the effect of enhancing learning interest cannot be effectively confirmed by the conclusions of this experiment.

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