ABSTRACT

This quantitative, quasi-experimental study aimed to propose research-based AI constructivist learning activities by measuring students' self-perceptions of their critical thinking using the Motivational Strategies and Learning Questionnaire (MSLQ). The study utilized the input–experience–output framework to evaluate how these learning pursuits affected students' self-perceptions of their critical thinking, motivational orientation, and learning strategies. In the past, instructors implemented constructivist learning activities to develop their students' critical thinking. Lately, students have become interested in using AI tools, which are now prevalent on college campuses. This prevalence has resulted in very limited research-based constructivist learning activities using AI to guide instructors to enhance their curricula to prepare students for future careers. The researcher surveyed first-year college students to determine whether learners who engaged in constructivist learning activities using AI scored higher on their self-perceptions of motivational orientation and learning strategies than those who did not. With reference to the research question, the results indicated that students who participated in constructivist learning activities with AI exhibited better self-perceptions of their motivational orientation and learning strategies. Therefore, this study suggested several constructivist learning activities that use AI for instructors to help students improve their critical thinking. Simultaneously, the study concluded that these lessons engage students, make learning user-friendly, and encourage students to take ownership of their learning.

Keywords: artificial intelligence; constructivist instruction; critical thinking; motivational strategies; learning strategies

TEACHING CRITICAL THINKING IN THE AGE OF ARTIFICIAL INTELLIGENCE

by

Peter Pavlis

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Submitted in Partial Fulfillment
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Teaching Critical Thinking in the Age of Artificial Intelligence

We, the Dissertation Committee, certify that we have read this dissertation and that, in our judgment, it is fully adequate in scope and quality as a dissertation for the degree of Doctor of Education in Higher Education.

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DEDICATION

To my past students, whose curiosity and dedication inspire me every day, thank you for the moments of shared discovery. The greatest reward has been witnessing your “aha!” moments. You challenged me to think differently, explore new perspectives and constantly refine my own understanding.

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Table of Contents

Contents

List of Tables

List of Figures

Chapter 1: Introduction

"I cannot teach anybody anything; I can only make them think."

Socrates

Most of today's students, with proper guidance and support, can develop their critical thinking skills, which are crucial for success in today's world (Beyer, 2001; Bitzenbauer, 2023; Nold, 2017; Paul, 1989; Tiruneh et al., 2014). Spector and Ma (2019) defined critical thinking as an experience in which individuals investigate a problem through inquiry, examine evidence, explore alternatives, engage in argumentation, test conclusions, rethink assumptions, and reflect on the entire process. Critical thinking helps individuals succeed in the workforce because this skill enables them to seek out the truth at a time when false information is abundant (Ku & Au, 2021). In addition to seeking out the truth, critical thinkers possess characteristics that future employers actively look for, such as being outcome-driven, open to new ideas, flexible, willing to change, innovative, creative, analytical, effective communicators, assertive, persistent, caring, energetic, risk-takers, observant, and "out of the box" thinkers (Mahdi et al., 2020). In a technology-driven world, these characteristics play a crucial role in achieving success in the workforce since technology handles the work while humans engage in the thinking behind it (Albert, 2021; Arisoy & Aybeck, 2021; Roohr et al., 2019). Critical thinking is a valuable asset enabling individuals to flourish in the workplace as technology enhances their higher-order thinking, making it a vital skill to teach students.

Critical thinking is worth teaching, as Spector and Ma (2019) highlighted, because a gap exists between the importance of higher-order thinking in academia and students' ability to engage in it. Kenedy (2024) pointed out that a significant proportion of secondary school and college students struggle to engage effectively in critical thinking skills necessary for success in life. Schools can help bridge this gap by creating a constructivist learning environment that uses artificial intelligence (AI) tools to support these cognitive skills. Such a constructivist learning environment can allow students to construct their own understanding based on their prior knowledge within an appropriate learning context (Makewa, 2019). It can serve as a practical and effective approach to teaching rather than offer a mere theoretical concept.

A meaningful education should offer various activities and resources for students to build their own knowledge. Albert (2021) emphasized that simply using textbooks is not enough to support students in developing these skills, as textbooks limit students to the authors' viewpoints. Classroom activities, such as small group and class discussions, should expose students to diverse perspectives. Ultimately, students need to engage in a constructivist learning environment where they actively gather information from different sources, analyze it, evaluate it, and transform it into their own knowledge (Rasul et al., 2023). To foster critical thinking in the classroom, students require appropriate resources and a supportive, active environment conducive to constructing their own knowledge.

Instructors play a crucial role in education by creating learning experiences that go beyond cognitive routine tasks. They need to establish learning environments that extend past mere knowledge transmission (Pedro et al., 2019). By implementing constructivist classroom learning experiences, instructors help cultivate their students' critical thinking skills. Courses that incorporate instructional programs focused on critical thinking have been demonstrated to positively influence students' abilities to think judiciously (Albert, 2021; Lumpkin et al., 2015; Nold, 2017; Rasul et al., 2023; Spector & Ma, 2019; Wright, 2011). Educators must fully understand how to teach critical thinking and develop strategies to effectively transmit this complex cognitive process (Paul, 1989; Soufi & See, 2019; Tanka, 2014). To create these strategies, Paul (1989) and Tanka (2014) emphasized the importance of understanding five fundamental assumptions about critical thinking and its instruction:

1. Students, like all people, tend to reason for their own benefit.
2. Teachers must bring the analysis and the synthesis of solutions for real-life problems back into the classroom.
3. Schools impose preexisting thoughts on students and fail to support them in developing their own thoughts.
4. All teachers need to teach children using dialogue and logic.
5. Teachers need to implement instructional strategies to allow students to develop their own self-reasoned thoughts and beliefs (Paul, 1989, pp. 200–209).

Paul (1989) and Soufi and See (2019) argued that educational institutions must first analyze the obstacles that hinder critical thinking development before developing a teaching strategy to help students become independent and detailed thinkers. These obstacles include:

- The denial of educators regarding the need to shape fair-mindedness in the students.
- The need to understand the difference between logical thinking (to consider many viewpoints) and technical thinking (based on one viewpoint).
- The need to teach our children pre-existing thoughts.

Paul (1989) and Duron et al. (2006) argued that instructors should develop long-term strategies to help students think logically as well as open their minds based on these assumptions and the analysis of the obstacles involved.

Many higher education institutions have attempted to address the deficit in critical thinking instruction from K–12 schools by making critical thinking their primary goal (Halpern, 2001; Liu et al., 2014; Nold, 2017) to help students succeed in their future careers. Despite this increased emphasis, college graduates often lack the higher-order thinking skills necessary to solve important academic and everyday life problems (Kouzov, 2019; Nold, 2017; Rasul et al., 2023). This inadequacy stems from college instructors not fully understanding how to effectively teach and incorporate higher-order thinking skills into their curriculum (Mahdi et al., 2020; Paul & Elder, 2005; Roohr et al., 2019). While college instructors are encouraged to integrate higher-order thinking skills into their courses, they continue to rely on lecturing as their primary instructional strategy (Lynch & Pappas, 2017; Nold, 2017; Rasul et al., 2023). Instructors expect students to analyze complex concepts without providing guidance on how to do so (Albert, 2021). The challenge arises from instructors receiving limited professional training on the instructional techniques that best promote students' highest level of critical thinking.

Implementing assistance from the growing field of generative AI, such as large language models (LLMs), can provide strategies to improve students' critical thinking (Spector & Ma, 2019). In today's world, individuals are flooded with information, and it has become vital for people to have a flexible filter of relevant knowledge. This filtering process consists of individuals using rational judgment, adaptive logic, and critical thinking to know what is important (Kouzov, 2019). To achieve this valuable goal, instructors need not oppose generative AI but must try to understand the positives that can be gleaned from the capabilities of its tools (Kouzov, 2019). The positives of AI must complement human intelligence.

AI tools, especially LLMs, have recently made significant advancements in natural language processing (NLP). These models are trained on massive amounts of text data and logical thinking patterns or rules. These models can generate human-like text, answer questions, and accurately complete other language-related tasks (Bitzenbauer, 2023; Crawford et al., 2023; Fuchs, 2023; Kasceni et al., 2023). Crawford et al. (2023) described how this technology achieves these accurate language tasks by using a given prompt and its pre-trained, huge database to string together words through logical, complicated thinking patterns, similar to neural pathways in a human brain, to create a novel and reasonable answer. However, each time the prompt is used, the LLM produces a different output because it uses different thinking patterns. This technology has the potential to change the way one learns, the way one teaches, and the way one accesses information (Betz et al., 2020; Kong et al., 2021; Kouzov, 2019). Within its first five days of launch in November 2022, ChatGPT attracted over one million users (Clark et.al, 2024) and garnered more than 100 million monthly visits by January 2023 (Ayo-Ajibola et al., 2024). The exponential growth of AI technology will significantly impact education, as it has potential uses in learning and teaching. AI technology is too irresistible and cheap not to make its way into the hands of students (Schatten, 2022). As with any technology, students must know how to achieve the best results from AI.

However, students may no longer be construct their own knowledge when completing their writing assessments if they misuse the technology (Rasul et al., 2023). Maintaining academic integrity becomes a significant challenge for instructors when writing academic assessments that integrate AI (Crawford et al., 2023; Halaweh, 2023; Kasceni et al., 2023; Rasul et al., 2023). The misuse of LLMs to create content instantly as a shortcut goes against the philosophy of learning. Such AI outputs could negatively impact students' critical thinking if students have too much confidence in AI and use it without reviewing its outputs (Kasceni et al., 2023; Lee et al., 2025). This misuse of this disruptive technology concerns instructors and university staff because of its adverse impacts on student learning (Bitzenbauer, 2023; Crawford et al., 2023; Fuchs, 2023; Halaweh, 2023; Kasceni et al., 2023; McMurtrie, 2022; Rasul et al., 2023; Rudolph et al., 2023; Sullivan et al., 2023; Zhai, 2022). The concern about the misuse of AI can lead to incorrectly assessing student learning.

Student learning outcomes need to involve the development of critical thinking and the ability to problem-solve. If students do not cultivate their critical thinking by directly misusing information from LLMs, they will be misjudged in their learning outcomes (Rasul et al., 2023). When students are incorrectly assessed on the outcomes, it may diminish the academic institution's reputation and lead employers to avoid hiring students from these institutions (Crawford et al., 2023). Ultimately, without instructors developing students' critical thinking, higher education institutions lose their purpose of preparing their students for the workforce.

As LLMs become increasingly prevalent in the workplace, graduates must be equipped with the necessary knowledge and skills to navigate these technologies effectively. Students need to use their higher-order thinking to evaluate outputs from LLMs (Rasul et al., 2023). Instructors need to integrate LLMs into their curriculum and create activities that will cultivate students' critical thinking (Crawford et al., 2023). These creative instructional activities will allow students to learn the proper use of AI tools.

Statement of the Problem

The problem this study addressed is that AI technology interests many college students because of its potential to enhance their learning (Kasceni et al., 2023), yet many instructors fail to use it to enhance students' critical thinking skills. When instructors do not promote critical thinking while using AI, they create challenges for their students' future careers (Bitzenbauer, 2023; Crawford et al., 2023; Fuchs, 2023; Kasceni et al., 2023; McMurtrie, 2022; Rasul et al., 2023; Spector & Ma, 2019). The issue is that instructors lack research-based constructivist instructional lesson activities that effectively use AI tools to improve students' critical thinking (Rasul et al., 2023; Ruiz-Rojas et al., 2024; Sullivan et al., 2023).

With the rise of AI, students need to be critical thinkers to evaluate the ever-increasing amount of information from mass media, the Internet, and AI-generated documents (Kenedy, 2024). Today, more editorialized documents exist than investigative or fact-driven ones (Kenedy, 2024). Student learning experiences need to aid them in learning to reflect and be open-minded when analyzing the information in such documents. Instead, college learning experiences have become about students getting their work done rather than about challenging them to use their critical thinking and be engaged learners (McMurtrie, 2022). This lack of engaged learning might lead students to cheat because the value of their educational work is irrelevant. When students do not see the relevancy of their education, they can use the available AI resources inappropriately. In 2015, 60% of students admitted to cheating on their exams (McMurtrie, 2022). Likewise, instructors are divided regarding the role AI should have in education. Some believe AI will make schools irrelevant, while others believe it will become a helpful tool for students and educators. It can assist instructors in prioritizing students' creativity and critical thinking to solve the diverse problems the world faces today. Nevertheless, instructors are challenged to figure out how they can use this technology to develop students' critical thinking skills (Kenedy, 2024). Therefore, instructors need tools to engage their students in active learning.

Roksa and Arum (2011) presented additional evidence explaining why students struggle to apply critical thinking when using AI. They found that 45% of college students made it through college without measurable gains in critical thinking, analytical reasoning, and writing skills, as assessed by the Collegiate Learning Assessment (CLA). Students in their sample reported studying only 12 hours a week. Additionally, the study showed that 25% of the students took courses that required about 40 pages of reading and approximately 20 pages of writing each week. These results indicated that students were missing opportunities for active learning and, consequently, were not enhancing their critical thinking skills (Lumpkin et al., 2015). Instructors face the challenge of creating learning environments that will foster the development of their students' critical thinking.

Students encounter courses that focus heavily on content rather than ones that foster critical thinking about the subject matter. They must absorb large volumes of knowledge without developing the critical thinking skills necessary to analyze and evaluate what they learn (Kenedy, 2024). Many college instructors claim to aim to teach students critical thinking indirectly, yet they often lack the knowledge to effectively develop these skills in their students (Albert, 2021; Kenedy, 2024; Mahdi et al., 2020; Nold, 2017; Wright, 2011). Nold (2017) stated that in a sample of college instructors, 89% identified critical thinking as a primary objective, but only 9% assigned class tasks designed to promote critical thinking on a typical day. Additionally, Kenedy (2024) reported that while 81% of instructors believed their graduates attained higher-order thinking, only 20% indicated that their departments shared a unified approach to teaching critical thinking. Consequently, teaching emphasizes "what to think" over "how to think."

Spector and Ma (2019) highlighted that many secondary and college students struggle to use critical thinking effectively for their future pursuits. Evens et al. (2013) reported that during their first year of post-secondary education, many students show only a marginal increase in critical thinking, despite higher education institutions emphasizing this as a major goal. Kenedy (2024) also noted that undergraduates often do not significantly enhance their higher-order thinking skills and frequently graduate with the same cognitive abilities they had at the start of their first year. Furthermore, Kenedy (2024) argued that critical thinking should play a crucial role in students' post-secondary experiences and contribute to their lifelong learning.

Employers have recognized this deficiency in their new employees (Kenedy, 2024). A survey showed that 81% of employers expressed a desire for a stronger emphasis on developing critical thinking skills in new hires (Lui et al., 2014). For instance, Vanguard, an investment services firm, places a significant emphasis on its AI tools to generate financial plans for its clients and provide goal-based forecasting in real-time. The company accentuates that its financial advisers utilize critical thinking while explaining investment goals to clients, customizing implementation plans, and monitoring spending to promote accountability. Teaching critical thinking becomes essential for students as it supports their career development and pursuit of lifelong learning.

Purpose of the Study

This study aimed to provide statistical evidence to show that students who engage in constructivist lesson activities using AI tools perceive their self-attributes regarding motivational and learning strategies significantly better than students who do not participate in such activities. This suggests that such lesson activities enhance students' critical thinking skills, and thus signal suggested lessons for instructors. As students go through social learning experiences, AI technology offers relevant learning material and other necessary tools for students to construct their knowledge (Bada, 2015; Rasul et al., 2023; Ruiz-Rojas et al., 2024).

Integrating technology has become essential for enhancing the higher education learning experience because it engages students and prepares them for the 21st-century workforce (Ruiz-Rojas et al., 2024). Technology equips students with tools that facilitate communication, teamwork, and problem-solving skills. Specifically, the ethical considerations of AI present unique learning opportunities that can transform instructional strategies (Ruiz-Rojas et al., 2024). Rasul et al. (2023) highlighted that AI tools foster constructive learning experiences by using logical algorithms to access knowledge and information stored in their data sets, allowing students to construct new knowledge. This capability benefits students by scaffolding their knowledge-building process. Additionally, AI tools actively engage learners in conversation, encouraging them to participate in and take ownership of their learning experiences (Chaparro-Banegas et al., 2024; Rasul et al., 2023). According to Rasul et al. (2023), AI tools, such as LLMs, provide students with various benefits while they navigate such constructivist learning experiences:

- Individualized feedback by LLMs can assist students in constructing their own knowledge by detecting errors and guiding them toward improvement.
- Incorporating LLMs can help students apply knowledge to help them solve real-world problems
- LLMs can provide students with personalized learning experiences at any time to help them clarify concepts being learned in the course.

However, instructors must understand the challenges of using LLMs in education. First, they may employ material that is plagiarized. Second, they may utilize biased information. Finally, students might rely too heavily on these models (Kasceni et al., 2023). In this quest for knowledge, the winning strategy involves not opposing AI but using it cautiously to complement human intelligence (Kouzov, 2019).

The process of teaching students how to properly use AI and integrating it into their learning experiences is still in its early stages. The appropriate use of AI is emerging as one of the essential skills students need to excel in their future careers. AI literacy involves the ability to use AI judiciously and practice ethical approaches to AI (Ng et al., 2021). Furthermore, developing competency in AI literacy strengthens students' social responsibility and enables them to use AI for the benefit of society (Ng et al., 2021). By becoming AI literate, students improve their learning, boost their success in the workplace, and, most importantly, contribute positively to society.

Empirical evidence shows that constructivist learning improves critical thinking (Bada, 2015). Additional evidence has demonstrated that students who use AI in their learning experiences produce higher-quality work (Huang et al., 2024). Finally, Ruiz-Rojas et al. (2024) provided evidence that integrating generative AI tools in higher education impacts students' critical thinking development and positively promotes collaboration among university students. However, this researcher found little evidence documenting the use of constructivist learning experiences while implementing AI tools in the classroom to improve students' critical thinking (Ruiz-Rojas et al., 2024; Southworth et al., 2023). Therefore, this research study sought to explore this topic.

Research Question

RQ1. Is there a statistically significant difference between the mean scores of students' self-perceptions of their motivational and learning attributes between students who participated in a course with constructivist learning activities using AI and the mean scores of students' self-perceptions among those who did not receive this instruction?

Hypotheses

$H1_0$. There is no significant difference between the mean scores of students' self-perceptions of their motivational and learning attributes across both groups of students.

$H1_a$. The mean scores of students' self-perceptions of their motivational and learning attributes will be higher for students who participated in a course with constructivist learning activities using AI than for those who did not.

Limitations and Delimitations

One limitation of this study was the number of constructivist learning activities that the instructor implemented during the semester using AI. A limited number of these learning experiences may not have significantly impacted the students' motivation and learning perceptions. Another limitation arose from the number of constructivist learning activities with AI the students had encountered from other instructors in their courses. If students had participated in these types of learning experiences elsewhere, the difference in their motivation and learning perceptions may have been minimal. A third limitation was that incorporating other instructional strategies into the course could also have influenced students' motivation and learning strategies. The final limitation was the extent of experience students had using AI to complete their coursework. This study focused on African-American first-year students enrolled in classes at a historically Black university and compared students from only one type of institution in a suburban region of the Northeastern United States, rather than examining several regions across the country, which was a delimitation.

Researcher Assumptions

The researcher assumed that the students had the same amount of experience with learning using constructivist learning strategies. They also assumed that all students were motivated to learn and would properly use AI tools during the course. Additionally, the study relied on the assumption that students would answer the questions on the survey truthfully.

Finally, it assumed that the instructor would properly implement constructivist learning activities.

Key Terms

Artificial intelligence (AI). A broad field that entails techniques and approaches to create intelligent machines that perceive their environment and take action (Gimpel et al., 2023).

Artificial intelligence literacy. The ability to understand, use, evaluate, and ethically navigate AI (Southworth et al., 2023).

Constructivist learning. When students construct their knowledge from prior knowledge and knowledge learned in an appropriate learning environment (Bada, 2015).

Generative artificial intelligence. A machine that uses computational techniques to generate seemingly new meaningful content, such as text, images, or audio, from training data (Feuerriegel et al., 2024).

Learning strategies. Cover students' ability to learn by using rehearsal, elaboration, organization, and metacognitive self-regulation (Johnson, 1991).

Motivational strategies. Cover students' ability to develop intrinsic motivation, assign positive task values to assignments, and improve their self-efficacy for learning (Johnson et al., 1991).

Summary

Instructors face the challenge of teaching students to critically assess AI outputs due to the increased use of AI among learners. However, many instructors lack effective strategies to guide students in utilizing AI tools while enhancing their critical thinking skills. To support their students, instructors must implement instructional strategies that provide opportunities for critical thinking practice by: 1) integrating relevant research problems into their lessons,

2) encouraging students to enhance their prior knowledge using technology, and 3) facilitating experiences that allow students to construct their understanding of concepts in a social and supportive environment. Critical thinking involves the ability to analyze information, draw conclusions, and ultimately create one's own understanding of the concepts being taught. Additionally, critical thinking attributes include being caring, creative, resourceful, and thinking outside the box. To adequately prepare students for their future careers, instructors must offer these essential learning experiences. While AI can perform certain tasks, students need to develop the skills to critically analyze its outputs. Furthermore, students learn best in social situations, thriving on caring, supportive interactions with their instructors and peers. If students experience limited interactions, they will have fewer opportunities to improve their critical thinking using AI tools. Thus, the researcher in this study aimed to suggest research-based constructivist learning activities involving AI that instructors can use to enhance their students' critical thinking skills.

Chapter 2: Literature Review

Introduction

Many college students are interested in LLMs because of their potential to enhance learning (Kasceni et al., 2023), yet many instructors fail to promote their students' critical thinking skills when using AI. When instructors neglect to encourage critical thinking while using AI, they create challenges for their students' future careers (Bitzenbauer, 2023; Crawford et al., 2023; Fuchs, 2023; Kasceni et al., 2023; McMurtrie, 2022; Rasul et al., 2023; Spector & Ma, 2019). One effective approach is constructivism, which helps instructors foster critical thinking by guiding students to integrate new information with their prior knowledge (Bada, 2015). However, instructors often struggle to find research-based constructivist instructional activities that effectively incorporate AI tools to improve students' critical thinking (Rasul et al., 2023; Ruiz-Rojas et al., 2024; Sullivan et al., 2023).

Along with the principles of constructivism, this literature review actively explores critical thinking and how individuals use cognitive skills to shape their identity (Fahim & Masouleh, 2012). It also examines the dispositions and motivational influences behind critical thinking, emphasizing that this involves not just having the skills but also being inclined to exert mental effort (Fahim & Masouleh, 2012). Instructors must teach critical thinking because it is a learned ability, and they must do so by utilizing positive reinforcements (Fahim & Masouleh, 2012). Additionally, the researcher addresses the concept of AI and its implications for the field of education, highlighting the opportunities and challenges instructors face when integrating generative AI technology. While AI offers students personalized learning experiences and aids in research, it also poses challenges, such as biased outputs and the potential for learners to rely too heavily on technology. Finally, the review presents the I–E–O (input–experience–output) model as a conceptual framework for analyzing the growth of critical thinking abilities in college students (Astin, 1993).

What is Critical Thinking?

Instructors often focus more on content than on teaching students to analyze and evaluate information, which results in a lack of critical thinking in their courses (Kenedy, 2024). One reason for this may be that students feel satisfied with their superficial learning. When asked to explain information, analyze text, or defend their position, they struggle to provide evidence to support their claims (Fahim & Masouleh, 2012). Additionally, instructors may struggle to define critical thinking (Kenedy, 2024).

According to Petress, Scriven and Paul state that "critical thinking involves an intellectually disciplined process where individuals actively and skillfully conceptualize, apply, analyze, synthesize and evaluate information gathered from or generated by observing, experiencing, reflecting, reasoning or communicating, guiding their beliefs and actions" (Petress, 2004, p. 3). Moreover, critical thinking requires that individuals are aware of their thought processes, which is often referred to as *reflective thinking*. Paul and Elder (2012) asserted that reflective thinking represents the highest form of cognitive processing, as individuals must reason to ensure that their thoughts remain clear, accurate, logical, and fair. Kenedy (2024) and Santos (2017) described critical thinking as an active yet sequential mental process that helps individuals comprehend events, situations, and theories in their surroundings as well as within themselves. This type of thinking incorporates personal perspectives and those of others with whom a person interacts. It includes developing justified reasons according to intellectual standards like accuracy, clarity, and significance (Paul & Elder, 2012). Engaging in actions such as analyzing, reasoning, self-correcting, reflecting, and interacting with others enhances the intricate, ambiguous nature of critical thinking.

Domains of Critical Thinking

Defining critical thinking presents challenges because scholars from the fields of philosophy, cognitive psychology, and education all take varied approaches (Fahim & Masouleh, 2012; Sternberg, 1986; Swanwick et al., 2014). Philosophers emphasize the ideal of thinking, cognitive psychologists investigate the underlying brain processes, and educators focus on individual learning experiences. By examining the perspectives of theorists in these disciplines and recognizing the limitations in their approaches, our understanding of critical thinking can be enhanced.

Philosophical Domain

The writings of Plato and Aristotle illustrate the philosophical approach to critical thinking (Fahim & Masouleh, 2012; Sternberg, 1986). In recent years, Richard Paul and Sharon Bailin have made significant contributions to this perspective (Fahim & Masouleh, 2012; Santos, 2017; Sternberg, 1986). This approach emphasizes hypothetical thinking and focuses on the characteristics of a critical thinker rather than on the specific behaviors or actions they might exhibit (Fahim & Masouleh, 2012; Kenedy, 2024; Sternberg, 1986). Critical thinkers closely tie their work to reflection and structured formal logic, which encompasses the interpretation and communication of knowledge (Swanwick et al., 2014). They maintain an attitude of openness, thoughtfulness, and persistence in pursuing inquiry (Paul & Elder, 2012; Sternberg, 1986; Swanwick et al., 2014). Paul (1989) defined critical thinking as “the art of thinking about your thinking while you are thinking, so as to make your thinking more clear, precise, accurate, relevant, consistent, and fair” (p. 200). This definition underscores the essential qualities of effective thinking, highlighting that disciplined thought processes must serve the interests of others, which makes the critical thinker fair-minded. Bailin et al. (1999) argued that "good creative thinking would also be considered critical thinking because it requires exercising sound judgment to compose great poetry, analyze scientific findings, or produce artistic works" (p. 288). Through robust critical thinking, individuals cultivate vital traits such as humility, integrity, and confidence in reasoning (Paul, 1989). This philosophical approach encompasses logical reasoning, reflective thought, as well as self-correction, positing that logical thinking nurtures positive character traits and contributes constructively to society.

Instructors must understand that students need to learn the rules of formal logical thinking, as this type of thinking is not innate. Additionally, instructors should exemplify the qualities of sound, effective thinking and emphasize the importance of ensuring that their students' thoughts meet the standards of accuracy (Fahim & Masouleh, 2012). Teachers can teach these two focuses of the philosophical approach through engaging learning experiences in the classroom.

The philosophical approach, characterized by effective thinking that can positively impact society, has its limitations. First, individuals must spend time developing this type of good thinking; it is not innate but rather a skill that they need to learn (Sternberg, 1986). Another limitation of this approach is its focus on ideal thinking rather than on addressing situations where people must deliberate under constraints such as limited time, information, and motivation (Sternberg, 1986). As a result, the high principles associated with ideal thinking present certain challenges.

Cognitive Psychological Domain

Cognitive psychologists offer a second approach to defining critical thinking. This approach emphasizes how individuals think in real-world situations rather than how they should think under ideal conditions (Fahim & Masouleh, 2012; Sternberg, 1986). Cognitive psychologists develop their theories based on experimental data (Sternberg, 1986) and define critical thinking by the actions critical thinkers exhibit (Sternberg, 1986).

Cognitive psychologists view critical thinking as purposeful, reasoned, and goal-directed. They emphasize its role in solving problems, formulating inferences, assessing probabilities, and making decisions using practical skills tailored to specific tasks (Ennis, 1989). West et al. (2008) defined critical thinking as “the use of those cognitive skills or strategies that increase the probability of a desirable outcome” (p. 931). Cognitive psychologists identify different cognitive skills (Fahim & Masouleh, 2012) and examine how these skills interact. For instance, West et al. (2008) illustrated that the ability to reason logically can be influenced when logic conflicts with prior knowledge. These psychologists investigate specific cognitive skills in various environmental situations.

Halpern (2003) defined critical thinking by emphasizing both strategies and outcomes. Halpern’s (2003) model illustrates how critical thinking processes lead to positive results. It starts when an environmental stimulus reaches the brain. Depending on the nature of this stimulus, and supported by critical thinking attributes, the brain determines whether critical thinking is necessary (Facione, 2020). If the stimulus signals a need for critical thinking, the brain initiates one of the following strategies: verbal reasoning, argument analysis, hypothesis testing, decision-making, or problem-solving techniques. The appropriate strategy is applied, and metacognitive monitoring evaluates whether the outcome is satisfactory. If the conclusion proves unsuitable, the thought process shifts to applying a different strategy until the results meet the desired outcome (Halpern, 2003).

The cognitive psychological approach has several limitations. One of the most significant limitations is that cognitive theorists primarily base their theories and models on data gathered from experimental subjects in controlled laboratory settings rather than in real-world, everyday situations (Sternberg, 1986). Additionally, because these approaches rely on experimental data, the resulting explanations may oversimplify the complexities involved (Sternberg, 1986). Critical thinking involves numerous complex processes that interact within an individual's mind, yielding unique and positive outcomes. No single model can capture its full scope.

Educational Domain

Developing and teaching critical thinking has become a crucial objective within the educational sphere because students today frequently fail to recognize the integral role of thinking in their learning. This deficiency can lead to challenges later in their adult lives (Beyer, 2001; Halpern, 2001; Kenedy, 2024; Tiruneh et al., 2013). Many educators find it difficult to teach critical thinking effectively because they lack reliable assessment methods to measure its development in students and to identify which instructional strategies best foster these higher-order thinking skills (Beyer, 2001; Halpern, 2001; Tiruneh et al., 2013).

Halpern (2001) presented several methods for assessing how students grow in their critical thinking skills. First, many critical thinking courses have undergone comprehensive formal evaluations to determine their effectiveness in enhancing higher-order thinking. Second, students can report their own progress in critical thinking by answering questions about their abilities to assess conflicting claims, suspend judgment, and employ problem-solving strategies. Third, research shows that students improve their IQ scores after receiving critical thinking instruction. Finally, students demonstrate the immediate application of critical thinking skills to real-life situations once they complete their instruction (Halpern, 2001). Additionally, Craig et al. (2020) emphasized the strong correlation between metacognitive skills and academic achievement, noting that students can assess their improvements in metacognition through self-reports, as metacognitive skills are not directly observable.

Beyer (2001) presented compelling evidence for effective critical thinking instruction through his three-phase framework. In the initial phase, instructors demonstrate the skill and encourage students to share their successful experiences with it. In the next phase, instructors provide ample practice opportunities and targeted feedback. Finally, instructors illustrate how students can transfer specific thinking skills to different contexts (Beyer, 2001).

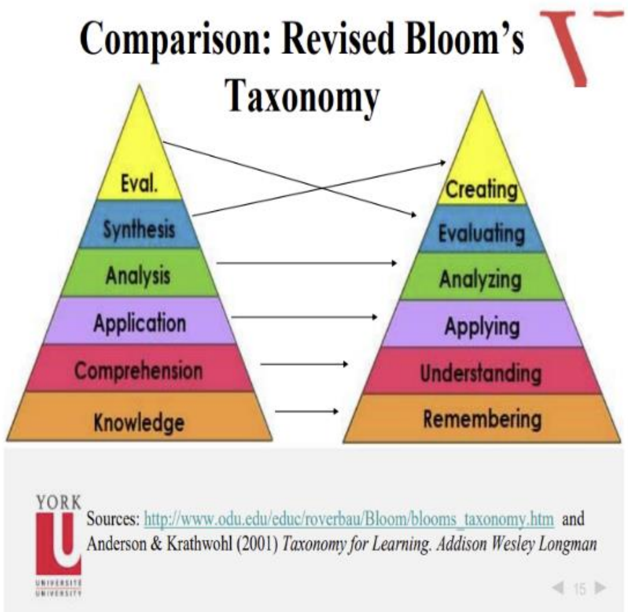
Educators must actively provide students with instruction on thinking skills and activities to help them practice these cognitive abilities continuously. According to bell hooks (2010), critical thinking involves "discovering the who, what, when, where, and how of things—finding the answers to those eternal questions of the inquisitive child—and then utilizing that knowledge in a manner that enables the thinker to determine what matters most" (p. 10). Classrooms should be rich in experiences that allow students to discover answers, analyze recent educational research studies, and explain the vital role of inquiry in student learning (Lumpkin et al., 2015; Lynch & Pappas, 2017). These experiences should be engaging so students are inclined to use them to develop the ability to analyze and evaluate information to allow them to integrate this information with what they already know.

Educators use Bloom's taxonomy as a highly regarded framework to implement critical thinking activities in the classroom. This framework delineates six stages of increasing cognitive complexity, which educators can integrate into their curriculum (Duron et al., 2006; Fahim &

Masouleh, 2012; Sternberg, 1986). Since its original development in 1956, scholars have made significant updates to Bloom's taxonomy. The 2001 revision clarifies how various levels of cognitive thinking interact with knowledge and provides instructors with enhanced guidance (Wilson, 2016). According to Kenedy (2024), Anderson and Krathwohl elevated "creating" to the highest order of thinking, placing it above "evaluating." They also reformulated the levels of cognitive processes to emphasize action. For example, in the revised taxonomy, they switched *analysis* to the action verb of *analyzing* (see Figure 1).

Figure 1

Comparison of Bloom's Taxonomy and the 2001 Revised Model

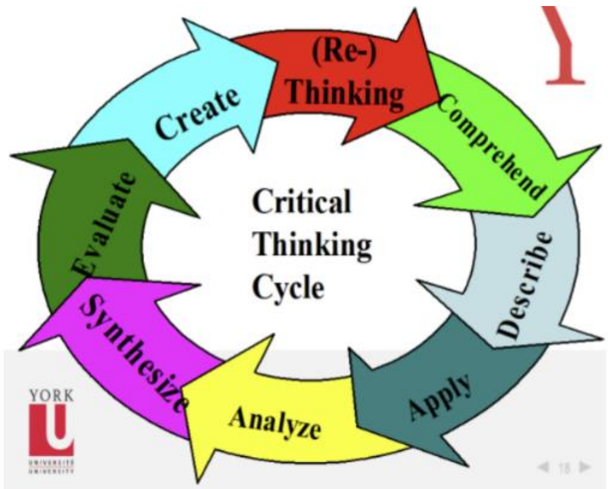


Source: Kenedy (2024, p. 28).

Kenedy's (2024) model of cyclical critical thinking actively builds on Bloom's taxonomy to produce knowledge at its highest form of thinking. As learners engage in this sequential process of cognitive tasks, they become active participants who navigate various levels of thinking while examining different types of information to generate new ideas based on original concepts. In the cycle's initial phase, students grasp the fundamental aspects of a concept. In the second phase, they describe or explain the concept in greater detail. Moving into the third phase, they apply the idea to different contexts (see Figure 2).

Figure 2

Kenedy's (2024, p. 31) Model of Cyclical Critical Thinking



Students thus progress into the higher-order thinking phase, where they analyze concepts and articulate them in their own words. During the synthesis stage, they compare and contrast various pieces of information to generate new ideas related to the original concept. Next, they evaluate these new ideas, which may lead to a fresh perspective on the model. In the *rethinking* phase, students think "outside the box" and develop new paradigms based on their ideas (see Figure 2).

This cyclical process encourages them to reassess their understanding and transcend established notions (Kenedy, 2024). For instance, we can view Kenedy's (2024) model as a new paradigm of Bloom's original taxonomy, offering deeper insights into critical thinking. This cycle illustrates how students continually rethink information to create, evaluate, and develop new models (Kenedy, 2024). Kenedy (2024) explained that students can apply this cyclical model when writing research papers. As they create their research papers, they can incorporate ideas they are learning into their understanding. While rethinking the information for their papers, they may constantly question the accuracy and completeness of the information they use, including data from AI outputs. They must ensure that their thoughts are clear for the reader. These elements are part of the rethinking stage to demonstrate how critical thinking fosters persistent, purposeful, and goal-directed dispositions as students pursue new notions.

Constructivists believe that learning is influenced by all three domains of thought (Bada, 2015). First, the philosophical domain explains the importance of the learning environment where constructivist learning experiences unfold because it directly affects what students learn. Additionally, these constructivist experiences shape the learner's attitudes and beliefs (Bada, 2015). Secondly, Bada (2015) argued that constructivist belief is a cognitive theory that explains how individuals learn. Finally, because it influences how students learn, it plays a crucial role in the educational domain (Bada, 2015). Constructivism involves students constantly rethinking their mental notions. As students actively use their critical thinking to fit new ideas with their prior knowledge, they engage in the constructivist learning process. Instructors need to recognize the importance of its role in student learning.

Dispositions for Critical Thinking

Critical thinking embodies purposeful thinking, where individuals systematically and consistently apply intellectual standards to their reasoning. A critical thinker actively seeks the truth instead of fabricating it by posing trivial questions (Duron et al., 2006). When engaging in critical thought, individuals can discern falsehoods when confronted with conflicting statements. They maintain an awareness of their own inherent biases. Furthermore, critical thinkers understand that their beliefs can have significant, everyday repercussions (Saulius & Malinauskas, 2021). However, critical thinking encompasses much more.

Besides engaging in purposeful thinking, researchers have identified certain dispositions that enhance an individual's capacity for critical thinking (Bailin et al., 1999; Berzins & Soto, 2008; Elder & Paul, 1996; Ennis, 1989; Facione, 2020; Grussendorf & Rogol, 2018; Halpern, 2003; Lui et al., 2014; Mahdi et al., 2020; Paul et al., 1997; Roohr & Burkander, 2020). Positive attributes that contribute to critical thinking include being inquisitive, organized, analytical, and tolerant. These dispositions describe individuals, providing insight into their potential behaviors rather than remaining elusive or hidden traits (Facione et al., 2000; Saulius & Malinauskas, 2021). To improve critical thinking, individuals must cultivate these dispositions or "habits of the mind." These habits involve posing challenging questions, remaining vigilant to potential issues, exercising careful judgment in making predictions, and allowing evidence or logical reasoning to guide decisions (Facione, 2000). Such "habits of the mind" develop a "critical spirit" in individuals, marked by a commitment to reasoning and a quest for reliable information (Halpern, 2003).

A well-rounded critical thinker actively demonstrates a variety of traits, such as being outcome-driven, open to new ideas, adaptable, innovative, creative, analytical, and an effective communicator. Such thinkers assert themselves, remain persistent, and show care while being energetic and willing to take risks. Critical thinkers possess knowledge, resourcefulness, observation skills, intuition, and the ability to think outside the box (Mahdi et al., 2020). As a result, consistent critical thinking fosters fairness and nurtures qualities like humility, courage, empathy, and integrity (Paul & Elder, 2014). True critical thinking empowers individuals to tackle difficult questions, assess the perspectives of others, and evaluate policies, which is essential to address social issues and achieve success in the workplace (Duron et al., 2006; Santos, 2017).

The ability to teach and assess critical dispositions alongside higher-order thinking skills has become an essential component of effective instructional strategies. For decades, college textbooks and K–12 education have emphasized cognitive skills such as analysis, evaluation, and synthesis. However, many theorists now advocate for intentionally teaching both dispositions and skills (Facione et al., 2000). The most effective way to ensure that students develop these attributes and cognitive abilities is through modeling along with instruction. Students who maintain positive attitudes or dispositions toward critical thinking tend to make more significant progress in their cognitive processes (Facione et al., 2000). Furthermore, when students are strongly inclined to utilize critical thinking, they are more likely to apply those skills outside the classroom environment (Facione et al., 2000).

Evaluating both cognitive skills and the necessary dispositions provides valuable feedback for students and instructors. The California Critical Thinking Skills Test can assess cognitive skills (Facione et al., 2000). In contrast, a questionnaire typically measures a student's disposition toward critical thinking, indicating how much an individual embodies this attitude (Facione et al., 2000). By concurrently teaching and assessing these skills, instructors can help students cultivate essential competencies in addition to dispositions that enable them to contribute positively to society.

Motivational Theory and Critical Thinking in Higher Education Learning

The human mind naturally engages in thinking, but it does not always employ critical thinking effectively. Individuals need motivation to think critically. According to Facione et al. (2000), "[a] consistent internal motivation is an overall disposition to employ one's critical thinking abilities in judging what to believe or do in any situation" (p. 9). Thus, motivation plays a crucial role in critical thinking, which is essential for effective learning (Chaparro-Banegas, 2024; Letseka & Zireva, 2013). In essence, while the mind is inherently inclined to think, it requires motivation to critically evaluate the standards that guide its thoughts and to question its innate beliefs (Műller & Palekčeć, 2005; Paul et al., 1997). Motivation drives, directs, and sustains goal-oriented behavior (Grigoreva & Solodkava, 2015).

Numerous theories explain how motivation enhances students' critical thinking skills (Műller & Palekčeć, 2005; Panisoara et al., 2015; Valenzuela et al., 2011). This study focused on two key theories that influence student motivation. Expectancy/value theory explores students' perspectives on these motivational factors, while self-determination theory demonstrates how intrinsic motivation develops within students. Both theories emphasize the crucial role instructors play in fostering student motivation and highlight the importance of creating an environment that nurtures students' intrinsic incentives.

The Expectancy/Value Theory of Motivation

Expectancy/value theory (Valenzuela et al., 2011) explains how various factors influence student motivation to complete assigned tasks. Chaparro-Banegas et al. (2024) connected critical thinking to this motivational theory, noting that motivational programs improve higher-order thinking in students. Students' expectations and the value they assign to the assignment drive their persistence in a task. Expectancy signifies students' beliefs about their ability to perform well on an assignment (Valenzuela et al., 2011). To enhance students' self-efficacy—their confidence in their ability to complete the task—instructors should create assignments that challenge students, while ensuring they remaining achievable and engaging (McMillian & Forsyth, 1991; Panisoara et al., 2015). Additionally, instructors should provide early opportunities for success and clearly explain the components necessary to complete the assignment (McMillian & Forsyth, 1991; Panisoara et al., 2015).

Students perceive value in a task through four key dimensions: attainment, utility, interest, and cost. Attainment reflects the significance that students place on performing the task well (Valenzuela et al., 2011). Educators should design assignments that help students recognize their potential (McMillian & Forsyth, 1991). This desire to excel and focus on the task at hand motivates students (Mulang, 2021). The journey toward realizing their potential, or self-actualization, allows students to fully harness their abilities and even surpass them (McMillian & Forsyth, 1991; Valenzuela et al., 2011). Instructors can foster this drive for excellence by ensuring that assignments challenge students' critical thinking and creativity (Panisoara et al., 2015).

Students can perceive the value of a task by assessing its utility or importance in achieving their future goals (Valenzuela et al., 2011). It is essential for students to feel a connection to the content. To foster this sense of connection, educators should design tasks that are timely and grounded in real-life problems (Panisoara et al., 2015).

Students often assign value to a task based on their personal interest or enjoyment in completing it (Valenzuela et al., 2011). To enhance students' interest in an assignment, instructors can offer options for which tasks to undertake. Providing such choices empowers students and gives them ownership of the task (Panisoara et al., 2015).

Ultimately, the level of commitment that students invest in completing a project can either enhance or detract from its perceived value (Valenzuela et al., 2011). When students feel that a project hinders their ability to accomplish other tasks, they perceive an increase in the costs associated with the assignment, which leads to a decline in motivation (Valenzuela et al., 2011). To mitigate these perceived costs, instructors should actively engage with students and empower them (McMillian & Forsyth, 1991; Panisoara et al., 2015). Reducing these perceived costs can foster a more positive self-image and enhance students' sense of self-worth.

Self-Determination Theory

Students need support for their autonomy, which allows them to fully approve of their engagement in the assigned task and the associated values (attainment, interest, utility, and cost). Autonomous students experience no conflict between their values and their intrinsic motivation to complete the task (Műller & Palekčeć, 2005). In contrast, students who lack autonomy face a conflict between their goals and interests tied to the assignment. For instance, they may feel capable of completing the task but lack interest in the subject matter. These students confront a conflict with their values related to the assignment and require external rewards to finish the task (Műller & Palekčeć, 2005). They have not internalized their external motivators to become intrinsically motivated. Instructors foster autonomy when they endorse students' engagement in their assignments without relying on external rewards (Valenzuela et al., 2011).

To reach competency in a task, this involves receiving feedback or helpful advice to enhance proficiency (Műller & Palekčeć, 2005). Instructors can predict that competent students will excel in any assignment (Mulang, 2021). These students demonstrate self-control, self-confidence, and endurance, enabling them to complete assignments to their fullest potential (Mulang, 2021). As students receive more positive feedback from their instructors, their competence grows. When students internalize positive advice, they become more successful (McMillian & Forsyth, 1991).

Lastly, students integrate more external motivations by interacting with others. Their intrinsic motivation develops as they feel part of the group (Műller & Palekčeć, 2005). Instructors and peers can provide this social support. This support can either benefit students significantly or negatively impact them (Panisoara et al., 2015). Instructors should consistently advise students and deliver constructive feedback in a highly positive manner (Panisoara et al., 2015).

Both theories rely on constant positive support from instructors. When instructors create assignments, they must ensure that their students will place value upon the assignment. While the students are completing the assignment, it is important that instructors give positive reinforcement to their students to ensure that they are competent in completing the assignment and feel socially accepted (Panisoara et al., 2015). Students are motivated when they receive positive reinforcement from their instructors.

Motivating individuals positively involves the need for approval. However, other theories also influence motivation. One key factor is students' drive to discover the most effective cognitive strategies that enhance their learning. These strategies can include improving their organizational skills, monitoring their comprehension of the material, and connecting new information to their prior knowledge (Panisoara et al., 2015). Researchers have studied additional factors that affect motivation, including: 1) the communication between instructors and students, 2) student attributes that foster meaningful learning, and 3) instructors' ability to question students and provide feedback on their motivational strategies (Panisoara et al., 2015). Understanding the sources of motivation is essential for building students' self-confidence and self-esteem.

Relevancy of Critical Thinking in Education

According to John Dewey, educators should prioritize growth as a major goal of education (Kuhn, 1999). Education should actively provide students with more opportunities to apply their reasoning and inquiry skills. Dewey argued that a significant issue with schooling is the focus on "intellectual education." In other words, educators must consider how to transform children's innate curiosity into "attitudes of alert, cautious, and thorough inquiry" (Kuhn, 1999, p. 18).

Kuhn (1999) posited that understanding how individuals develop meta-knowing can shed some light on the relevancy of critical thinking instruction. Kuhn (1999) explained that meta-knowing is one approach to fostering students' critical thinking. Meta-knowing involves being aware of one's own thinking and the thinking of others, asking questions like "How do I know?" or "How do they know?" Kuhn (1999) stated that by thinking about one's own thought processes, individuals open up a new level of cognition or meta-knowing. Kuhn (1999) identified three categories of meta-knowing: metacognitive, metastrategic, and epistemological. *Metacognition* refers to the selection and monitoring of what one knows in addition to how that knowledge is obtained, rising above mere declarative knowledge. *Metastrategic* acts as the manager of cognitive strategies, allowing individuals to select and monitor the strategies they employ, which goes beyond simply applying procedures to meet their goals. Finally, *epistemological* understanding addresses the questions, "How does anyone know?" and "How do I know it?" These three components of meta-knowing are one aspect of critical thinking. They involve reflective thinking about knowledge and its justification. Individuals who possess well-developed metacognitive abilities can control their beliefs, understand their thought processes, and justify their reasoning. This conscious coordination of thoughts also enables them to evaluate the beliefs of others effectively (Kuhn, 1999).

There are four developmental levels of epistemological understanding: realist, absolute, multiplist, and evaluative. In the realist stage, individuals take assertions directly from the external world as facts and assume these statements to be true. At this level, they believe that everything in the world is directly knowable and critical thinking is unnecessary (Kuhn, 1999).

When individuals transition to the absolute level, they determine whether assertions are true or false. In this stage, Kuhn (1999) explained that they use critical thinking to assess the likelihood of assertions being factual based on observations or the authority of experts. This fundamental thinking helps them decide if something is valid and serves as a developmental basis for critical thinking. Most individuals spend their time at this absolute level, though some may advance to the next level (Kuhn, 1999).

At the multiplist level, individuals view assertions as opinions, recognizing that even experts disagree on what to believe. Their opinions stem from personal beliefs, and they feel entitled to them. At this multiplist stage, critical thinking becomes unnecessary since everyone's assertions hold equal validity; after all, everyone is entitled to their opinions (Kuhn, 1999).

Finally, at the evaluative level, individuals strive to understand that some opinions may carry more weight than others. They intermix subjective beliefs and objective facts to evaluate assertions using proper evidence. During this stage, they employ critical thinking to support sound assertions, enhance their understanding and advance society (Kuhn, 1999).

Over the years, instructors have engaged in debates about how to teach critical thinking. Some believe that just teaching the necessary cognitive skills is essential. Instructors can deliver this instruction either through a dedicated course or within the context of the subject matter. Recently, educators have recognized that teaching critical thinking should also involve fostering the dispositions necessary for higher-order thinking. Regardless of how instructors teach these skills, this developmental framework enables them to equip their students with the ongoing ability to discern the truth in a world filled with misinformation (Kuhn, 1999).

First, educators should treat higher-order thinking as a social custom that students actively practice, share, and discuss with one another. Second, they should help students recognize and easily learn complex cognitive abilities. Finally, education should guide students to carefully apply these intellectual skills to construct their beliefs and values, which in turn shape their thoughts (Kuhn, 1999).

In the past, instructors focused primarily on preparing students for promising careers. Today, they must teach more than just the basics of job training. Their instruction should also include problem-solving, creativity, flexibility, teamwork, leadership, and digital literacy skills (Kivunja, 2014). Ultimately, learning to become a critical thinker and practicing cognitive skills fosters an "intellectual education." This approach significantly contributes to personal growth and character development (Saulius & Malinauskas, 2021). With this understanding, instructors can enhance their teaching skills by researching practices that support these framework concepts.

Constructivist Theory of Learning

Learning involves individuals actively constructing their own knowledge rather than simply receiving information (Bada, 2015; Huang et al., 2024; Pritchard, 2018). Learners discover new experiences, transform knowledge, compare new information with old, and revise rules that no longer apply (Bada, 2015). Ultimately, constructivism occurs when learners recognize that they have invested time and energy to create their own knowledge (Makewa, 2019).

Constructivist learning theory emphasizes four key aspects. First, learners actively engage with their existing knowledge and the new information they are acquiring (Pritchard, 2018). One way learners may engage with knowledge is to generalize or apply what they learn to broader contexts (Dorko, 2019). Students can generalize by using expansive generalization or assimilation to enhance their existing schema by adding new information without changing it. For example, Dorko (2019) described a calculus student who built on her knowledge of $f(x)$ to understand $f(x, y)$. Learners can also employ reconstructive generalization or accommodation to revise their schema when encountering situations that create a disequilibrium. Dorko (2019) illustrated this with the same math student, who graphed the equations $y = x$, $y = 2x + 1$, and $z = 4$. The student used reconstructive generalization or accommodation when she met unexpected results, resulting in two line graphs and one plane graph. She realized that all three equations could be represented on a plane, prompting her to modify her schema about equations. Dorko (2019) emphasized that instructors should enable students to practice both assimilation and accommodation generalizations. Additionally, constructivist teaching methods allow students to connect their learning with prior knowledge (Dorko, 2019). As students experience these constructivist teaching methods, they need to apply their critical thinking skills to self-regulate these interactions to create their generalizations.

Learning is a social process. When learners explore their environment and draw conclusions about their world, interacting with others enhances this process (Bada, 2015). As individuals engage in conversations, they share their prior knowledge with one another. Through this communication, learners process information and generate new ideas based on each other's insights. Learners might interact with individuals who possess greater knowledge, such as instructors or generative AI. When educators encourage students to engage with LLMs during constructivist learning activities, these tools help scaffold learners' prior knowledge, facilitating the creation of new knowledge. By incorporating generative AI tools into their constructivist activities, students actively employ critical thinking to generate new insights (Rasul et al., 2023).

In the third point, constructivist learning occurs in a relevant and appropriate context, effectively utilizing the students' cognitive potential (Bada, 2015; Les & Moroz, 2021; Pritchard, 2018). Students engage in appropriate learning when they have prior knowledge of the concepts being explored. This learning also needs to be challenging, allowing them to connect their prior knowledge with the support of others (Makewa, 2019). The primary goal of instructors in a constructivist lesson is to spark learners' actions by encouraging them to solve problems (Les & Moroz, 2021). Instructors should design activities using raw data and primary sources to implement this approach. They should aim for lesson objectives that lead students to classify, analyze, predict, and create. Instructors need to pose thoughtful, open-ended questions to foster student dialogue and provide feedback as students build their knowledge (Makewa, 2019). Incorporating these elements into lessons will create an invigorating, interactive, immersive, informative, collaborative, action-packed, and enjoyable learning environment.

Learning is a metacognitive process (Bada, 2015; Pritchard, 2018). Metacognition enables learners to take active control of their thinking. It involves reorganizing information and applying the knowledge-building process. The learner seeks to reorganize ideas with support from the teacher, who actively promotes the creation of knowledge. Additionally, instructors encourage students to exchange viewpoints and reveal differences in thought by prompting them to ask questions (Les & Moroz, 2021). For instance, many methods exist for arriving at the correct answers in mental math. When learners develop a particular approach to achieving accurate answers, they share their methods and critique them through questioning (Pritchard, 2018). When individuals recognize how to regulate and take control of their thinking effectively, they succeed in their learning.

Students would find it impossible to complete a constructivist learning activity without applying critical thinking (Les & Moroz, 2021), making their positive dispositions toward learning essential (Pritchard, 2018). Zajda (2021) argued that self-concept characteristics, such as self-esteem and self-efficacy, significantly influence learning attitudes. Self-concept reflects what learners believe they are and develops through the praise they receive from others. Learners internalize this praise, which shapes their attitudes toward learning. Furthermore, Vygotsky's sociocultural theory of learning highlights the community's role in helping students construct their knowledge and shaping their attitudes toward learning. Constructivism emphasizes how learners' cultural and social identities impact their learning (Huang et al., 2024; Zajda, 2021). Students' cultural identity stems from their way of life, attitudes, beliefs, values, language, and educational practices. Their social identity develops from the wealth, income, and property of their upbringing (Zajda, 2021). Both students' self-concept and sociocultural identities influence their attitudes, so instructors must recognize how constructivism can positively impact students' mindsets in learning.

Two research studies have demonstrated how constructivism cultivates learners' critical thinking skills. First, Florez-Buitrago et al. (2021) showcased a lesson in computational thinking where students engaged in a problem-solving activity to construct their own knowledge. The researchers noted that the students improved their critical thinking by analyzing the components of computational thinking and enhancing their collaboration abilities. Second, Hosein and Rao (2017) reported an increase in learners' critical thinking as students reflected on their experiences when completing a research study. These reflective essays gave insight into the learners' thoughts as they considered ways to improve their learning experiences. Such reflection encourages students to express the depth of meaningful learning they encounter during active engagement. As students write their reflections, instructors provide minimal guidance, allowing the essays to represent the students' contemplations rather than the instructors' (Hosein & Rao, 2017).

Constructivist learning environments aim to create experiences in knowledge construction, embed collaboration in learning activities, and promote metacognitive processes (Bada, 2015). These goals empower instructors to nurture learners' critical thinking as students exchange ideas and evaluate their contributions, which are essential skills for success in the workplace (Bada, 2015). Constructivist learning experiences enable students to recognize their own and others' perspectives. Afterward, they can apply their critical thinking skills to analyze and question them.

AI and Its Implications in Education

AI enables computer technology to perform tasks that typically require human intelligence, such as learning, reasoning, and solving problems (Ng et al., 2021; Rad et al., 2023; Spector & Ma, 2019; Zhai, 2022). Developers train generative AI, such as LLMs, using the same assumptions about critical thinking as textbooks that teach students how to reason. First, they believe that specific fundamental reasoning abilities are essential for critical thinking. Second, they view drawing deductive inferences as one of those foundational abilities. Finally, they argue that individuals must study numerous examples and complete high-quality exercises to enhance their logical reasoning (Betz et al., 2020). To build these LLMs, computer developers create various quality reasoning exercises for the models to train on, allowing them to generate outputs. Afterward, evaluators assess the LLMs' reasoning ability based on their end products. However, because critical thinking encompasses more than just deductions, these LLMs only have a limited ability to process information (Betz et al., 2020).

Generative AI faces several limitations. First, it cannot search the Internet for current information and relies solely on its training data. For instance, some LLMs only use information from 2021, which makes them outdated in terms of factual knowledge (Rudolph et al., 2023). Additionally, LLMs struggle with understanding certain subtleties in conversation, often having difficulty with specific words or phrases in the inputs. Their creativity and originality depend on the patterns learned in their neural networks, which can lead to hallucinations or the generation of nonsensical information (Rudolph et al., 2023). Furthermore, LLMs can amplify existing biases within society, negatively impacting teaching and learning processes. For example, they may be trained on biased data that favors specific groups and produce discriminatory results against those groups (Kasceni et al., 2023).

Implications of AI in Education

LLMs have transformed educational practices, offering instructors various opportunities and challenges (Baidoo-Anu & Anasah, 2023). One major concern is that LLMs threaten the use of essays as a form of assessment. Instructors worry that students will merely copy information from its outputs. To address this concern, students must learn to use generative AI with integrity and honesty (Gimpel et al., 2023; Halaweh, 2023; Kasceni et al., 2023; Rasul et al., 2023; Rudolph et al., 2023; van Dis et al., 2023). Instructors should create more relevant assessments and emphasize personal reflections. Additionally, they can specify which tools are permitted in the exam instructions (Gimpel et al., 2023). By explaining the risks of failing to achieve key learning outcomes, instructors can foster a culture of academic integrity (Rasul et al., 2023). Halaweh (2023) argued that while written communication skills are essential, instructors must prioritize cultivating critical thinking, problem-solving, creative thinking, collaboration, and technology skills to prepare students for success in the workplace.

Instructors are concerned about students' ability to evaluate outputs from LLMs. Some students may have high confidence in LLMs' ability, leading them to use these tools without critical thinking (Lee et al., 2025). Many students fail to assess the relevance or accuracy of the information provided by these AI tools. To address this issue, instructors must teach students to have higher self-confidence and to use their critical thinking skills while using generative AI (Gimpel et al., 2023; Lee et al., 2025; Rasul et al., 2023; Rudolph et al., 2023). Kasceni et al. (2023) recommended that students consult other educational resources, like textbooks, to verify the factual information obtained from AI outputs. Instructors should implement various activities that help students develop their evaluation skills regarding these outputs (Kasceni et al., 2023; Makewa, 2015).

When using LLMs in the classroom, educators face several concerns. Much of the information that generative AI uses to create outputs comes from copyrighted materials, and LLMs do not cite their sources according to copyright laws (Kasceni et al., 2023; Rasul et al., 2023; van Dis et al., 2023). Additionally, students may not accept the feedback that generative AI provides because it lacks a human touch (Rasul et al., 2023). Instructors can address these concerns by offering feedback to ensure accuracy and help students build trust in technology (Rasul et al., 2023). However, educators often struggle to integrate this AI technology into their courses due to their limited knowledge and expertise (Makewa, 2019; Reddy et al., 2020). Furthermore, some institutional policies may prohibit students from using technology in the classroom (Makewa, 2019; Reddy et al., 2020).

Instructors are taking a more positive view of LLMs, recognizing that many technological innovations will continue to emerge. They believe it is essential to use these tools to supplement their instruction instead of banning them (Huang, 2023). Many instructors leverage the opportunities that generative AI tools provide for enhancing critical thinking instruction (Baidoo-Anu & Anasah, 2023; Huang, 2023; Kasceni et al., 2023). They utilize these tools to create practice problems and develop formative assessments that help students grasp concepts (Baidoo-Anu & Anasah, 2023; Javaid et al., 2023; Kasceni et al., 2023). These AI-generated assessments enable students to understand the reasoning behind the solutions. LLMs also assist students in conducting research by generating content ideas and improving their writing through immediate feedback (Irfan et al., 2023; Rad et al., 2023; Rasul et al., 2023).

Instructors can use LLMs to enhance their lessons in several ways. First, they can generate more reflective writing prompts that generative AI tools cannot produce, which aids students in their critical thinking development (Huang, 2023; Javaid et al., 2023; Kasceni et al., 2023). Second, they can engage students in creative learning projects that encourage them to develop their own ideas and solutions with the help of AI tools (Javaid et al., 2023; Kasceni et al., 2023). Third, instructors can implement strategies to evaluate the factual correctness of the information provided by LLMs using books, articles, and other authoritative resources (Javaid et al., 2023; Kasceni et al., 2023). Finally, instructors can teach students to use these tools to explore different perspectives rather than simply produce answers (Javaid et al., 2023; Kasceni et al., 2023).

Instructors must recognize that LLMs can bring many benefits to the classroom. Most importantly, generative AI tools can assess students' language levels and abilities to create more individualized curricula. Instructors play a crucial role in motivating students to engage in debates that enhance their understanding of specific topics. While generative AI tools are designed to complement learning and instruction, they do have limitations. Therefore, instructors should familiarize themselves with these tools to use them effectively in their teaching. The personal connection teachers build with their students is a significant aspect of instruction that technology can never replace.

Incorporating AI Into the Curricula

Embracing LLMs can transform instructional strategies and learning experiences. Therefore, educators must revise their curricula to emphasize teaching AI literacy and AI's ethical, responsible application, which fosters students' critical thinking (Irfan et al., 2023; Kong et al., 2021; Southworth et al., 2023). Four key areas define AI literacy: the ability to understand, use, evaluate, and ethically navigate AI (Ng et al., 2021; Southworth et al., 2023; Wong et al., 2020). Students need to grasp the basics of AI and learn how it works. They should also apply AI to solve problems and accomplish tasks effectively. Evaluating AI involves developing the skills to assess the quality and reliability of AI outputs. Additionally, students must understand AI's social and ethical implications to make informed decisions when using AI in various situations, considering fairness, transparency, accountability, and the potential impacts on society (Ng et al., 2021; Southworth et al., 2023; Wong et al., 2020). Students can explore AI literacy by reading texts, watching videos, or attending lectures. The most effective way to teach AI literacy involves hands-on, experiential and constructivist learning, which fosters creativity, critical thinking and problem-solving skills (Bitzenbauer, 2023; Ng et al., 2021; Southworth et al., 2023). By using and evaluating AI, students will be well-prepared for the workplace.

Suggested Activities for Using AI to Cultivate Critical Thinking

Bitzenbauer (2023) suggests a classroom activity that helps students recognize the limitations of AI, such as LLMs, while fostering critical thinking. In this method, students first produce documents on a specific topic using AI. Next, they analyze and evaluate the information in the AI output. After this, students exchange their AI documents to compare how different prompts led to varied responses from the LLMs. Finally, they revise the documents using additional resources, such as textbooks, scientific articles, or other online sources. Through this activity, students actively analyze and modify the AI outputs, which aids in developing their critical thinking skills (Bitzenbauer, 2023; Gimpel et al., 2023).

Halaweh (2023) suggests that students document the steps they take when writing an LLM-supported document. In this reflective report, students should include any contradictory findings, texts without references, new facts, how they built upon the latest ideas and any judgments they made that AI did not support. This reflection process helps students develop their metacognitive ability in their research procedures while using LLMs.

Stachowiak (2022) also suggests a lesson where the instructor used a futuristic approach to help students think critically. This approach involves students following trends related to societal problems, such as climate change or poverty. In this constructivist learning activity, students utilize AI technology to identify data trends related to their societal problem and project them 20 years into the future. They analyze the data trends and compare them with other resources. After evaluating the trends, students imagined what living in the future would be like if the problem remained unaddressed. Although this may not accurately reflect reality, the assignment encourages students to think critically and share their perspectives. At the end of the assignment, students conclude what society could do now to help solve the problem (Stachowiak, 2022). This constructivist lesson activity allows students to actively analyze, evaluate, create and rethink. As they engage in this process, they experience knowledge construction, encounter diverse points of view, become motivated by relevant problems, develop collaboration skills and reflect on their knowledge construction (Bada, 2015).

Stachowiak (2024) presents another example of teaching students about AI bias. In this lesson, the instructor demonstrates how altering a single word in an AI prompt yielded vastly different journal articles. The lesson starts with students searching for journal articles on learning styles, concluding that they could trust these academic-based sources. The instructor then asked them to add another word to the “learning styles” prompt, resulting in a completely different set of scholarly articles. The students examine these articles and notice the variations between the two sets. Stachowiak (2024) concludes by emphasizing that the instructor's goal was not to determine right or wrong but to understand the perspectives and assumptions of the authors of the different journal articles.

In this final example, Stachowiak (2017) presents a lesson that teaches students to think creatively and approach problems innovatively through reflection. This lesson starts with the instructor providing students with prompts that encourage different viewpoints. Next, they provide loose guidelines by showing students’ reflections from previous classes. In their responses, students connect information they discuss in class, in other courses, or in real life (Stachowiak, 2017). Afterward, students shared their responses, creating a collective pool of thoughts. They engage in discussions and learn from one another, understanding that they should think creatively rather than conventionally.

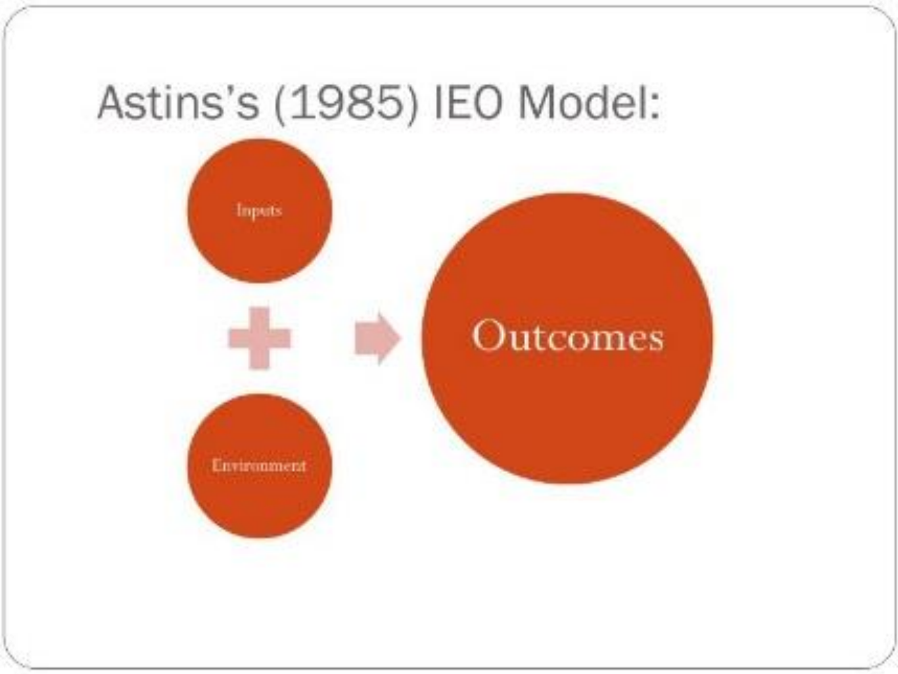
These activities emphasize constructivist learning theory through the use of LLMs. By integrating LLMs into constructivist learning activities, educators create a natural fit (Rasul et al., 2023). LLMs help students construct their knowledge by providing adaptive learning opportunities tailored to individual needs (Huang et al., 2024). They offer personalized feedback that enhances students’ existing knowledge and improves their comprehension of concepts. Additionally, LLMs support research by helping students conduct initial literature reviews, summarize research papers and translate resources (Rasul et al., 2023). In these activities, students actively explore and learn about the limitations of AI. As they learn about these limitations, LLMs scaffold their learning by connecting their existing knowledge of AI to new experiences that deepen their understanding of AI tools (Rasul et al., 2023). Furthermore, these activities challenge students to engage in authentic assessments by revising AI-generated documents to ensure accuracy and promote higher-order thinking (Makewa, 2015; Rasul et al., 2023). In conclusion, integrating LLMs into constructivist learning activities helps students develop critical thinking skills by analyzing and evaluating LLM outputs to create new knowledge.

Conceptional Framework

In his book, *What Matters in College?*, Alexander Astin (1993) presented a conceptual framework called the I–E–O model. This model aims to study student outcomes by analyzing how different types of environmental experiences impact students. The input–environment–output (I–E–O) model investigates whether students grow or change differently based on the varying environmental conditions they encounter (Figure 3).

Figure 3

Astin's (1993) I–E–O Model



Source: Slideshow (2014).

In Figure 3, students' characteristics at the time of entry into the institution serve as the inputs. The environment encompasses the various programs, policies, faculty, peers, and educational experiences that students encounter while attending the institution. Outcomes reflect students' characteristics after they experience the environment. To determine the change or growth in students during their college experience, the outcome characteristics are compared with the input characteristics.

There are two types of outcomes. *Cognitive outcomes* involve using higher-order thinking skills and aligning with the educational objectives of students, faculty, and policymakers. *Affective outcomes* address students' attitudes, values, and self-concept. Additionally, results can be analyzed as either long-term or short-term effects. Most colleges aim to produce long-term outcomes rather than short-term ones. While long-term outcomes develop over 4 years, students sometimes want to understand how specific experiences, such as taking a challenging course, may affect them (Austin, 1993).

The I–E–O model ultimately provided the best framework for this research project because it showed how students' participation in technology-integrated, constructivist learning activities improved their critical thinking. This improvement in critical thinking was demonstrated by an increase in students' perceptions of their motivational and learning strategies as they engaged in constructivist learning activities. If these perceptions (outcomes) were higher for students who participated in these activities than for those who did not, then this would signal that college instructors should incorporate more of these activities into their courses to help students succeed in their post-graduate careers.

Summary

Critical thinking relies on essential skills such as interpretation, analysis, and evaluation. It also relies on attributes like open-mindedness and perseverance (Ennis, 1998; Fahim & Masouleh, 2012; Paul, 1989; Roohr & Burkander, 2020). Educational outcomes have shifted from simply acquiring information to developing the ability to manage overwhelming data (Bada, 2015; Huang et al., 2024; Pritchard, 2018). By applying critical thinking, individuals can effectively filter information. Educators need to design instructional activities that allow students to practice using higher-order thinking to solve problems in an organized, persistent manner (Bada, 2015; Hosein & Rao, 2017).

Instructors motivate students through cognitive tasks by using effective teaching strategies (McMillian & Forsyth, 1991; Panisoara et al., 2015). One practical approach is to incorporate technology and constructivist learning. By engaging students with technology, instructors enhance their intellectual development through constructivist learning activities (Makewa, 2019). This research utilized the I–E–O (input–experience–output) conceptual framework to demonstrate how integrating technology with constructivist learning activities improved students' perceptions of learning and strengthened their critical thinking.

Chapter 3: Methodology

Introduction

The problem this study addressed is that AI technology captivates many college students due to its potential to enhance their learning (Kasceni et al., 2023), but many instructors fail to foster critical thinking skills among their students through the use of AI. By not promoting critical thinking while using AI, instructors create challenges that may impact their students' future careers (Bitzenbauer, 2023; Crawford et al., 2023; Fuchs, 2023; Kasceni et al., 2023; McMurtrie, 2022; Rasul et al., 2023; Spector & Ma, 2019). The issue lies in instructors' lack of research-based constructivist instructional lesson activities that effectively utilize AI tools to enhance students' critical thinking (Rasul et al., 2023; Ruiz-Rojas et al., 2024; Sullivan et al., 2023).

The researcher aimed to suggest learning activities based on constructivist principles that can cultivate students' critical thinking while they use AI tools. Instructors who offer constructive learning experiences promote critical thinking and encourage active, autonomous learning. They also pave the way for significant student development, inspiring instructors and students alike (Rasul et al., 2023; Sullivan et al., 2023).

At the start of this quantitative, quasi-experimental study, an instructor with two classes of university-required English composition courses volunteered to participate by teaching one class using constructivist learning activities with AI and the other class without them. Each student completed a questionnaire to assess their motivational and learning strategies. The research team analyzed the responses to determine if significant differences existed in students' perceptions of their motivation and learning attributes between those who experienced constructivist learning activities using AI and those who did not. The study aimed to show that students who engaged in constructivist learning activities with AI would have improved perceptions of their motivational and learning attributes. Ultimately, this evidence would suggest instructional strategies for educators that promote students' critical thinking.

Research Question

RQ1. Is there a statistically significant difference between the mean scores of students' self-perceptions of their motivational and learning attributes between students who participated in a course with constructivist learning activities using AI and the mean scores of students' self-perceptions among those who did not receive this instruction?

Hypotheses

$H1_0$. There is no significant difference between the mean scores of students' self-perceptions of their motivational and learning attributes for both groups of students.

$H1_a$. The mean scores of students' self-perceptions of their motivational and learning attributes will be higher for students who participated in a course with constructivist learning activities using AI than for those who did not.

Research Methodology and Design

This quantitative, quasi-experimental study examined how different treatments affected the participants (Mertler, 2022). The researcher did not randomly assign participants to the two groups before introducing quasi-experimental elements into the study. This design suited the educational setting since the school had already assigned participants to their respective classes (Mertler, 2022). Additionally, the researcher utilized a matching posttest-only control group design, employing two groups from the same population in two intact classrooms (Mertler, 2022). Since participants belonged to separate classes, the researcher did not try to assign them to groups or match them using a pretest. Achieving equivalent groups could have been possible with pretest results to normalize variables like students' reading and writing abilities (Mertler, 2022). However, the absence of randomization efforts led to nonequivalent groups, which could have introduced confounding variables (Price et al., 2024) and diminished the study's internal validity (Pasnak, 2018).

In this study, the researcher manipulated the instructional techniques used in the classroom. He changed only the instructional technique while keeping the other variables, such as the instructor and reading materials, the same between the two groups or classes (Mertler, 2022). The experimental group received constructivist learning activities using AI, whereas the comparison group did not receive these instructional lessons (Mertler, 2022). The study aimed to measure if the students who participated in the constructivist instructional activities significantly differed in their self-perceptions of motivation and learning attributes compared to those in the comparison group. The researcher used a student survey tool to measure the dependent variable, which reflected the effects of the treatment on the participants (Mertler, 2022).

The design included four statistical tests. The first test summarized the characteristics of the data from the two student samples by using descriptive statistics. In this case, the descriptive statistics provided the number of students in each sample, the minimal value, the maximum value, the mean, and the standard deviation of each sample (Geher & Hall, 2016).

Before starting the study, the researcher performed a second statistical test, conducting a power analysis. He used this analysis to ensure that the sample size was large enough to support a well-designed methodology. The researcher aimed to determine the probability of finding results if they existed (Geher & Hall, 2016). He utilized the power analysis to identify the necessary sample size for the study to achieve sufficient power (Geher & Hall, 2016).

In this study, the researcher used the two independent sample Kolmogorov–Smirnov (K–S) test because this normality test has no restrictions on sample sizes and was suitable for the small sample obtained in the initial data. Additionally, the K–S test allowed the examiner to compare an observed sample with a theoretical distribution, testing for differences without assuming normality (Faster Capital, 2024).

The researcher conducted an independent samples t-test to compare the mean scores of the two independent sample groups in this study and to determine whether the scores significantly differed from each other (Geher & Hall, 2016). The examiner used XLSTAT 2024 to perform these tests.

Research Sample and Data Sources

The study enrolled participants from a suburban, 4-year, historically Black university located in the Northeast United States. The researcher selected these students specifically because they were enrolled in a required English composition course during the spring semester. The investigator used purposive sampling (Mertler, 2022) since the instructor was the only volunteer willing to collaborate in the study. This instructor taught two English composition classes and welcomed the opportunity to experiment with new instructional techniques involving AI in the classroom. A total of 37 first-year students, including 10 males and 27 females, enrolled in the two classes. The students participated in the study by volunteering and completing a required survey. To participate, students had to be 18 or older and provide their student ID. Throughout the study, the researchers protected the students' rights in accordance with the consent procedures outlined in the Institutional Review Board (IRB) application.

Instrumentation and Procedures

Instrumentation

The investigator employed the Motivational Strategies and Learning Questionnaire (MSLQ), a published self-assessment instrument with 81 statements, to assess students' motivational strategies and study habits for three reasons. First, this questionnaire effectively measured two concepts related to critical thinking through its two sections: motivational orientation and learning strategies. In the motivational section, students rated their goals, value beliefs for the course, and necessary skills for success using 31 statements (Pintrich et al., 1991). The second section included statements about students' learning strategies, quantifying nine concepts and evaluating the students' use of cognitive and metacognitive strategies (Pintrich et al., 1991). See Appendix A for all the survey statements.

Second, the MSLQ constructs aligned with constructivist learning aspects and enhanced student abilities (see Appendix B) (Johnson, 1991; Pintrich et al., 1991). The final reason was that the questionnaire demonstrated a relationship between motivational beliefs, cognitive processes, and educational advancement (Tabatabael et al., 2017). Since motivation, learning approaches, and student success in school are directly related, this tool served well in measuring changes in these attributes as students experienced different learning environments.

The authors of the MSLQ instrument conducted repeated tests to determine its reliability and validity (Artino, 2005). They found that the instrument reliably measured its intended constructs. According to Table 1, the authors reported strong Cronbach's alpha scores for nine out of the 15 concepts, with scores greater than 0.70. Among the remaining concepts, they noted that the lowest score was 0.52. The authors validated this instrument by correlating students' scores with their final grades and discovered that this instrument significantly predicted academic achievement (Artino, 2005; Tabatabael, 2017). In other words, students who had high scores on this questionnaire also achieved high final grades in their courses.

Table 1

MSLQ Item by Concep Reliability (Cronbach's Alpha)

	Items	α
MSLQ motivational concepts		
Intrinsic goal orientation	4	.74
Extrinsic goal orientation	4	.62
Task value	6	.90
Control of learning beliefs	4	.68
Self-efficacy for learning and performance	8	.93
Test anxiety	5	.80
MSLQ learning strategies concepts		
Rehearsal	4	.69
Elaboration	6	.75
Organization	4	.64
Critical thinking	5	.80
Metacognitive self-regulation	12	.79
Time/study environmental management	8	.76
Effort regulation	4	.69
Peer learning	3	.76
Help-weeking	4	.52
Total items on the questionnaire	81	

Source: Nold (2017, p. 22).

Study Procedures

Before the course began, the investigator and the collaborating instructor incorporated three constructivist learning experiences using AI into one of the classes. In the first lesson, students created a multiple-choice question to review for a quiz. Afterward, the students prompted AI to create the same. The students compared the two questions to determine which multiple-choice question did a better job of reviewing the concept that would be covered on the quiz (Schmidli et al., 2023). The second lesson had the students prompt AI to create a bad essay on a particular topic. Once AI created the bad essay, students had to make appropriate corrections to improve it (Schmidli et al., 2023). Finally, the students prompted AI to create thesis statements for their research papers. The students worked together by comparing the thesis statements that AI generated and the prompts they used to ask AI. Students compared them to determine what was necessary in an AI prompt for it to produce the best thesis statement for their research papers (Schmidli et al., 2023). For more details about these lessons, refer to Appendix E.

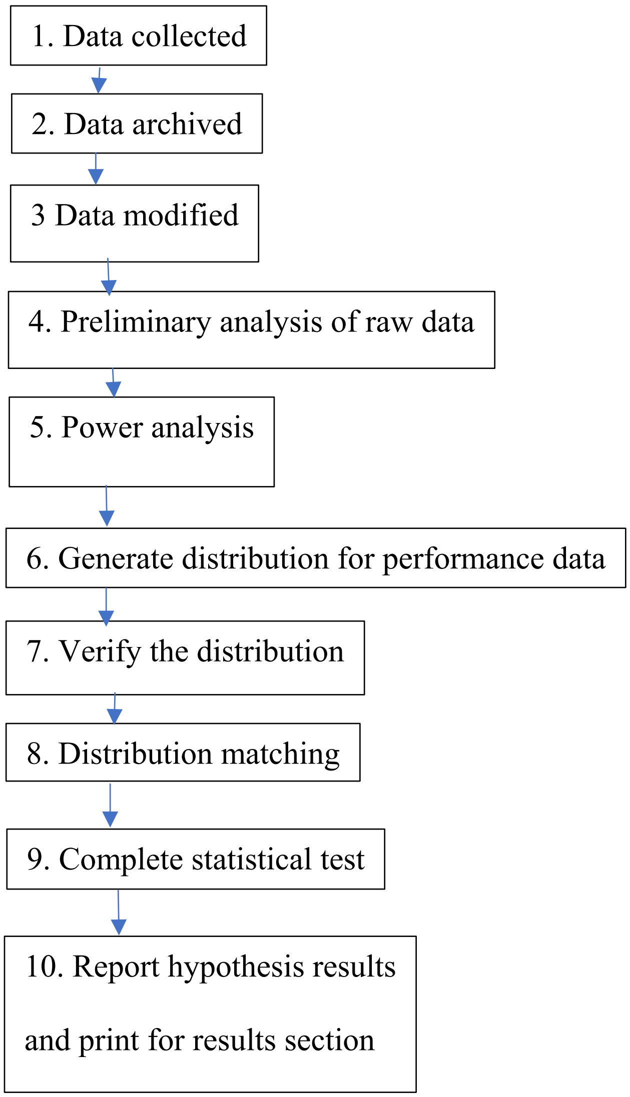
Before starting the research study, the investigator created two surveys containing the 81 statements from the MSLQ using Survey Monkey to compare the two classes separately. The researcher generated a link for each survey and placed each link in separate emails. These emails introduced the researcher and explained the study, clarifying the participants' roles, rights, and the risks involved. Through the emails, the researcher informed the students that their participation was voluntary and that their involvement would not affect their course grades. The only difference between the emails was the survey link. At the end of the course, the researcher sent each student the appropriate email according to their class via the course instructor. When the students received the email and opened the link, they again found information regarding their participation and rights in the study. In the introduction, the survey requested participants' consent by asking if they were over 18 and required them to submit their student ID numbers. Following this introduction, the students completed all 81 questions of the MSLQ, with Likert-style answers ranging from 1 to 7.

Data Analysis

In his 2022 study, Griffith (2022) employed a statistical cross-validation process based on numerical augmentation to achieve sufficient power to reject the null hypothesis and validate the results. This researcher adapted Griffith's statistical cross-validation process to create a similar progression for data analysis in this study. The researcher conducted this comprehensive data analysis procedure (see Figure 4) because the sample size in this study was inadequate to yield enough power and provide a strong probability of rejecting the null hypothesis.

Figure 4

Comprehensive Data Analysis Procedure



1. *Data collected*: The researcher collected student data using two different Survey Monkey files, with one file assigned to each class.

2. *Data archived*: The researcher converted the Survey Monkey files into Excel files, archiving all 81 responses from each student participant. He titled the Excel file for the class with the constructivist activities using AI the "experimental group," and labeled the other Excel file for the class with regular instruction the "control group."

3. *Data modified*: After collecting and archiving the participant data, the researcher recomputed the scores for the negatively-worded questions by subtracting each student's response from 8 (Pintrich et al., 1991). Next, the researcher calculated the mean for all 81 questions on an Excel worksheet for each participant's survey, resulting in a single mean score for each participant from both the experimental and control groups.

4. *Preliminary analysis of the raw data*: The researcher archived the mean scores in a CSV file and determined each group's descriptive statistics using XLSTAT.

5. *Power analysis*: The researcher conducted a power analysis to check if the sample sizes were sufficient to ensure the probability of rejecting the null hypothesis when the alternative hypothesis was actually true. To determine the necessary sample size for this study, he entered the following data into JASP version 0.19.3: power size (.8), alpha (.05), and effect size (.5).

6. *Generate distribution for performance data*: To achieve sufficient power, the researcher performed a statistical augmentation procedure to generate 60 data points per group instead of the initial 10. He used the random number generator in Microsoft Excel, drawing on the mean and standard deviation of the initial data set. This approach ensured that the augmented data sample maintained similar mean and standard deviation measures as the initial.

7. *Verify the distribution*: Using XLSTAT, the researcher conducted the two-independent sample Kolmogorov–Smirnov (K–S) test to compare the distributions of the augmented and initial data by determining their normality. The researcher used the data and the graph to verify whether the two samples followed the same distribution.

8. *Distribution matching*: The researcher used XLSTAT to conduct a distribution matching process with the initial and augmented data.

9. *Complete statistical test*: The researcher conducted an independent samples t-test using XLSTAT on the performance data to test the hypothesis and answer the research question. The researcher also included the Shapiro–Wilk test for normality in the analysis.

10. *Report hypothesis results and print for results section*: The researcher reported the descriptive analysis and t-test outcomes in the supplemental tables and figures section. In addition, he printed all tables and graphs produced by XLSTAT to place in the supplemental tables and figures section.

Ethical Assurances

Before starting the data collection, the researcher obtained approval from the IRBs at Gwynedd Mercy University and Lincoln University. The IRB's approval indicated that the participants in this study faced minimal risks, but the principal investigator took steps to mitigate those risks. For example, the principal investigator collected student ID numbers to ensure that the participants who consented were at least 18 years old and to contact any students about their surveys if necessary. The researcher reassured the participants that he stored the student ID numbers on a password-protected computer, which only the researcher could access. To address the risk of coercion, the principal investigator informed students that their participation in the survey was voluntary and assured them that their decision not to participate would not impact their course grades or enrollment at the university.

Summary

In this quasi-experimental research study, students in two different English composition classes completed surveys about their motivational orientation and learning strategies. The researcher did not randomly assign students to similar groups; they were separated into two classes before the investigation. Since the study did not attempt random sampling or matching, it followed a post-survey nonequivalent group design. The researcher varied the instructional activities that each class received during the course. One class engaged in constructivist instructional activities using AI to explore whether these activities affected the students' perceptions of their motivational orientation and learning strategies. In contrast, the other class received regular instruction. The dependent variable consisted of the survey measurements that assessed the students' beliefs about how they became successful in the course. At the end of the semester, students completed the survey.

The researcher analyzed the survey data by completing a 10-step data analysis, which included creating a descriptive analysis of the data groups, conducting power analysis, performing Kolmogorov–Smirnov tests, and executing an independent samples t-test. He hoped the findings would show that the experimental group, which engaged in constructivist learning activities using AI, improved their perceptions of motivational orientation and learning strategies. These findings aimed to provide instructors with evidence to incorporate constructivist AI-based lessons into their instruction, helping students develop critical thinking skills.

Chapter 4: Results

Introduction

This chapter discusses the reliability and validity of the MSLQ instrument and the data set. It also describes the data and presents the preliminary results of the validation methods. Next, it links the results to the research question and indicates the hypothesis results using tables and figures from the independent two-sample t-test. The chapter concludes by summarizing the data and its analysis.

This study aimed to provide statistical evidence that students who engaged in constructivist lesson activities using AI tools perceived their self-attributes regarding motivational and learning strategies significantly better than students who did not participate in these undertakings. In this quasi-experimental study, college students from one English composition class participated in constructivist learning activities using AI, while students in another English composition course, taught by the same instructor, did not. Both groups of students completed a self-reported survey about their perceived motivational and learning strategies for success in the class. If there were statistical evidence that the students who participated in the constructivist learning activities improved their critical thinking, this would suggest that these lessons were effective. Consequently, instructors could use these lessons to prepare students for their future careers.

Validity and Reliability of the Data

The researcher strengthened the validity and reliability of the data through the robust MSLQ instrumentation used in the study. He found that the reliability of the MSLQ instrument was strong, with Cronbach's alpha scores exceeding 0.70 for nine out of the 15 concepts. Among the remaining concepts, the lowest score was 0.52 (see Table 3). In addition, the MSLQ's authors correlated the students' scores with their final grades, demonstrating that this instrument significantly predicted academic achievement (Artino, 2005; Tabatabael, 2017). Based on the strong scores of the questionnaire, the validity and reliability of the data for this study were bolstered.

However, the posttest-only control group design and the purposive sampling negatively affected the study's internal validity. The researcher chose the purposive sampling method because the instructor of the English composition classes volunteered to collaborate in the study. Therefore, the investigator selected the sample for a specific reason (Mertler, 2022). The original sample included only 20 participants because the instructor had 37 students in both of her classes and the students volunteered to participate in the study; they did not feel coerced into participating. The researcher determined the required sample size using a power analysis test in JASP. The researcher needed to increase the sample size to achieve greater power in this study. Using an effect size of 0.5 and a power of 0.8, the analysis revealed that the sample size for each group should have been 60. See Figure A.1 in the appendix.

After conducting the power analysis test, the researcher ran a descriptive analysis of the initial data. This analysis found that the control group's mean and standard deviation were M = 4.716, SD = 0.715, while the experimental group's values were M = 4.994, SD = 0.294 (see Table A.1 in the appendix). The investigator used this information to validate the performance data. The researcher began the validation process by comparing the means from the descriptive analysis between the augmented control group (N = 60, M = 4.696, SD = 0.73) and the experimental group (N = 60, M = 5.025, SD = 0.311) (see Table A.2). The Kolmogorov–Smirnov test results indicated that the initial and augmented samples followed similar distributions for both groups (see Figures A.2 and A.3). The Shapiro-Wilk test showed high values above their respective *p*-values, confirming that we could reject the null hypothesis, indicating that the respective samples exhibited the same normality (see Tables A.3–A.6).

The re-validation or cross-validation process yielded similar results with a different augmented sample size (*N* = 25). The control group's mean (*M* = 4.706, *SD* = 0.842) slightly differed from the experimental group's (*M* = 5.010, *SD* = 0.254) (see Tables B.1–B.5 and Figure B.3). Again, the Kolmogorov–Smirnov tests showed that the initial and augmented samples had very similar distributions (see Figures B.1–B.2). This re-validation confirmed the reliability of the performance data.

Results

The study aimed to answer a research question about how constructivist lesson activities affected students' critical thinking. The researcher used a self-reported questionnaire to measure students' motivational and learning strategies. Initially, the researcher had 10 students who received constructivist learning instruction using AI tools and 10 who did not. To ensure that the study had enough power, the researcher used the initial sample data to increase the sample size from 20 to 120.

Table 2

Descriptive ***Statistics for Results Comparing Augmented Samples (N=60)***

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
Experimental normal (4.99,0.294073)	60	0	60	4.326	5.674	5.026	0.311
Control normal (4.716,0.715)	60	0	60	3.206	6.404	4.696	0.733

Table A.12 depicts the performance data descriptive analysis for students who participated in constructivist lesson activities (the experimental group) and for those who did not (the control group). This analysis shows that students who received constructivist instruction using AI tools reported higher mean scores for their self-perceptions of motivational and learning attributes (*M* = 5.025, *SD* = 0.311) than those who did not receive the instruction (*M* = 4.696, *SD* = 0.715) based on the augmented sample size of 120.

Research Question and Hypotheses: Data and Hypothesis Testing Results

The research question guiding this study was: Is there a statistically significant difference between the mean scores of students' self-perceptions of their motivational and learning attributes between students who participated in a course with constructivist learning activities using AI and the mean scores of students' self-perceptions among those who did not receive this instruction?

The researcher investigated this research question using descriptive statistics, including the means and standard deviations. The means for each performance data were recorded in Table A.12. The means scores of the self-perceptions of students' motivational and learning strategies indicated that the students who participated in constructivist lesson activities had higher mean scores than those who did not. The researcher conducted an independent two-sample t-test, confirming a significant difference between the mean scores of the two groups ($t(118) = 3.204$ and $p = 0.002$) (see Table 2 and Figure 5). Hence, the results suggest that the null hypothesis was rejected and that the alternative hypothesis was accepted, showing that students who participated in constructivist learning instruction using AI tools exhibited statistically significantly higher self-perceptions of their motivation and learning attributes than those who did not. (See Table 3 and Figure 5).

Table 3

T-Test for Two Independent Samples/Upper-Tailed Test (Control vs. Experimental Group)

95% confidence interval on the difference between the means:	
[0.124,	0.535]
Difference	0.329
t (Observed value)	3.204
|t| (Critical value)	2.001
DF	79.593
p-value (Two-tailed)	**0.002**
alpha	0.05

The number of degrees of freedom was approximated by the Welch-Satterthwaite formula.

The critical t was estimated using the Cochran-Cox approximation.

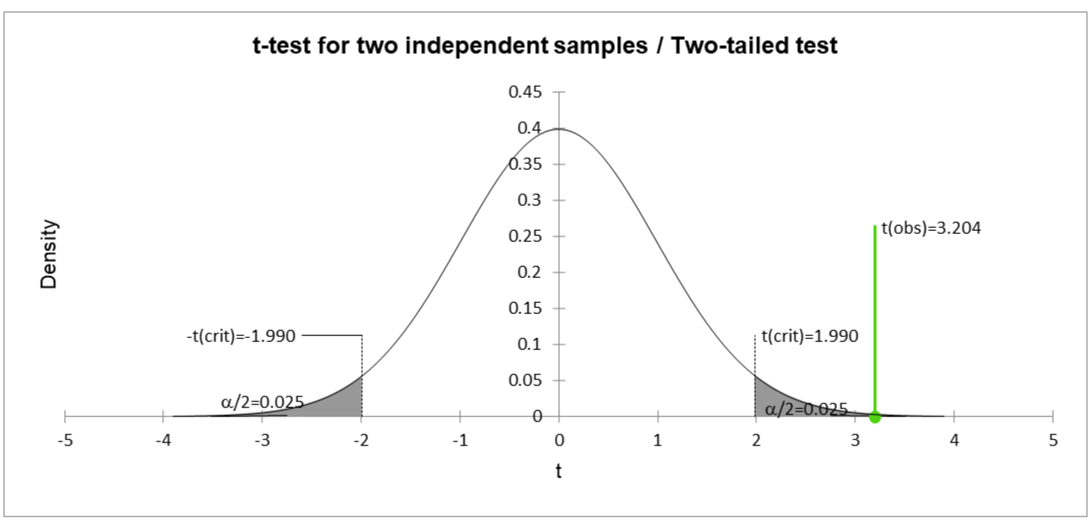
Test interpretation:

H0: The difference between the means is equal to 0.

Ha: The difference between the means is different from 0.

Figure 5

T-Test for Two Independent Samples/Upper-Tailed Test (Control vs. Experimental Group)



Summary

The researcher strengthened the validity and reliability of the data in this study because the MSLQ questionnaire was found to have high scores for both when tested by the instrument's authors. However, the posttest-only control group design and the purposive sampling negatively affected this study's internal validity. The purposive sampling resulted in a small sample size for the study and low power. To increase the study's power and the data's validity, a power analysis was performed to determine that the size for each group in the sample had to be statistically increased to 60 from 10. This statistically augmented sample had to be tested for its normality against the initial sample data using the Kolmogorov–Smirnov and Shapiro–Wilk tests. The performance data distribution and the initial distribution were found to be close to each other. A cross-validation test was conducted and the distributions were also similar.

After validating the performance data, the researcher used the information from the descriptive analysis and found that the mean scores of the students' self-perceptions were higher for the students who participated in constructivist learning activities using AI than for those who did not. The researcher used an independent two-sample t-test to see if there was a statistically significant difference between the mean scores of the two groups. The results of this t-test provided statistical evidence of the difference, which showed that the null hypothesis could be rejected and the alternative hypothesis accepted.

Chapter 5: Implications, Recommendations, and Conclusions

Introduction

This chapter summarizes the entire study and discusses the research question's results. Next, it explores the implications of the results for critical thinking instruction using AI tools in the classroom. It explains how this research contributes to the body of knowledge about teaching critical thinking using AI technology. Finally, the chapter concludes by making recommendations for future research and practice.

Study Summary

Many inconsistencies exist between how educators should teach critical thinking and what critical thinking truly entails. This study highlights three key issues. First, although higher educational institutions prioritize critical thinking (Halpern, 2001; Liu et al., 2014; Nold, 2017), many students lack the higher-order thinking skills essential for success in their future careers (Kouzov, 2019; Nold, 2017; Rasul et al., 2023). Instructors expect students to think critically without offering adequate guidance (Mahdi et al., 2020; Paul & Elder, 2005; Roohr et al., 2019). Second, as AI technology permeates society, individuals encounter a surge of misinformation online (Kenedy, 2024). It becomes crucial for people to develop flexible filters to discern relevant information (Kouzov, 2019). To help students achieve this, instructors should not oppose generative AI; instead, they should recognize the benefits it can bring to enhance student learning (Kouzov, 2019). When used correctly, AI technology can engage students effectively (Schatten, 2022). Finally, educational experiences must focus on developing students' critical thinking skills (Kenedy, 2024). Critical thinking learning experiences should play a significant role in post-secondary education and foster lifelong learning (Kenedy, 2024). Students must learn to actively analyze and evaluate information to generate new ideas (Liu et al., 2014). As they begin their careers, they need to understand that most companies utilize AI to perform tasks while employees critically analyze and evaluate the outputs of that technology (Davenport & Ronanki, 2018).

The literature review in this study proposed that critical thinking acts as an active yet sequential mental process that helps individuals understand the world and themselves (Kenedy, 2024; Santos, 2017). Kenedy (2024) explained this sequential mental process using his model of cyclical critical thinking, which incorporates the six stages of complex thinking in Bloom’s taxonomy. As individuals move through the various levels of cognitive thinking, they engage actively in this process. Kenedy’s (2024) model introduces rethinking as a cognitive task and emphasizes that students should continually rethink information to generate new ideas. This rethinking process fosters critical thinking attributes, such as persistence and out-of-the-box thinking (Facione et al., 2000; Saulius & Malinauskas, 2021).

This study suggested that instructors can assist students in developing their critical thinking skills through constructivist learning activities using AI. These activities require students to continuously rethink new information in relation to their prior knowledge to generate new ideas (Bada, 2015). Without applying critical thinking, students would find it impossible to complete a constructivist learning activity (Les & Moroz, 2021). Instructors who design constructivist learning environments create experiences for knowledge construction, embed opportunities for collaboration, and promote reflective thinking. These objectives nurture learners’ critical thinking as students exchange ideas and evaluate their contributions, which are essential skills for the workforce (Bada, 2015).

Individuals do not always engage in critical thinking effectively. They need consistent internal motivation to think critically (Facione et al., 2000). Many motivational theories highlight the crucial role instructors play in helping students integrate external factors that foster this internal motivation. To cultivate internal motivation, instructors should provide consistent positive reinforcement and feedback, especially as students develop their learning strategies (McMillian & Forsyth, 1991). In constructivist learning activities, instructors guide students to solve complex problems and create challenging lessons using raw data and primary sources. This approach allows students to analyze the information and formulate their own thoughts (Panisoara et al., 2015).

Many college students are interested in AI technology due to its potential to enhance their learning (Kasceni et al., 2023). To address this interest, this study proposed that instructors implement constructivist learning activities using AI tools in the classroom. These activities can help students build their critical thinking skills and incorporate proper AI literacy practices (Bitzenbauer, 2023; Crawford et al., 2023; Fuchs, 2023; Kasceni et al., 2023; McMurtrie, 2022; Rasul et al., 2023; Spector & Ma, 2019). Recognizing the lack of research-based teaching practices available, this study focused on guiding educators to use instructional approaches that develop their students' critical thinking skills through AI technology, ultimately preparing them for success in their future careers (Bada, 2015; Makewa, 2019; Nold, 2017; Rasul et al., 2023). The study aimed to provide instructors with research-based constructive learning experiences that cultivate students' critical thinking while utilizing AI tools.

In this quantitative, quasi-experimental study, researchers employed a posttest, non-equivalent design to determine whether a statistically significant difference existed between the mean scores of students' self-perceptions of their motivational and learning attributes across two groups or classes. One class participated in constructivist learning activities using AI tools, while another received regular instruction. The researcher measured the self-perceived attributes of the students using the MSLQ survey at the end of the semester. The results indicated that students who received constructivist learning instruction with AI achieved higher mean scores in their self-perceptions of motivation and learning attributes compared to those who did not.

This study sought to answer the following research question: Is there a statistically significant difference between the mean scores of students' self-perceptions of their motivational and learning attributes between students who participated in a course with constructivist learning activities using AI and the mean scores of students' self-perceptions among those who did not receive this instruction?

The researcher conducted an independent two-sample t-test, confirming a significant difference between the mean scores of the two groups (t (118) = 3.204 and p = 0.002). Therefore, the results suggested rejecting the null hypothesis and accepting the alternative hypothesis, which stated that students who participated in constructivist learning instruction using AI tools exhibited statistically significantly higher mean scores in their self-perceptions of motivation and learning attributes compared to those who did not.

Discussion of Results

This study showed that implementing constructivist learning activities using AI significantly improved first-year college students' critical thinking abilities. These results supported previous research demonstrating the positive impact of higher-order activities on developing students' critical thinking (Arisoy & Aybek, 2021; Chaparro-Banegas et al., 2024; Crawford et al., 2023; Huang et al., 2024; Makewa, 2019). This evidence indicated that college-level English composition instructors can effectively teach and enhance critical thinking skills.

Several possibilities exist to highlight the positive impacts of technology-based constructivist instruction on students. First, technology-based environments actively engage students in their learning (Kasneci et al., 2023; Makewa, 2019; Rasul et al., 2023; Reddy et al., 2020). By introducing technology into instruction, educators encourage students to learn responsibly and independently. Instead of relying solely on instructors for new information, students take the initiative to find sources themselves. Once instructors provide general directions for a project, students determine their own approach to completing it (Makewa, 2019). Additionally, technology significantly boosts student motivation. Students who experience a technology-integrated learning environment find their learning process to be more enjoyable and often surpass the requirements of their assignments compared to those who do not engage with technology (Irfan et al., 2023; Makewa, 2019).

Constructivist learning activities inspire students to self-regulate and create new ideas through reflection and abstraction (Makewa, 2019). Students actively seek to make sense of the information they perceive and construct meaning from it (Bada, 2015). Constructivists emphasize that learners know best how to build their own knowledge, placing students at the center of the process. This approach makes learning user-friendly and encourages students to become more inquisitive and innovative (Makewa, 2019).

Engaging students in metacognitive activities can contribute to significant results. Alewehaibi (2012) highlighted that these activities positively influence the development of students' critical thinking. They enhance content material retention and improve problem-solving skills. One effective metacognitive activity involves students constructing reflective essays, which compels them to make sense of their learning experiences while building mental models of their acquired processes and knowledge (Hosein & Rao, 2017). Activities focused on critical thinking, such as reasoning, analyzing, questioning, and problem-solving, encourage students to become more active participants (Arisoy & Aybek, 2021). This active learning engages students in educational tasks and prompts them to think critically about their actions (Lumpkin et al., 2015). As a result, college students invest in their learning and take ownership of their educational experiences (McMurtrie, 2022).

From this discussion, the researcher concluded that well-structured constructivist learning activities using AI promote higher-order thinking and serve as effective instructional tools for developing critical thinking skills in college students. These activities engage students, make learning more user-friendly, and, most importantly, encourage them to take ownership of their learning experiences. Therefore, these findings carry important implications for classroom instruction.

Implications

Implications for a Technology-Based Learning Environment

Adopting a technology-learning environment helps educators achieve their teaching objectives and increase student engagement (Reddy et al., 2020). Technology allows instructors to structure lessons that accommodate their students' various learning styles (Makewa, 2019). It also empowers instructors to create lessons that challenge students to think critically and solve complex problems (Reddy et al., 2020).

The researchers conduct an independent two-sample t-test, confirming a significant difference between the mean scores of the two groups.Bringing technology into the classroom increases interactions between students and teachers, as well as among students themselves. Students frequently share their computer skills and take on the role of tutors, which boosts their confidence (Makewa, 2019). Instructors should encourage students to make practical choices about the tools and media they use. For example, when instructors embed AI technology into lessons, they teach students about its ethical use. AI technology acts as a coach by identifying problems and allowing students to practice as much as needed to complete tasks. Learners also engage with AI to gain knowledge and skills. These generative AI tools can democratize education and support diverse students' participation in higher education by providing personalized, accessible learning experiences (Rasul et al., 2023).

Implications for Constructivism

Constructivist learning theory emphasizes that instructors and learners interact effectively to enhance learning (Rasul et al., 2023). This interaction significantly improves the quality of students' education and influences their cultural identity, self-concept, self-esteem, self-efficacy, and motivation to learn active engagement, all of which relate closely to academic performance. By implementing constructivist learning activities, instructors help students develop and reinforce their own learning strategies in the classroom. This approach allows students to maintain their cultural identity while boosting their self-esteem, self-efficacy, and motivation to learn (Zajda, 2021). Instructors should employ questioning techniques to encourage students to engage in dialogue and elaborate on their learning strategies to facilitate improvement. They also recognize how social and cultural factors shape students' knowledge construction. Most importantly, instructors must consistently provide positive feedback to assist students in refining their learning strategies (Zajda, 2021). In a constructivist classroom environment, students feel motivated to learn as they build their self-esteem and self-efficacy by developing effective learning strategies that suit them.

Implications for the Development of Critical Thinking

College students consider their learning experiences essential for becoming strong critical thinkers. These experiences should help students sift through information and assess its value (Kouzov, 2019). To develop this ability, instructors must include the following in their teaching.

First, students need to recognize that misinformation challenges everyone and shapes people's beliefs. They should pursue the truth relentlessly and go beyond just checking their facts. They must seek justifications instead of merely accepting opinions (Ku & Au, 2021).

Students must understand that people's assumptions play a crucial role in forming their opinions. Higher education instructors should encourage students to identify these assumptions through critical thinking (Ku & Au, 2021). For example, if someone believes that the government should increase military spending, they might assume that this will lead to greater national security. To uncover such assumptions, students need to engage in critical analysis by asking questions. For instance, they could ask, "Does military spending always make a country safer?" By asking more questions, they can dive deeper and reveal hidden assumptions. Finally, higher education instructors must actively nurture critical thinking skills to equip students with the means and motivation to expose misinformation (Ku & Au, 2021).

Based on the literature review, this study narrowed the gap between the empirical evidence demonstrating that constructivist learning activities with AI tools enhance students' critical thinking compared to lessons that do not incorporate AI. The study suggested three constructivist learning activities that used AI and provided statistical evidence of improvements in students' critical thinking and AI literacy skills. These activities encouraged students to rely less on AI and to engage more critically when analyzing and evaluating AI outputs (Lee et al., 2025).

Future Research

This quantitative study suggested that constructivist learning activities using AI do positively affect students' critical thinking. The recommendations for future research are as follows:

1. Since constructivism positively affects students' critical thinking, would other instructional strategies have similar effects when instructors use AI as a tool in their lessons? Other instructional strategies could include inquiry-based instruction, problem-solving activities, case studies, and direct instruction.
2. Since AI has only been around for several years, what long-term effects will AI have on students? A longitudinal study could be conducted.
3. Since instructors need to understand critical thinking better and how to implement instruction to improve this skill for students in their courses, what effect would professional development courses have in improving students' critical thinking?
4. How would students' critical thinking be affected if higher-order thinking was implemented campus-wide rather than just in certain subjects?
5. If the college curriculum focused more on the quality of education than on the quantity, how much would this impact students' employment after graduation and employers' retention of new hires?

Recommendations

After completing the study, the researcher found that the following changes to the study should have been in place to achieve better results:

1. Students needed to have some personal relevance in completing the surveys.
2. A survey instrument with fewer questions and the same high reliability and validity was needed.
3. A mixed-methods approach might have offered more information than a quantitative study alone.

4. Students should have been placed in groups based on a pretest matching sampling procedure to avoid confounding variables.
5. A multi-classroom study with instructors using the same curriculum could have been conducted to ensure more study participants.

Conclusion

Instructors continually nurture human intelligence in their students to help them grow. For hundreds of years, they have worked to develop their students' critical thinking skills. Making students think is not easy. Instructors face numerous challenges as they encourage their students to participate actively in their learning. This study addresses several of these instructional challenges.

With the development of the Internet and AI, students live in an age of information. They have access to all the information they need, which gives them a range of choices. However, making good choices about sources and information is key. Instructors must teach students to develop trust and proper values when selecting sources (Stachowiak, 2024). Instructors also need to create assignments that are adventurous and fun, motivating students to complete them (Stachowiak, 2019). Another challenge is to help students confront uncertainty and apply critical thinking to solve difficult societal problems, such as climate change, poverty, political strife, or the use of energy resources (Stachowiak, 2022). Lastly, instructors must teach students to think creatively. The current educational system often teaches students to reach a goal without helping them realize how they achieved it (Stachowiak, 2017). However, instructors can implement some immediate best practices to overcome these challenges.

This study suggests that educators utilize constructivist learning activities in conjunction with AI tools. Constructivist learning theory posits that knowledge is constructed within the mind. As individuals interact with their environment, they update their knowledge to reflect new information they are learning (Bada, 2015). This change creates a new mental notion. Individuals share this mental notion with others and as they rethink it, it develops into a creative new idea. Using AI tools enriches the learning environment and supplements the human thought process. Instructors need to teach students about AI bias, which is another best practice. Students learn AI literacy skills by analyzing information from AI. Through analysis, students apply correct decision-making processes to choose proper information. Another best practice is to motivate learners by engaging them in challenges. Teaching happens not only in the classroom; it involves the instructor constantly thinking about who their students are. Instructors engage their students in ways that foster a greater desire to learn. In the final best practice, instructors teach students to think creatively. They build students' creative confidence and help them develop skills to approach problems innovatively through reflection.

This study suggests that college instructors implement constructivist learning activities using AI to promote critical thinking. Questioning, critiquing, and argumentation serve as effective classroom activities for fostering critical thinking (Santos, 2017). Instructors need to teach differently from the norm, especially with students who come from a traditional, didactic, and memorization-based learning background. Students need to feel comfortable with ambiguity and understand that it is acceptable for them to arrive at different answers (Stachowiak, 2017). Instructors can leverage AI as a tool in their lessons to enhance the quality, efficiency, and effectiveness of the learning process. Part of the learning process involves equipping students with AI literacy, which boosts their productivity, creativity and understanding (Chapparro-Banegas et al., 2024). Additionally, constructivism enables instructors to encourage students to self-reflect and evaluate their strategies, helping them discover how to think (Bada, 2015). Good educators provide students with the right tools and guide them to think critically, empowering students to make revolutionary changes and pave the way for a bright future.

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Appendix A: Supplemental Tables and Figures of Results

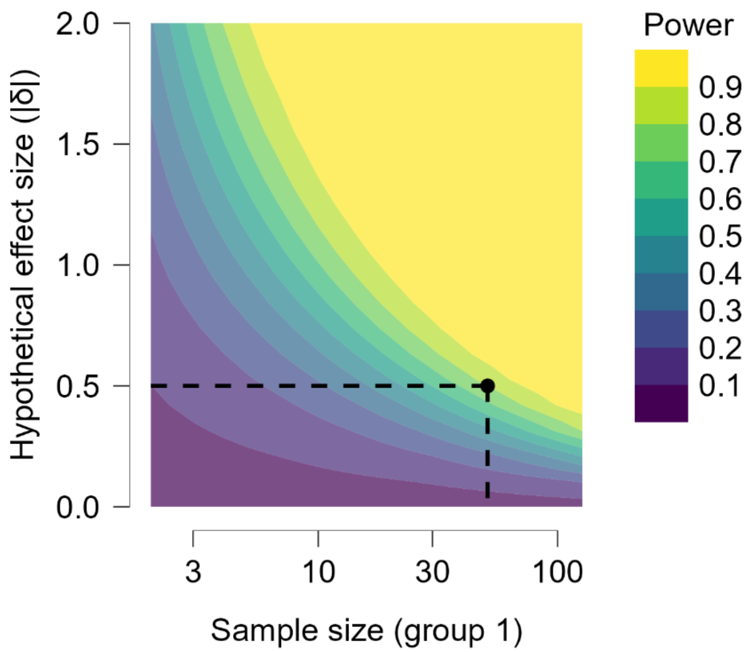
Table A.1

Descriptive Statistics for Initial Data (N = 10)

Control	Mean	4.716
	Standard deviation (n-1)	0.715
Experimental	Mean	4.99
	Standard deviation (n-1)	0.294

Figure A.1

Power Contour for the Power Analysis



Note. This graph shows that with an effect size of .5 and a power of .8, the sample size needed to be about 60.

Table A.2

Descriptive Statistics of Augmented Samples for Performance Data

	Control augmented sample	Experimental normal augmented sample
Maximum	6.404	5.674
Mean	4.696	5.025
Minimum	3.206	4.326
Missing	0	0
Std. deviation	0.733	0.311
Valid	60	60

Table A.3

Initial vs. Augmented Descriptive Analysis (Experimental Group)

Variable	Obs	Obs. with missing data	Obs. without missing data	Min	Max	Mean	Std. deviation
Experimental	10	0	10	4.642	5.568	4.994	0.294
Normal (4.99, 0.294073)	60	0	60	4.326	5.674	5.026	0.311

Table A.4

Two-Sample Kolmogorov–Smirnov Test/Two-Tailed Test: Initial vs Augmented Data Experimental Groups

D	0.167
p-value (two-tailed)	0.971
alpha	0.05

An approximation was used to compute the p-value

Test interpretation:

H_0: The residuals follow a normal distribution

H_a: The residuals do not follow a normal distribution.

As the computed p-value was greater than the significance level, alpha = 0.05, one could not reject the null hypothesis H_0.

Figure A.2

Comparison of Experimental Distributions (Initial vs. Augmented)

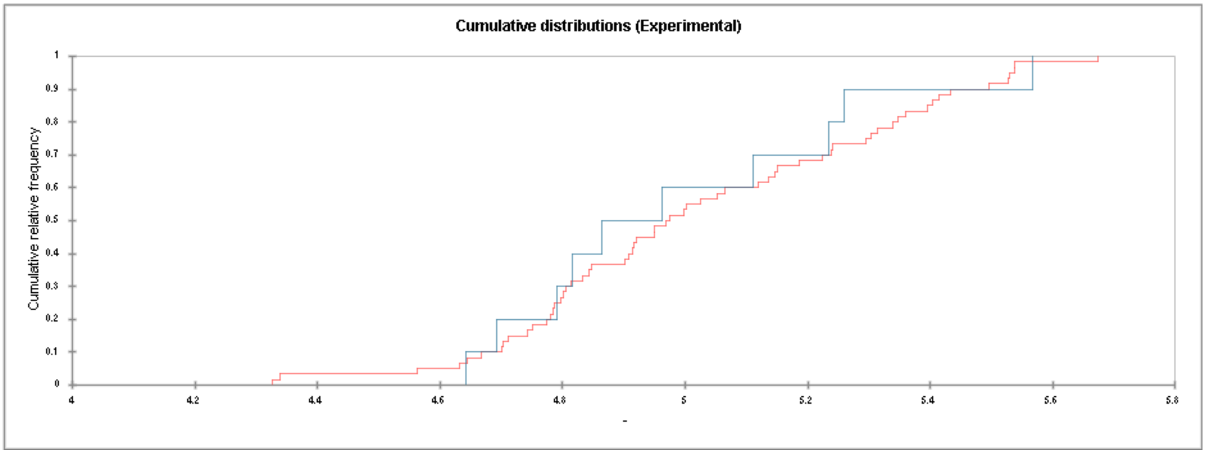


Table A.5

Initial vs. Augmented Descriptive Analysis: Control Groups

Variable	Obs	Obs. with missing data	Obs. without missing data	Min	Max	Mean	Std. deviation
Control	10	0	10	3.642	6.025	4.716	0.715
Control Normal (4.716, 0.715)	60	0	60	3.206	6.404	4.696	0.733

Table A.6

Two-Sample Kolmogorov–Smirnov Test/Two-Tailed Test

D	0.167
p-value (Two-tailed)	0.971
alpha	0.05

An approximation was used to compute the p-value

Test interpretation:

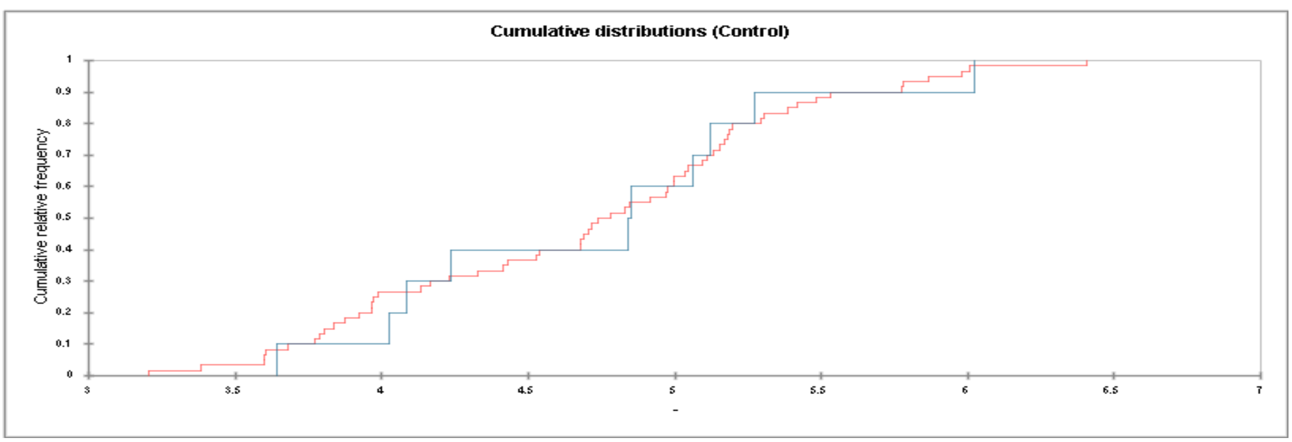
H0: The two samples follow the same distribution.

Ha: The distributions of the two samples are different.

As the computed p-value is greater than the significance level alpha=0.05, one cannot reject the null hypothesis H0.

Figure A.3

Comparison of Control Distributions (Initial vs. Augmented)



Appendix B: Supplemental Tables and Figures of Results Statistical Cross-Validation

Table B.1

*Descriptive Statistics **for Cross-Validation of Experimental Group Samples (N=25)***

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
Experimental normal (4.99, 0.294073)	60	0	60	4.326	5.674	5.026	0.311
Cross validation experimental normal (4.99, 0.294073)	25	0	25	4.632	5.530	5.010	0.254

Table B.2

*Two-Sample **Kolmogorov–Smirnov Test/Two-Tailed Test (Experimental Group)***

D	0.140
p-value (Two-tailed)	0.880
alpha	0.05

An approximation value was used to compute the p-value.

Test interpretation:

H0: The two samples follow the same distribution.

Ha: The distributions of the two samples are different.

Figure B.1

Two-Sample Kolmogorov–Smirnov Test/Two-Tailed Test (Experimental Group)

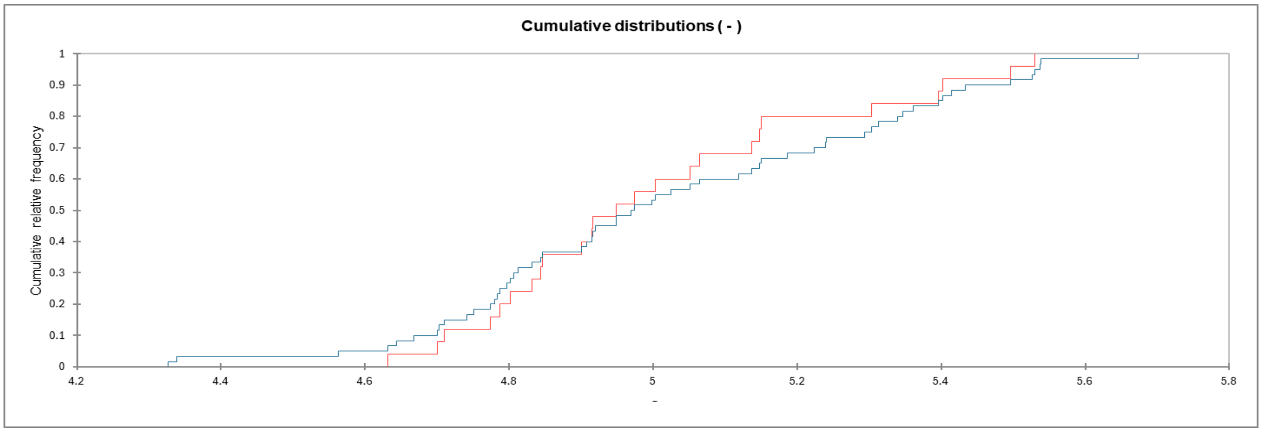


Table B.3

*Descriptive Statistics **for Cross-Validation of Control Group Samples (N=25)***

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
Control normal (4.716,0.715)	60	0	60	3.206	6.404	4.696	0.733
Cross validation control normal (4.716,0.715)	25	0	25	3.206	6.006	4.706	0.842

Table B.4

*Two-Sample **Kolmogorov–Smirnov Test/Two-Tailed Test (Control Group)***

D	0.140
p-value (Two-tailed)	0.880
alpha	0.05

An approximation has been used to compute the p-value.

Test interpretation:

H0: The two samples follow the same distribution.

Ha: The distributions of the two samples are different.

Figure B.2

Two-Sample Kolmogorov–Smirnov Test/Two-Tailed Test (Control Group)

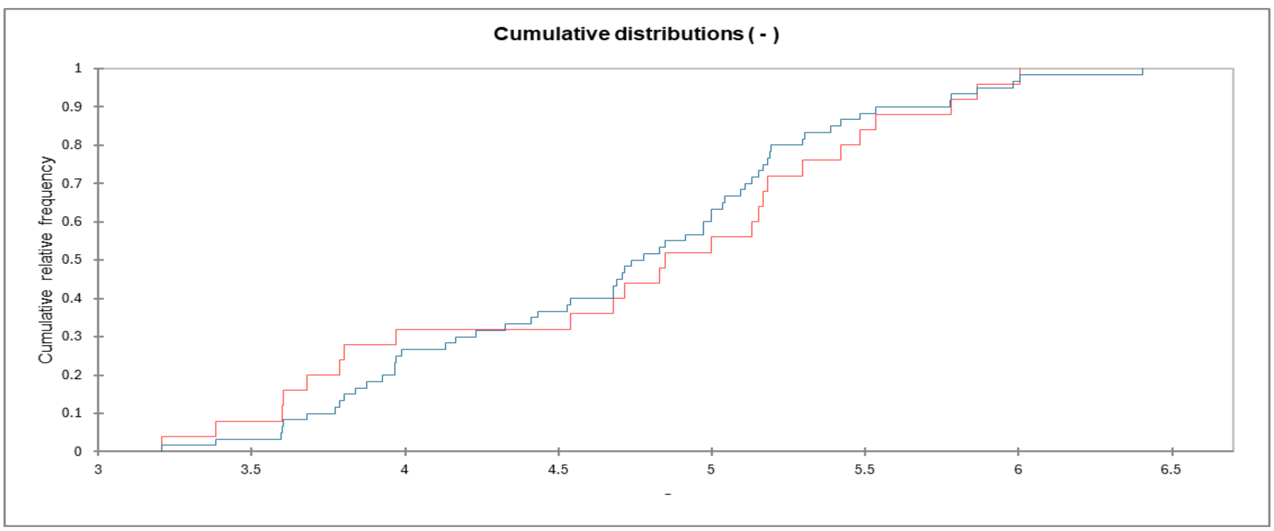


Table B.5

*Descriptive **Statistics for Cross-Validation of** Experimental **and** Control **Group Samples (N=25)***

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
Cross validation experimental normal (4.99, 0.294073)	25	0	25	4.632	5.530	5.010	0.254
Cross validation control normal (4.716, 0.715)	25	0	25	3.206	6.006	4.706	0.842

Table B.6

*T-Test for T**wo I**ndependent S**amples/Upper-**T**ailed T**est (Control vs. Experimental Group) Cross-Validation***

] 0.006,	+Inf [
Difference	0.305
t (Observed value)	1.733
t (Critical value)	1.700
DF	28.348
p-value (one-tailed)	0.047
alpha	0.05

The number of degrees of freedom is approximated by the Welch-Satterthwaite formula.

The critical t is estimated using the Cochran-Cox approximation.

Test interpretation:

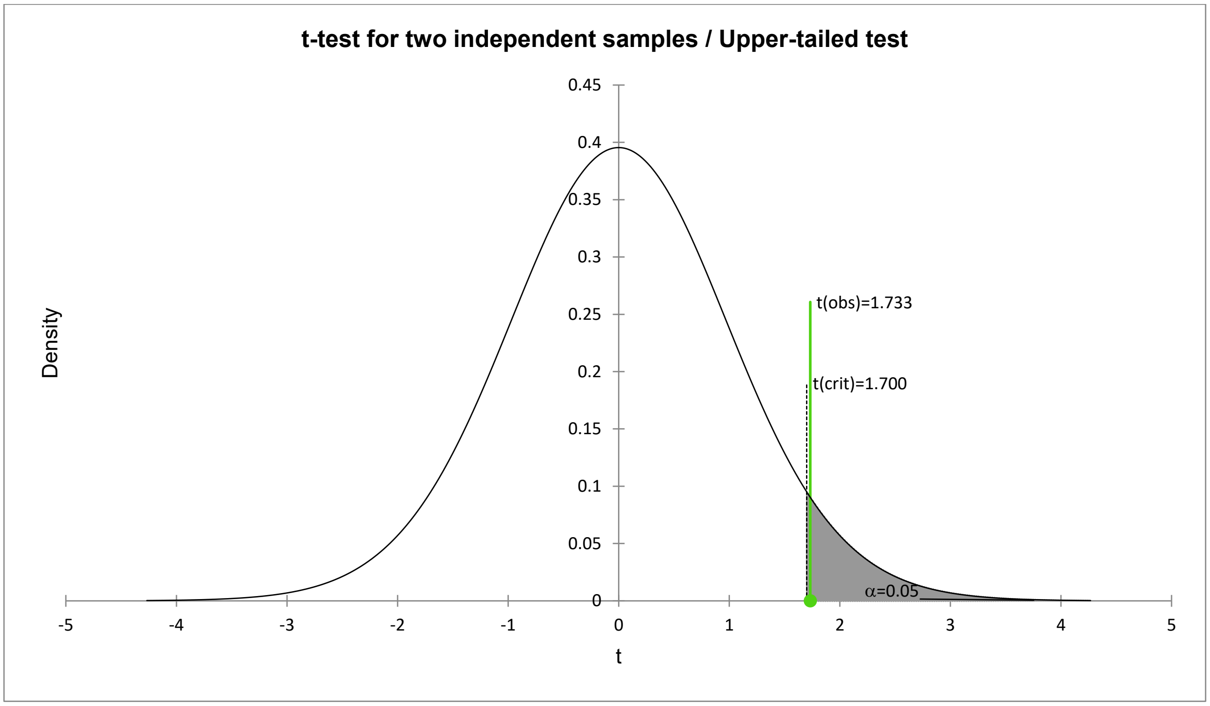
H0: The difference between the means is equal to 0.

Ha: The difference between the means is greater than 0.

As the computed p-value is lower than the significance level alpha=0.05, one should reject the null hypothesis H0, and accept the alternative hypothesis Ha.

Figure B.3

T-Test for Two Independent Samples/Upper-Tailed Test (Control vs. Experimental Group) Cross-Validation



Appendix C: Motivated Strategies for Learning Questionnaire (MSLQ)

Part A. Motivation

The following questions ask about your motivation for and attitudes about this class. Remember that there are no right or wrong answers, just answers as accurately as possible. Use the scale to answer the questions. If you think the statement is very true of you, circle 7; if a statement is not at all true of you, circle 1. If the statement is more or less true of you, find the number between 1 and 7 that best describes you.

1	2	3	4	5	6	7
Not at all true of me					Very true of me	

1. In a class like this, I prefer course material that really challenges me so I can learn new things.

1 2 3 4 5 6 7

2. If I study in appropriate ways, then I will be able to learn the material in this course.

1 2 3 4 5 6 7

3. When I take a test I think about how poorly I am doing compared with other students.

1 2 3 4 5 6 7

4. I think I will be able to use what I learn in this course in other courses.

1 2 3 4 5 6 7

5. I believe I will receive an excellent grade in this class.

1 2 3 4 5 6 7

6. I'm certain I can understand the most difficult material presented in the readings for this course.

1 2 3 4 5 6 7

7. Getting a good grade in this class is the most satisfying thing for me right now.

1 2 3 4 5 6 7

8. When I take a test I think about items on other parts of the test I can't answer.

1 2 3 4 5 6 7

9. It is my own fault if I don't learn the material in this course.

1 2 3 4 5 6 7

10. It is important for me to learn the course material in this class.

1 2 3 4 5 6 7

11. The most important thing for me right now is improving my overall grade point average, so my main concern in this class is getting a good grade.

1 2 3 4 5 6 7

12. I'm confident I can learn the basic concepts taught in this course.

1 2 3 4 5 6 7

13. If I can, I want to get better grades in this class than most of the other students.

1	2	3	4	5	6	7

14. When I take tests I think of the consequences of failing.

1	2	3	4	5	6	7

15. I'm confident I can understand the most complex material presented by the instructor in this course.

1	2	3	4	5	6	7

16. In a class like this, I prefer course material that arouses my curiosity, even it if is difficult to learn.

1	2	3	4	5	6	7

17. I am very interested in the content area of this course.

1	2	3	4	5	6	7

18. If I try hard enough, then I will understand the course material.

1	2	3	4	5	6	7

19. I have an uneasy, upset feeling when I take an exam.

1	2	3	4	5	6	7

20. I'm confident I can do an excellent job on the assignments and tes in this course.

1	2	3	4	5	6	7

21. I expect to do well in this class.

1	2	3	4	5	6	7

22. The most satisfying think for me in this course is trying to understand the content as thoroughly as possible.

1	2	3	4	5	6	7

23. I think the course material in this class is useful for me to learn.

1	2	3	4	5	6	7

24. When I have the opportunity in this class, I choose course assignments that I can learn from even if they don't guarantee a good grade.

1	2	3	4	5	6	7

25. If I don't understand the course material, it is because I didn't try hard enough.

1	2	3	4	5	6	7

26. I like the subject matter of this course.

1	2	3	4	5	6	7

27. Understanding the subject matter of this course is very important to me.

1	2	3	4	5	6	7

28. I feel my heart beating fast when I take an exam.

1	2	3	4	5	6	7

29. I'm certain I can master the skills being taught in this class.

1	2	3	4	5	6	7

30. I want to do well in this class because it is important to show my ability to my family, friends, employer, and others.

1	2	3	4	5	6	7

31. Considering the difficulty of this course, the teacher, and my skills, I think, I will do well in this class.

1	2	3	4	5	6	7

Part B. Learning Strategies

The following questions ask about your learning strategies and study skills for this class. Again, there are no right or wrong answers. Answer the questions about how you study in this class as accurately as possible. Use the same scale to answer the remaining questions. If you think the statement is very true of you, circle 7; if a statement is not at all true of you, circle 1. If the statement is more or less true of you, find the number between 1 and 7 that best describes you.

1	2	3	4	5	6	7
Not at all true of me					Very true of me	

32. When I study the readings for this course, I outline the material to help me organize my thoughts.

1	2	3	4	5	6	7

33. During class time, I often miss important points because I'm thinking of other things.

1 2 3 4 5 6 7

34. When studying for this course, I often try to explain the material to a classmate or friend.

1 2 3 4 5 6 7

35. I usually study in a place where I can concentrate on my course work.,

1 2 3 4 5 6 7

36. When reading for this course, I make up questions to help focus my reading.

1 2 3 4 5 6 7

37. I often feel so lazy or bored when I study for this class that I quit before I finish what I planned to do.

1 2 3 4 5 6 7

38. I often find myself questioning things I hear or read in this course to decide if I find them convincing.

1 2 3 4 5 6 7

39. When I study for this class, I practice saying the material to myself over and over.

1 2 3 4 5 6 7

40. Even if I have trouble learning the material in this class, I try to do the work on my own, without help from anyone.

1 2 3 4 5 6 7

41. When I become confused about something I'm reading for this class. I go back and try to figure it out.

1 2 3 4 5 6 7

42. When I study for this course, I go through the readings and my class notes and try to find the most important ideas.

1 2 3 4 5 6 7

43. I make good use of my study time for this course.

1 2 3 4 5 6 7

44. If course readings are difficult to understand, I change the way I read the material.

1 2 3 4 5 6 7

45. I try to work with other students from this class to complete the course assignments.

1 2 3 4 5 6 7

46. When studying for this course, I read my class notes and the course readings over and over again.

1 2 3 4 5 6 7

47. When a theory, interpretation, or conclusion is presented in class or in the readings. I try to decide if there is good supporting evidence.

1 2 3 4 5 6 7

48. I work hard to do well in this class even if I don’t like what we are doing.

1 2 3 4 5 6 7

49. I make simple charts, diagrams, or tables to help me organize course material.

1 2 3 4 5 6 7

50. When studying for this course, I often set aside time to discuss course material with a group of students from the class.

1 2 3 4 5 6 7

51. I treat the course material as a starting point and try to develop my own ideas about it.

1 2 3 4 5 6 7

52. I find it hard to stick to a study schedule.

1 2 3 4 5 6 7

53. When I study for this class, I pull together information form different sources, such as lectures, readings and discussions.

1 2 3 4 5 6 7

54. Before I study new course material thoroughly, I often skim it to see how it is organized.

1 2 3 4 5 6 7

55. I ask myself questions to make sure I understand the material I have been studying in this class.

1 2 3 4 5 6 7

56. I try to change the way I study in order to fit the course requirements and the instructor's teaching style.

1 2 3 4 5 6 7

57. I often find that I have been reading for this class but I don' know what I was all about.

1 2 3 4 5 6 7

58. I ask the instructor to clarify concepts I don't understand well.

1 2 3 4 5 6 7

59. I memorize key words to remind me of important concepts in this class.

1 2 3 4 5 6 7

60. When course work is difficult, I either give up or only study the easy parts.

1 2 3 4 5 6 7

61. I try to think through a topic and decide what I am supposed to learn from it rather than just reading it over when studying for this course.

1 2 3 4 5 6 7

62. I try to relate ideas in this subject to those in other courses whenever possible.

1 2 3 4 5 6 7

63. When I study for this course, I go over my class notes and make an outline of important concepts.

1 2 3 4 5 6 7

64. When reading for this class, I try to relate the material to what I already know.

1 2 3 4 5 6 7

65. I have a regular place to set aside for studying.

1 2 3 4 5 6 7

66. I try to play around with ideas of my own related to what I am learning in this course.

1 2 3 4 5 6 7

67. When I am study for this course, I write brief summaries of the main ideas from the readings and my class notes.

1 2 3 4 5 6 7

68. When I can’t understand the material in this course, I ask another student in this class for help.

1 2 3 4 5 6 7

69. I try to understand the material in this class by making connections between the readings and the concepts from the lectures.

1 2 3 4 5 6 7

70. I make sure that I keep up with the weekly readings and assignments for this course.

1 2 3 4 5 6 7

71. Whenever I read or hear an assertion or conclusion in this class, I think about possible alternatives.

1 2 3 4 5 6 7

72. I make lists of important items for this course and memorize the lists.

1 2 3 4 5 6 7

73. I attend this class regularly.

1 2 3 4 5 6 7

74. Even when course materials are dull and uninteresting, I manage to keep working until I finish.

1 2 3 4 5 6 7

75. I try to identify students in the class whom I can ask for help if necessary.

1 2 3 4 5 6 7

76. When studying for this course I try to determine which concepts I don't understand well.

1 2 3 4 5 6 7

77. I often find that I don't spend very much time on this course because of other activities.

1 2 3 4 5 6 7

78. When I study for this class, I set goals for myself in order to direct my activities in each study period.

1 2 3 4 5 6 7

79. If I get confused taking notes in class, I make sure I sort it out afterwards.

1 2 3 4 5 6 7

80. I rarely find the time to review my notes or readings before an exam.

1 2 3 4 5 6 7

81. I try to apply ideas from course readings in other class activities such a lecture and discussion.

1 2 3 4 5 6 7

Appendix D: Constructivist Learning Aspects and Improved Student Abilities

Constructivist learning aspects	MSLQ construct	Improved student ability
Making long-term connections with information being learned	Elaboration	Paraphrasing, summarizing, and creating analogies
	Critical thinking	Solving problems, making decisions, and evaluating situations
Social aspects of learning	Interacting with others	Working collaboratively in groups to learn concepts
	Seeking help	Using LLMs for adaptive learning
Relevant and appropriate learning situations	Organization	Clustering, outlining, and identifying main ideas
	Study management planning	Correct study environment, setting up study schedule, planning appropriate study activities
Taking control of your learning	Self-regulation	Planning appropriate learning goals, monitoring progress, and staying focused
	Effort regulation	Avoiding distractions

Source: Johnson et al. (1991); Pintrich et al. (1991).

Appendix E: Constructivist Learning Activities Implemented in the Study

1. A comparison of exam questions activity was incorporated to review for a quiz. In this lesson, individual students wrote one multiple-choice question and then asked AI to create a second multiple-choice question. They also assessed which questions better assessed the concepts (Schmidli et al., 2023).

2. The activity 'Correcting a Bad Essay' was employed when the students had to write a paper. At the beginning of this lesson, the students ask AI to write a grammatically poor and inaccurate essay about their topic. The students should try using different prompts and large language models to get their worst essay. Then, students will copy and paste their AI essay into a Word document. They will trace and correct the grammatical errors using annotations and why they think AI made the errors. They will need to write a one-page addendum to their bad essay answering the following questions:
   - What was your topic?
   - Which prompt and model gave you your worst essay?
   - How does prompting affect your results?
   - Were there any trends in the grammatical errors? Why do you think that the model made these errors?
   - Were there any trends in the factual errors? Why do you think that the model made these errors?
   - Share some insights about AI and your topic that might have surfaced through this assignment (Schmidli et al., 2023)

3. In this course, students created a thesis for a research paper. As they developed their thesis statements, they were asked to use AI to revise them. In this activity, students used AI to develop and revise their thesis statements to acquire two to share with a group of students for feedback from their peers (Schmidli et al., 2023).