THE EFFECTS OF QUESTION PROMPT-BASED SCAFFOLDING AND SOCIAL PRESENCE ENHANCEMENT ON STUDENTS' ARGUMENTATION AND ILL-STRUCTURED PROBLEM-SOLVING

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by

NGOC-MINH THI PHAM

Dr. Rose M. Marra, Dissertation Supervisor

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The undersigned, appointed by the dean of the Graduate School, have examined the dissertation entitled

THE EFFECTS OF QUESTION PROMPT-BASED SCAFFOLDING AND SOCIAL PRESENCE ENHANCEMENT ON STUDENTS' ARGUMENTATION AND ILL-STRUCTURED PROBLEM SOLVING

presented by Ngoc-Minh Thi Pham,

a candidate for the degree of Doctor of Philosophy of Information Science and Learning Technologies, and hereby certify that, in their opinion, it is worthy of acceptance.

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Professor Rose M. Marra

_____

Professor Heather Moulaison-Sandy

_____

Professor Isa Jahnke

_____

Professor Jane Howland

_____

Professor Matthew Easter

DEDICATION

To my amazing children – Minh Chau Ngoc Nguyen and Brian Lee whose love and admiration for me encouraged me not to quit in the middle of my dissertation.

To my mother – Hien Vu for instilling in me a love for books and a curiosity for the world.

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Ngoc-Minh Thi Pham

Dr. Rose M. Marra, Dissertation Supervisor

ABSTRACT

Asynchronous online discussions have the potential to facilitate meaningful learning activities, such as ill-structured problem-solving, due to their asynchronicity and connectivity. However, the literature identifies two significant challenges in effectively supporting students' ill-structured problem-solving in these environments - argumentation and social interactions. Although argumentation is critical for ill-structured problem-solving, students tend to avoid engaging in critical argumentation activities, such as generating rebuttals and counterarguments, to construct meaning in discussion forums. Similarly, social interactions are essential to ill-structured problem-solving, but students tend to display low levels of engagement in asynchronous online discussions.

This study aimed to explore how these two critical components of problem-solving can be supported in asynchronous online discussions using question prompt-based argumentation scaffolds in combination with social presence enhancement strategies. The primary focus was to compare the differential effects of question prompts alone and the combination of question prompts with social presence enhancement prompts on students' argumentation behaviors, problem-solving processes during discussions, and post-test problem-solving performance.

This study randomly assigned 44 students to three conditions (control, question prompt-based, and question prompt with social presence enhancement) to analyze their argumentation behaviors, problem-solving processes, and problem-solving performance in asynchronous online discussions. The findings reveal that: (1) lower level interactive argumentation behaviors dominate over higher level interactive ones; (2) students focus more on identifying problem representations and generating solutions than on justifying and evaluating them; (3) there is no significant difference in argumentation behaviors and problem-solving processes in asynchronous online discussions across the conditions. However, students who received both the question prompt scaffolds and the social presence enhancement strategies consistently showed more evidence of engaging in argumentation, especially higher level interactive argumentation, and in problem-solving processes; and (4) there is a significant difference in post-test problem-solving performance across conditions, where students in the condition that received both the question prompt scaffolds and the social presence enhancement strategies performed significantly better than students in the control condition.

The study's findings underscore the importance of supporting students' social presence to engage them in interactive argumentation and problem-solving processes, thereby enhancing their problem-solving performance. This study contributes to the understanding of argumentation scaffolding and social interactions in asynchronous online discussion environments and provides design recommendations for instructional designers and instructors seeking to support students' argumentation and social presence in these environments.

1. INTRODUCTION

Overview

Problem-solving is widely recognized as the most critical learning outcome in life, according to psychologists and educators (Jonassen, 1997). Both young and old individuals frequently encounter and solve problems in their daily lives, whether in the workplace or personal settings. In educational environments, engaging and supporting problem-solving has demonstrated positive learning outcomes, including improved content comprehension, heightened knowledge construction and retention levels, and ultimately, greater knowledge transferability (Jonassen, 2010; Tawfik et al., 2019; Wang et al., 2017). Problem-solving also facilitates intentional learning, which is goal-driven and necessary for achieving meaningful learning outcomes (Jonassen, 2011). Given these benefits, problem-solving should be prioritized in students' learning, particularly in online education, which is gaining increasing attention in formal education. Problem-solving is essential to create meaningful online learning experiences for learners in virtual environments.

Unfortunately, in educational settings, activities that foster meaningful learning, such as problem-solving, are often not given the attention they deserve. Traditional student assessment formats and high-stakes standardized tests typically evaluate memorized knowledge and lower levels of understanding rather than focusing on higher-order thinking skills (Frey, 2018). In many cases, learning activities in educational settings emphasize obtaining correct answers rather than fostering a deeper understanding of concepts (Jonassen, 2011).

When presented with problems to solve, students are often expected to complete exercises that rely on applying previously learned procedures rather than tackling real-life ill-structured problems that require critical thinking, decision-making, and argumentation skills (Carlgren, 2013; Chiang & Lee, 2016; Jonassen, 2000; Vos, 2018). Consequently, a significant body of evidence suggests that students, even at the higher education level, lack vital skills such as problem-solving that are essential for thriving as citizens in the 21st century (e.g., Aslan, 2021; Carlgren, 2013; Khoiriyah & Husamah, 2018).

As formal education increasingly shifts towards online instruction, it is essential to prioritize and support meaningful learning activities, such as problem-solving, in virtual settings. A crucial component of online learning is asynchronous online discussion forums (AODFs), which provide an environment for fostering collaborative and meaningful learning activities, including problem-solving. Through AODFs, students can engage in collaborative learning and social interactions, which are crucial aspects of the learning process, as emphasized by social constructivists (Qureshi et al., 2021; Webb et al., 2004).

AODFs also can facilitate the development of higher-order thinking skills such as critical thinking, creativity, metacognition, and problem-solving (Gašević et al., 2015; Koszalka et al., 2021; Marra et al., 2004). Given these features, AODFs can be viewed as well-placed to facilitate quality learning; however, the evidence of collaborative learning and higher-order thinking skills, such as engagement, critical thinking, and problem-solving in AODFs is limited (Al-Husban & Almad, 2020; Cheung & Hew, 2005; Kew & Tasir, 2021; Marra et al., 2004).

This study will examine how components that are critical to problem-solving may be applied in asynchronous online discussion forums: argumentation and social interactions.

Solving problems, especially ill-structured problems, requires argumentation (Cerbin, 1998; Chiu, 2008; Cho & Jonassen, 2002; Kim et al., 2022; Oh & Jonassen, 2007; Tawfik, 2017; Tawfik et al., 2018, 2021) and social interactions (Hesse et al., 2015; Rosen et al., 2020). Substantial evidence has shown the positive effects of argumentation during problem-solving. For example, argumentation supports the generation of the shared mental model or joint problem space (Hesse et al., 2015) and enables the production of coherent arguments to justify solutions and actions (Jonassen, 2011).

Social interactions are also well-established to be important to learning (Blasco-Arcas et al., 2013; Fawcett & Garton, 2005; Fu et al., 2009; Kuo et al., 2014; Lave & Wenger, 1991b; Luo et al., 2017; Piaget, 1985; Sims, 2003; Slavin, 1995; Vygotsky, 1978; Ye & Pennisi, 2022) and problem-solving (Fawcett & Garton, 2005; Graesser et al., 2018; Lumpe, 1995; Nelson, 1999; Roschelle & Teasley, 1995; Tawfik et al., 2018). Research also shows that the effects of social interactions on problem-solving are optimized when it involves critical discourse (Fawcett & Garton, 2005). Yet research to understand the impacts of different approaches to support students' co-constructive discourse while solving problems in AODFs on students' learning has been sparse.

This chapter aims to provide the necessary background information for the study. It will conclude with a statement of the specific problem that this study intends to address, the overall purpose of the research, the key research questions that guided the

study, a summary of the chapter, and an explanation of the key terms used throughout the research.

Problem-solving

The primary focus of education should be to engage and support students' problem-solving abilities is well established in the literature. Gagné (1980) emphasized this point by stating that "the central point of education is to teach people to think, to use their rational powers, to become better problem solvers" (p. 85). Similarly, Jonassen (2000) regarded problem-solving as a crucial cognitive activity in both personal and work-related situations, stating that "virtually everyone, in their everyday and professional lives, regularly solves problems" (p. 63).

While problems can be solved individually, collaborative problem-solving is one of the most common and natural situations in which people accomplish the work of society (Ak, 2016; Ge & Land, 2003; Graesser et al., 2018; Lin et al., 2014; Nelson, 1999; Wu, 2020). Problems can be classified into two categories: well-structured and ill-structured. Well-structured problems, such as finding the value of x in an algebraic equation or determining the acceleration of a falling object, are characterized by clear goals, a constrained content domain, defined problem elements, a known procedure for solving, and convergent solutions (Huang & Ge, 2022; Jonassen, 2011). Ill-structured problems, such as global warming, school shootings, rising gas prices, or designing a product for a new market, are characterized by their complexity and lack of clear definition. These problems typically lack defined elements and may have conflicting goals. Additionally, they may involve interdisciplinary knowledge domains, making it challenging to identify an appropriate problem-solving procedure (Huang & Ge, 2022;

Jonassen, 2011; Simon & Simon, 1978). As a consequence, ill-structured problems often have multiple possible solutions, and solution paths, or may even have no clear solutions at all, which makes problem-solving more challenging and requires higher-order thinking skills, such as critical thinking, creativity, and argumentation to solve (Jonassen, 1997, 2000, 2002, 2011).

Problem-solving is crucial in life, yet formal educational settings often neglect to provide students with opportunities to engage in meaningful problem-solving activities (Jonassen, 2011; Radermacher et al., 2014; Rios et al., 2020). Instead, the emphasis is often placed on rote memorization and the application of previously learned procedures (Carlgren, 2013; Chiang & Lee, 2016; Jonassen, 2010). Unfortunately, problem-solving is often taught as a procedure to be memorized, practiced, and trained, with the focus on obtaining the correct answer rather than understanding the underlying concept (Jonassen, 2011; Vos, 2018). Over-reliance on solely quantitative problem representations in educational problem-solving is incongruent with the complex, real-world problems students encounter in their daily lives. Such problems require an understanding of deep-level structural characteristics and qualitative problem representations or schemas (Jonassen, 2011).

The present approach to teaching problem-solving in formal education mirrors our limited understanding of the entire range and complexity of problem-solving processes and activities (Jonassen, 2011) and the instructional strategies required to effectively engage and support students in these processes (Caena & Redecker, 2019). Hence, this demands further research in this field.

Argumentation and Problem-solving

Problem-solving is a multifaceted activity that requires various skills and activities, including argumentation (Cerbin, 1998; Chiu, 2008; Jonassen, 1997, 2000, 2011; Kim et al., 2022; Tawfik, 2017; Tawfik et al., 2018, 2021; Voss & Post, 1988). Argumentation involves creating, questioning, invalidating, and comparing arguments using different forms of reasoning and supporting evidence (Andriessen et al., 2003; Eemeren et al., 1987; Toulmin, 2003; van Eemeren et al., 2015).

Argumentation is a crucial factor that predicts student performance in both well-structured and ill-structured problems (Burnett, 1993; Chiu, 2008; Jonassen, 2011; Kim et al., 2022; Pratiwi et al., 2019; Shin et al., 2003). While argumentation can facilitate problem-solving in both cases, it is particularly critical for supporting ill-structured problem-solving (Jonassen, 2011; Kim et al., 2022; Tawfik et al., 2018; Yeong, 2021). Since ill-structured problems lack convergent answers or consistent solutions, students must construct arguments to justify each step of their problem-solving process and decisions (Cho & Jonassen, 2002; Jonassen, 1997; Kim et al., 2022; Voss & Post, 1988).

Argumentation and Problem-solving in Discussion Forums

A body of empirical studies reveals that asynchronous online discussion forums can promote problem-solving skills among students (Chandrasekaran et al., 2019; Jonassen & Kwon, 2001; Lin et al., 2014; Wu, 2020). These forums engage students in collaborative problem-solving, similar to how problems are solved in natural situations (e.g., Cho & Jonassen, 2002; Wu, 2020; Yeong, 2021). The types of problems integrated into asynchronous online discussion forums for students to solve are diverse, ranging from well-structured to ill-structured ones.

However, students, especially novices in problem-solving, face challenges when participating in problem-solving in online discussions. First, they may lack domain-specific knowledge, which can negatively affect the generation of adequate solutions (Yeong, 2021). Second, students may not have adequate structural knowledge to retrieve appropriate solution procedures for ill-structured problems (Funke, 2019; Ng & Tan, 2006). Third, although they may have essential critical thinking skills, evidence of higher-order thinking skills such as metacognition, critical thinking, and creativity is still limited (Al-Husban & Almad, 2020; Cheung & Hew, 2005; Kew & Tasir, 2021; Marra et al., 2004). Fourth, students may not engage in the full range of metacognition skills, especially argumentative skills, which can help construct meaning in discussion forums during problem-solving (Jeong & Joung, 2007; Tawfik et al., 2021; Tsai & Tsai, 2014). Fifth, students may lack engagement in co-constructive critical discussions in online forums, which can negatively affect the meaning-making from multiple perspectives in problem-solving (Ding et al., 2018; Snyder & Dringus, 2014; Zhu, 2006).

Despite the importance of argumentation in problem-solving, peer-led argumentative activities in online discussions are not always productive, even with strong instructional support. Students in online discussions rarely engage in counterarguments and rebuttals (e.g., Cho & Jonassen, 2002; Ding et al., 2018; Jeong & Joung, 2007; Oh & Jonassen, 2007; Snyder & Dringus, 2014; Zhu, 2006). For example, Snyder and Dringus (2014) found that student-led discussions tend to consist mainly of declarative statements rather than critical arguments and reflections that advance the discussion. Consequently, the lack of substantial argumentation beyond defending one's position can lead to a degradation in the quality of arguments, insufficient exploration of conflicting ideas, and

failure to construct knowledge that integrates multiple perspectives on an issue (Cho & Jonassen, 2002; Ertmer et al., 2011; Snyder & Dringus, 2014).

Several factors can contribute to students' lack of engagement in co-constructive critical discussions in online forums. First, they may lack domain-specific knowledge (Valero Haro et al., 2022; Yeong, 2021). Second, students may lack structural knowledge (Jonassen, 2011). Third, students may lack argumentation skills (Kim et al., 2022; Kuhn, 1991; Oh & Kim, 2016; Stegmann et al., 2007; Tawfik, 2017; Tsai & Tsai, 2014), especially those who rarely deal with counterarguments and rebuttals. Fourth, individual differences such as social skills, argumentativeness, and epistemological beliefs affect their disposition to argue (e.g., Gronostay, 2019; Infante & Rancer, 1982; Michael Nussbaum & Bendixen, 2003; Noroozi, 2018; Nussbaum, 2002). Fifth, social reasons can also play an important role in students' disposition toward argumentation (Albe, 2008; Grooms et al., 2018). Finally, social presence in online discussions may affect students' disposition toward argumentation. A warm, trustful, and comfortable environment nurtures collaborative learning. Rourke and Anderson (2002) found that students may not willingly critique their peers' ideas and may take others' critiques as a personal offense unless they feel close to them, and sense warmth, belonging, and mutual trust.

The issues in collaborative problem-solving in online discussions and challenges to engage students in critical argumentation during the problem-solving processes present the need for scaffolding students' argumentation during problem-solving processes in a way that can create an environment in which students feel comfortable learning to argue and arguing to learn.

Scaffolding

Theory Base

The term "scaffolding" was first introduced by Wood and his colleagues in 1976 (Wood et al., 1976). They defined scaffolding as the process in which an instructor or a more knowledgeable peer provides supportive tools to learners as they construct knowledge. Scaffolding instruction, as a teaching strategy, is based on Vygotsky's Sociocultural Theory of Development and his concept of the Zone of Proximal Development (ZPD) (Vygotsky, 1978). Vygotsky proposed that learning activities should provide appropriate challenges to the learner based on their current knowledge, but not so difficult as to be unattainable. Several theories, including the social learning theory (Bandura & Walters, 1977), the community of practice (Lave & Wenger, 1991b), the cognitive apprenticeship (Brown et al., 1989), and connectivism (Siemens, 2017), are associated with scaffolding. All these theories emphasize the importance of modeling and social interactions to learning.

Scaffolding via Question Prompts

There is a substantial body of literature on the use of question prompts as a scaffolding strategy, as evidenced by numerous studies; However, while most of these studies have focused on using question prompts to support the cognitive aspects of ill-structured problem-solving, research on using question prompts to support interactivity in problem-solving is still limited (e.g., Byun et al., 2014; Ge & Land, 2004).

Questioning is “at the heart of virtually any complex task that an adult performs” (Graesser & Olde, 2003, p. 524), and it supports problem-solving in multiple ways. Firstly, questioning is one of the most fundamental cognitive components that guide

human reasoning (Graesser et al., 1996; Jonassen, 2011; Okwumabua et al., 2018). Therefore, during problem-solving, questioning can function as a cognitive strategy to support students in comprehending the problem and generating solutions (Jonassen, 2011). Secondly, answering deep reasoning questions also supports the articulation of causal processes, goals, plans, actions, and justifications (Graesser et al., 1996; Jonassen, 2011; Tawfik et al., 2020). Thirdly, question prompts facilitate the active processing of materials, thereby increasing the understanding of the problem and generating better solutions (Shin et al., 2003). Additionally, questions help individuals focus on the task at hand by activating concepts stored in their memory (Okwumabua et al., 2018).

Given the benefits of question prompts, they serve as powerful scaffolds to support problem-solving tasks. Research has shown a variety of positive effects of question prompts on students' problem-solving performance, especially in the states of justification, monitoring, and evaluation (e.g., Byun et al., 2014; Davis, 2000; Ge & Land, 2003; Mahtari et al., 2020; Xie & Bradshaw, 2008), cognition demands in ill-structured problem-solving (e.g., Ge & Land, 2003; Gu et al., 2015; Jonassen, 1997; Mahtari et al., 2020; Papadopoulos et al., 2011; Tawfik et al., 2018), and supporting argumentation (Graesser et al., 1996; Jonassen, 2011; Ju & Choi, 2017; Nussbaum, 2021).

However, research on scaffolding via question prompts has not always shown that they support problem-solving. Several factors may account for these undesirable situations. First, students may lack cognitive, metacognitive, and argumentation skills to solve problems (Safari & Meskini, 2015). Second, students may not be motivated to achieve learning outcomes. (Lavrinenko et al., 2019). Third, students may not be actively

involved in collaborative problem-solving, even when placed in groups to solve problems (Ge & Land, 2004).

Problem Statement

Prior studies have identified major problems that negatively affect students' learning in asynchronous online discussion forums, particularly in the context of problem-solving. Firstly, students tend not to engage in critical argumentation to construct meaning in discussion forums, even with strong instructional support. Research has consistently shown that students rarely engage in counterarguments and rebuttals (Cho & Jonassen, 2002; Ding et al., 2018; Jeong & Joung, 2007; Oh & Jonassen, 2007; Snyder & Dringus, 2014; Zhu, 2006). Secondly, despite the importance of social interactions for successful online learning and collaborative knowledge building, students tend to disengage in co-constructive critical discussions, which negatively affects meaning-making from multiple perspectives (An et al., 2009; Ding, 2019; Fehrman & Watson, 2021; Hara et al., 2000).

While research on using question prompts to support students' problem-solving and argumentation is well-established, studies on question prompts as a scaffolding strategy to support ill-structured problem-solving in asynchronous online discussion forums are limited and inconsistent in terms of problem-solving performance and the generation of co-constructive critical discussions. Similarly, there is limited research on the use of question prompts to support interactive argumentation in ill-structured problem-solving, in which students are more willing to use rebuttals and counterarguments. Furthermore, the effects of combining question prompts with

strategies to enhance students' social presence in discussion forums on problem-solving performance and argumentation are not well understood.

Purpose of Study

The aim of this study is twofold: (1) to investigate how asynchronous online discussion forums can support two critical components of problem-solving, namely argumentation and social interactions, and (2) to examine their impact on students' argumentation behaviors and problem-solving.

To achieve this purpose, the study was designed to scaffold students' argumentation during problem-solving in a way that enhances their interactive argumentation and to investigate the effects of scaffolding on students' argument behaviors, problem-solving processes, and problem-solving performance.

To assess the effects of the scaffolding strategy, the study established three experimental conditions: a control condition and two treatment conditions. In the control condition (condition 1), students received no question prompts while solving the problem and composing messages. In the first treatment condition (condition 2), students received cognitive question prompts to support argumentation behaviors. In the second treatment condition (condition 3), students received the same cognitive question prompts to support argumentation behaviors, along with social presence enhancement strategies.

Research Questions

The following research questions are examined in this study:

RQ1. How do argumentation behaviors in the discussion vary by the use of the scaffolds versus the use of the scaffolds together with social presence enhancement strategies, and no scaffolding in the three groups?

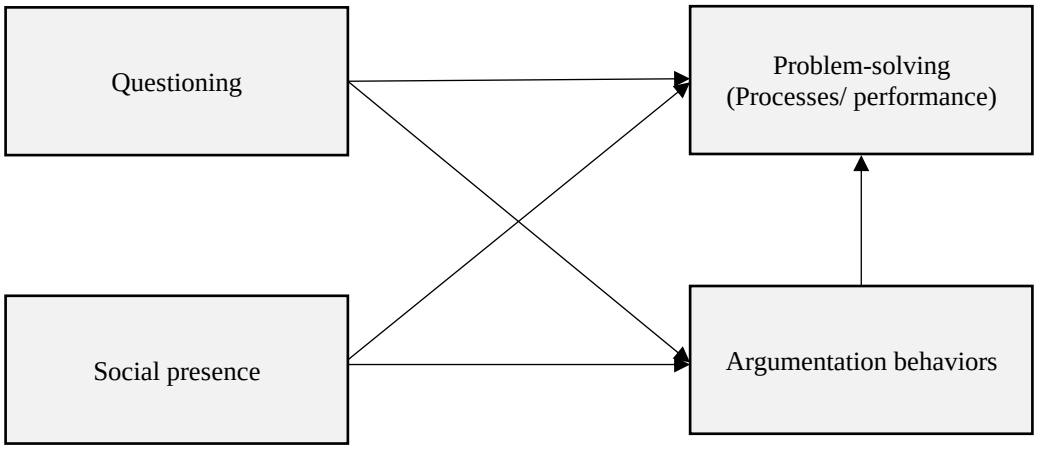
RQ2. How do students' problem-solving processes in the discussion vary between the three groups?

RQ3. How does the problem-solving performance vary between the three groups on a post-discussion problem-solving activity?

To enhance understanding, the key constructs explored in the research questions and their relationships to each other, are presented in Figure 1.1.

Figure 1.1

Key Constructs in the Study



Chapter Summary

This chapter introduces the background, research gap, purpose of the study, and research questions. Problem-solving is essential for life and is considered the most crucial cognitive activity for students (Jonassen, 1997). However, there is currently a gap in understanding how cognitive scaffolding strategies, such as question prompts, can support ill-structured problem-solving in asynchronous online discussion forums effectively, leading to meaningful learning for students.

Making arguments, including rebuttals and counterarguments, is a critical component of ill-structured problem-solving processes and the construction of higher

levels of knowledge (Oh & Kim, 2016; Oh & Jonassen, 2007; Tawfik et al., 2021). However, there is a research gap in understanding how question prompts can support and facilitate students' generation of critical argumentation.

While social interactions play an important role in learning in general (Blasco-Arcas et al., 2013; Fawcett & Garton, 2005; Fu et al., 2009; Kuo et al., 2014; Lave & Wenger, 1991b; Luo et al., 2017; Piaget, 1985; Sims, 2003; Slavin, 1995; Vygotsky, 1978; Ye & Pennisi, 2022) and in problem-solving in particular (Fawcett & Garton, 2005; Graesser et al., 2018; Lumpe, 1995; Nelson, 1999; Roschelle & Teasley, 1995; Tawfik et al., 2018), prior studies have mainly focused on supporting students' problem-solving from cognitive perspectives. Therefore, this study aims to bridge the gap by examining how two critical components of problem-solving: argumentation and social interactions can be supported in asynchronous online discussion forums using question prompts as a cognitive scaffolding strategy and social presence enhancement strategies.

Definition of Terms

- Argument: A purposeful and logical statement that conveys meaning and is supported by reasoning and evidence, intended to persuade, or convince others of a particular viewpoint or position (Andriessen et al., 2003)
- Argumentation: The process of creating, questioning, discrediting, and comparing arguments using various forms of reasoning, evidence, and critical thinking to reach a conclusion (Andriessen et al., 2003; Carr, 1999; Toulmin, 1985)
- Well-structured problem: A problem that has clear goals, all elements defined, and a known solution procedure leading to a single, convergent solution (Jonassen, 1997)

- Ill-structured problem: A complex, interdisciplinary problem that lacks clear goals, may have missing or conflicting elements, and has multiple possible solutions and solution paths (Jonassen, 1997; Simon, 1978)
- Social presence: The extent to which individuals can project themselves socially and emotionally in a virtual or physical learning community (Rourke et al., 2001)
- Scaffolding: A cognitive aid or support system that assists learners in the process of constructing knowledge, skills, and understanding (Vygotsky, 1978; Wood et al., 1976)

2. LITERATURE REVIEW

Overview

This chapter starts with an overview of the key constructs used in this study, including problem-solving, argumentation, social interactions, and question prompts. Each section discusses the constructs used in this study and their interdependencies through a theoretical lens and prior empirical studies. The chapter then delves into the challenges of supporting ill-structured problem-solving in asynchronous online discussion forums, followed by a discussion of research challenges and a summary of the chapter.

Problem-solving

Overview of Problems and Problem-solving

The word "problem" is derived from the Greek term "problema," meaning obstacle. This obstacle can take the form of a question or an issue whose solution or answer is uncertain, requiring careful analysis and resolution. According to Jonassen (2000), problems have two critical attributes: the unknown and its perceived value. Jonassen (2004) stated that the unknown aspect of a problem varies depending on the situation. In terms of the perceived value, the unknown must hold social, cultural, or intellectual significance to inspire people to seek a solution (Jonassen, 2004).

Problem-solving is one of the most complex yet crucial skills for the 21st-century (Chi & Glaser, 1985; Funke et al., 2018; Trilling & Fadel, 2009). It is vital for academic achievement and success in various workplace environments. According to Briones et al. (2021), problem-solving ranks among the top employability skills preferred by employers

because it helps employees tackle challenges in today's workplace. The significance of problem-solving skills is well-articulated by Stottler (2018), who states:

> "Problem-solving is at the core of human evolution. It is the methods we use to understand what is happening in our environment, identifying things we want to change, and then figure out the things that need to be done to create the desired outcome. Problem-solving is the source of all new inventions, social and cultural evolution, and the basis for market-based economies. It is the basis for continuous improvement, communication, and learning" (para. 2).

Solving problems, particularly ill-structured ones, often necessitate producing coherent arguments to justify solutions and actions (Oh & Kim, 2016; Oh & Jonassen, 2007; Tawfik et al., 2021), as well as social interactions for collaboration to achieve the objective (Fawcett & Garton, 2005; Graesser et al., 2018; Lumpe, 1995; Nelson, 1999; Roschelle & Teasley, 1995; Tawfik et al., 2018). Therefore, these two elements should be supported to enhance ill-structured problem-solving performance.

Argumentation in Ill-Structured Problem-solving

Argumentation plays a central role in problem-solving in various ways. Firstly, argumentation can lead to a shared mental model or joint problem space where problem-solving collaborators have similar individual problem representations (Hesse et al., 2015). Second, exposing students to arguments that contradict their current understanding can lead to a change in their concepts and correct any misunderstandings or "conceptual violations" (Eakin, 2005). This process supports problem-solving by allowing learners to adjust their previous beliefs, identify and correct reasoning errors, improve their problem representation, and reach a consensus on the most appropriate action to take (Asterhan &

Resnick, 2020; Diakidoy et al., 2015; Nussbaum & Sinatra, 2003; Schroeder & Kucera, 2022; Zengilowski et al., 2021). For example, when comparing undergraduate students who read a refutation text and control group subjects who read an expository text, Asterhan and Resnick (2020) found strong effects of the refutation text on improving students' conceptual understanding of the topic of their study. Third, argumentation supports problem solvers throughout the problem-solving process by enabling them to identify multiple alternative perspectives, views, and opinions. This process involves developing and selecting a preferred and reasonable solution and supporting it with coherent arguments using data and evidence (Cho & Jonassen, 2002; Hsu et al., 2015; Pratiwi et al., 2019; Voss et al., 1991; Wecker & Fischer, 2014). Last but not least, making arguments can improve students' reasoning (Nussbaum & Edwards, 2011; Nussbaum & Sinatra, 2003), which is critical to problem-solving, especially for ill-structured problems that do not have convergent answers or consistent solution criteria and require justifications for selected solutions and actions. The study by Nussbaum and Sinatra (2003) showed that students who were required to make arguments for their selected solution demonstrated improved reasoning on the problems. When the students were retested a year later, the quality of their reasoning remained strong.

In addition, promoting argumentation in problem-solving learning environments can improve problem-solving performance (Cho & Jonassen, 2002; Oh & Jonassen, 2007; Tan et al., 2001; Tawfik et al., 2018). By utilizing computer-supported collaborative argumentation tools, students can enhance their clarity of thought, organize their ideas, analyze in-depth, and consider multiple perspectives (Cho & Jonassen, 2002;

Hsu et al., 2015; Pratiwi et al., 2019; Tan et al., 2001; Voss et al., 1991; Wecker & Fischer, 2014).

Engaging in argumentation within problem-solving learning environments leads to higher levels of involvement. Students who receive argumentation scaffolding may be more engaged in problem-solving, as measured by their participation in the problem-solving environment, since dialogical argumentation supports knowledge recognition and retrieval (Voss et al., 1991). Studies by Cho and Jonassen (2002) and Oh and Jonassen (2007) have found that argumentation-scaffolded students produce more problem-solving communications, evidence notes, hypothesis messages, and hypothesis tasking messages than non-scaffolded groups, leading to more exposure to different perspectives and better problem-solving performance. Therefore, increased participation in argumentation activities can result in higher problem-solving performance.

Argumentation behaviors directly impact problem-solving performance, with positive behaviors correlating with better outcomes in collaborative problem-solving. When people engage in pleasant argumentation, they are more likely to consider and share multiple perspectives, which leads to better problem-solving. In a study by Chiu (2008), students who exhibited negative argumentation behaviors, such as being rude, disagreeable, or commanding, demonstrated less creativity in generating ideas during problem-solving than those who demonstrated polite argumentation behaviors. Providing evidence to support claims is also an important behavior for constructing arguments, but arguers often use insufficient or inconclusive evidence (Kuhn & Modrek, 2018; Walton, 2013) or fail to provide evidence (Oh & Jonassen, 2007; Stein & Miller, 2019).

Social Interactions in Problem-solving

Problem-solving is often a collaborative social process in natural contexts, as people work together to achieve a common goal. Argumentation, which is an essential component of problem-solving, is also inherently a social activity. According to van Eemeren et al. (2013), argumentation is defined as "a verbal and social activity of reasoning aimed at increasing (or decreasing) the acceptability of a controversial standpoint for the listener or reader, by putting forward a constellation of propositions intended to justify (or refute) the standpoint before a rational judge" (p. 5). As a social activity for knowledge construction, argumentation is associated with a social constructivist concept of meaning-making, where students learn through reflective interactions, such as making arguments that engage the social co-construction of knowledge (Driver et al., 2000; Newton et al., 1999; Yang et al., 2022).

In addition to its importance in argumentation, social interactions play a crucial role in problem-solving. Social interactions facilitate meaningful negotiations and the co-construction of knowledge, which have been significantly correlated with successful problem-solving (Danby et al., 2018; Mercer & Howe, 2012). This is especially important in the context of ill-structured problem-solving, which requires negotiations among parties to reach the most preferred and reasonable solutions. Social interactions also create favorable conditions for question-asking and answering (Clark, 2018), which is essential in problem-solving as it activates prior knowledge and supports the understanding of causal relationships among problem elements (Jonassen, 2011). Asking questions also stimulates creativity (Sternberg, 2019), which is beneficial to problem-solving as it contributes to generating innovative and effective solutions.

The importance of social interactions in problem-solving can be explained through learning theories such as social learning theory and social constructivism. From the lens of social learning theory, social interactions provide opportunities for "observational learning" (Bandura et al., 1963), or learning from observing others. People can observe through their interactions with others how a problem can be solved or what behaviors should be performed for problem-solving. From a social constructivist viewpoint, social interactions offer learners the opportunity to move from their current level of development, also known as actual development, to their potential level of development, also known as the "zone of proximal development." This potential level is the development stage that learners can achieve with the guidance or collaboration of their peers, and it is the stage beyond their current level of independent problem-solving capabilities (Vygotsky, 1978). Problems presented to be solved are usually challenges that can be best addressed when problem solvers are supported to reach their "zone of proximal development." Also, from social constructivist perspectives, thanks to social interaction, ideas and experiences are shared, cognitive changes occur, and knowledge is co-constructed (Sims, 2003). Other learning theories that can be used to explain the importance of social interactions in problem-solving include but are not limited to, connectivism, collaborative learning, cooperative learning, and self-determination theory.

The literature shows that certain social interactions support behaviors can enable individuals to work in synchrony with others during problem-solving for successful outcomes. Sullivan et al. (2010) observed social interactions support behaviors among newlywed couples and found that behaviors such as empathy, validation, and caring led to higher levels of problem-solving and conflict management. Jeong and Davidson-

Shivers (2006) found that the use of social presence enhancement language had positive effects on communication in online discussions. They found that messages that had more social presence enhancement language (e.g., name referencing, signatures, questions, and "I agree, but") elicited more responses (e.g., more challenging replies to arguments and explanations in greater detail in response to challenging messages) in an asynchronous argumentation context. According to Jeong and Davidson-Shivers (2006), when the author of the argument presents themselves as personal and open to opposing opinions, in order words, when the author of the argument has a high level of social presence in the interactions with others, others in the argumentation context are more motivated to respond to the challenges.

Questions Supporting Problem-solving

The most frequent dialogue pattern observed in naturalistic conversations is the question-answer rhetorical structure (Graesser et al., 1996). Learning can take place through social interactions, and the nature of the questions asked during these interactions can play a crucial role in facilitating learning (Jonassen, 2011). Studies have demonstrated that the effectiveness of questions in supporting learning is not solely dependent on their frequency. Rather, the quality of questions asked plays a crucial role in facilitating students' understanding, as the level of thought, reasoning, and cognitive skills needed to answer a question is reflected in its quality (Aflalo, 2021; Dori & Herscovitz, 1999; Ertmer et al., 2011; Graesser & Olde, 2003; Hamaker, 1986; Liu, 2020; Richardson et al., 2013)**.**

For example, in a study conducted by Graesser and Olde (2003), learners were given troubleshooting tasks, and it was found that those who demonstrated a better

understanding of the device did not ask more questions than those with a shallow understanding. However, they generated higher-quality questions to provide better explanations. In another study that required students to generate questions on a topic that had already been covered in the course and to answer and comment on other students' questions, Aflalo (2021) found that engaging in higher-order thinking questions led to higher achievements in solving higher-order thinking problems.

There exist different kinds of questions that can support problem-solving in different ways. However, the best questions for learning in general and problem-solving, in particular, are the ones that require deep reasoning (Jonassen, 2010).

Deep Reasoning Questions

Deep reasoning questions that target reasoning are among the most effective question types for supporting learning in general and problem-solving in particular (Graesser et al., 1995, 1996; Sullins et al., 2010). These questions promote deep understanding by connecting different components and mechanisms of the subject matter (Craig et al., 2018). Examples of deep reasoning questions include those that start with "why," "why not," "how," "what," "what if," or "what if not" (Craig et al., 2018; Gholson et al., 2009; Graesser et al., 1996; Jonassen, 2011; Tawfik et al., 2020).

In contrast, shallow questions do not require much intrinsic thinking from the answerer and do not require them to integrate or connect different areas of knowledge (Craig et al., 2018; Gholson et al., 2009; Graesser et al., 1996; Jonassen, 2011; Tawfik et al., 2020). Examples of shallow questions include simple yes-no questions, which do not demand much cognitive effort or knowledge integration from the answerer (Craig et al., 2018; Gholson et al., 2009; Graesser et al., 1996; Jonassen, 2011; Tawfik et al., 2020).

Deep reasoning questions are known to support learning in multiple ways. Firstly, they promote higher levels of learning. Graesser and Person (1994) found that the use of deep reasoning questions was positively correlated with higher levels of cognition in Bloom's taxonomy of educational objectives in the cognitive domain (Bloom, 1994). Similarly, in another study by Driscoll et al. (2003), learners who were exposed to a video tutorial with deep reasoning questions demonstrated higher levels of learning than those exposed to content statements containing the same information, but without the deep reasoning questions. Secondly, deep reasoning questions enhance learners' engagement with the learning material. Craig et al. (2000) found that presenting informational videos using deep reasoning questions led participants to be more interactive and inquisitive in follow-up tutoring sessions. Thirdly, deep reasoning question prompts can lead to positive behavioral changes in learning. For example, Okwumabua et al. (2018) found that students who were assigned to a deep reasoning question condition showed more positive behavioral changes in terms of sexually transmitted infection prevention practices compared to students in the control group.

Asking and answering deep reasoning questions can also support problem-solving (Graesser & Person, 1994). How deep reasoning questions can support learning mentioned in the paragraph above is also beneficial to support problem-solving. Engaging in deep reasoning questions also has the potential to stimulate students to elaborate and reflect (Dekker-Groen et al., 2015), which are two key processes of ill-structured problem-solving, especially reflection which helps reframe the problem (Ge & Land, 2003, 2004).

There are many types of deep reasoning questions. Graesser et al. (1992) created a question taxonomy and identified seven categories of deep reasoning questions, including causal antecedent, causal consequence, goal orientation, instrumental/procedural, enablement, expectational, and judgmental questions. Causal antecedent questions explore what led to an event or state, while causal consequence questions explore the consequences of an event or state. Goal orientation questions examine the motives or goals behind an agent's action, and instrumental/procedural questions explore the steps necessary to accomplish a goal. Enablement questions consider the tools or resources necessary to perform an action, while expectational questions examine why an expected event did not occur. Judgmental questions consider the value placed on an idea or advice. Using deep reasoning questions can help individuals gain insights into complex issues, consider multiple perspectives, and make more informed decisions.

Graesser et al. (2009) cautioned against blindly relying on the categorization of deep reasoning questions proposed in Graesser et al. (1992) as it may not always accurately reflect the cognitive effort required to answer a question. They pointed out that some questions classified as deep reasoning questions, such as instrumental or procedural questions, may require minimal thought and reasoning. Therefore, Graesser et al. (2009) suggested that to determine if a question is truly deep, one should take into account the cognitive processes and knowledge representations involved in answering the question.

According to Mosenthal's (1996) taxonomy of question types, deep reasoning questions are characterized by a high level of abstractness. This classification rates questions based on their level of abstractness, which is linked to their depth. The rating system is based on the information required to answer the question and how it interacts

with knowledge and cognitive processes. The taxonomy consists of five levels, with level one being the most concrete and level five being the most abstract.

The first level involves identifying a specific person, thing, or action based on explicit information. The second level involves identifying objectively observable attributes based on explicit information. The third level involves identifying manners, procedures, and goals that cannot be directly observed in explicit information. The fourth level involves identifying cause, effect, reason, and evidence derived from explicit information. The fifth level involves identifying theories, equivalences, differences, and themes that go beyond explicit information.

According to Graesser et al. (2009), the use of deep reasoning questions is crucial for acquiring comprehensive knowledge and achieving deep comprehension of the problem at hand. However, in addition to deep reasoning questions, other types of questions can support problem-solving in various ways. The choice of these questions will depend on the skills, activities, and knowledge that instructors aim to foster in learners. These questions can also help students achieve deeper levels of comprehension of the problems they are required to solve and can thus be viewed as other types of deep reasoning questions.

Other Kinds of Questions for Problem-solving

Jonassen (2011) identified six types of questions that can support problem-solving: task-relevant problem-solving questions, metacognitive questions, problem schema questions, analogical reasoning questions, causal reasoning questions, and argumentation questions. Task-relevant problem-solving questions relate to the problem-solving process and can help students consider different aspects of problem

representation, articulate their solutions, build grounded arguments, assess their solutions, and rationalize the most viable solution. Metacognitive questions aid in planning, monitoring, evaluating, and reflecting on the problem-solving process, while problem schema questions allow individuals to utilize previous knowledge and experiences to solve new problems. Analogical reasoning questions prompt individuals to analyze and distinguish between two scenarios to determine similarities and differences, while causal reasoning questions help individuals comprehend the causal connections among the elements of a problem. Argumentation questions support specific argumentation skills, such as controversy, compromise, or weighing, and can aid individuals in constructing cogent arguments.

In conclusion, questions and questioning support problem-solving in many ways. Questions can be a useful tool for enacting behavioral change, including argumentation behavioral change (Okwumabua et al., 2018). Questions can activate past experiences and trigger expectations based on past experiences (Craig et al., 2006). They help learners reflect on their expectancies and past experiences (Craig et al., 2006), rectify "conceptual violations" (Eakin, 2005), encourage attempts to understand new information in the face of "expectation violation" (Schank, 2013) or "cognitive disequilibrium" (Graesser et al., 2005), or the collapse of the "illusion of knowing" effect (Glenberg et al., 1982). Due to the benefits of questions and questioning to students' learning, including learning to argue, it can be argued that the use of question prompts may challenge learners to modify their argumentation behaviors as well as focus students on target argumentation behaviors.

Argumentation

An Overview of Arguments and Argumentation

Argumentation, which involves the process of justifying claims, encompasses the construction, refutation, and comparison of arguments in situations where there is uncertainty, and relies on a range of reasoning techniques (Van Eemeren et al., 2019). As such, argumentation only occurs when a claim is further supported with reasons and justifications (Novaes, 2021). According to Novaes (2021), an 'argument' is a coherent and rational statement that includes premises that support a conclusion. On the other hand, 'argumentation' refers to the various communicative practices and activities in which arguments are presented, evaluated, and discussed (Novaes, 2021).

The roots of argumentation date back to Aristotle, who identified three main functions of argumentation: apodictic (demonstrative), rhetorical, and dialectical (van Eemeren et al., 2013). Aristotle categorized arguments based on their intended purposes (van Eemeren et al., 2013). In summary, van Eemeren et al. (2013) describe Aristotle's three main forms of arguments as follows:

> Arguments designed to achieve absolutely certain and reliable knowledge, he called apodictic or demonstrative; arguments calculated to lead to generally acceptable opinions or points of view, are dialectical; and arguments that are primarily intended to convince a particular audience of the correctness of a standpoint, are called rhetorical arguments. (p.32)

Among the three kinds of argument, dialectical arguments, also known as dialogical or multi-voiced arguments are more applicable to education purposes than rhetorical arguments, according to Jonassen and Kim (2010). Dialectical arguments are

aimed at rectifying ‘conceptual violations’ by asking and responding to questions in order to resolve contradictions related to a claim (Van Eemeren et al., 2019). Therefore, they are suitable to support students’ collaborative problem-solving. The dialectical nature or social nature of this kind of argument is also a component of meaningful learning from the social constructivist standpoint.

There are three prominent types of dialectical argumentation: pragma-dialectics (Van Eemeren et al., 2019), presumptive arguments (Walton, 2013), and interactive argumentation (Chinn & Anderson, 1998).

Pragma-dialectics, proposed by Van Eemeren et al. (2019), views argumentation as a means of resolving differences of opinion in a critical discussion and provides a formal model for conducting such a discussion. Critical discussions have four essential stages: confrontation, opening, argumentation, and concluding (Van Eemeren et al., 2019). Differences of opinion are only resolved when they have passed through all those stages (Van Eemeren et al., 2019).

During the confrontation phase, involved parties present different claims or viewpoints. If there are no conflicting perspectives to be addressed, then a critical discussion cannot take place (Van Eemeren et al., 2019). In the opening stage, roles such as protagonist and antagonist may be assigned to the participants, who then undertake the responsibilities of both to facilitate a productive conversation (Van Eemeren et al., 2019). During the stage of argumentation, individuals both defend their perspectives and challenge the viewpoints of others (Van Eemeren et al., 2019). In the concluding stage, differences in opinions are resolved in favor of the party that has effectively and convincingly defended their standpoint (Van Eemeren et al., 2019). The pragma-

dialectical approach offers a valuable framework for conducting debates, whether in a face-to-face classroom setting or online discussions, where participants assume distinct roles as either the protagonist or antagonist to argue various aspects of an issue (Jonassen & Kim, 2010).

Presumptive arguments were first introduced by Walton in 2013. According to Walton, arguments are "plausible" or "presumptive" when they are only "provisionally acceptable even when they are correct" (p. 1). In presumptive arguments, participants engage in collaborative discussions to prove or disprove presumptions. This type of argumentation is goal-directed and interactive, emphasizing the importance of counterarguments and the use of reasoning and evidence (Walton, 2013). By considering alternative viewpoints and challenging assumptions, presumptive arguments promote critical thinking and help participants reach more informed conclusions.

Another prominent type of dialectical argumentation is interactive argumentation – a term coined by Chinn and Anderson (1998). During interactive argumentation, participants respond to the arguments of other participants by presenting arguments and counterarguments with reasons and evidence, which contributes to exposing them to a greater variety of ideas and leading to higher levels of thinking (Chinn & Anderson, 1998). The aim of interactive argumentation is not to establish the truth or win an argument but rather to explore an issue at stake. Nussbaum (2005) suggests that interactive arguments do not require debates, where participants try to win points, but should be a collaborative process for participants to work together to construct and critique different arguments.

Various definitions of interactive argumentation exist. Nussbaum (2002, 2005) defines interactive argumentation as a co-constructive style of argumentation that occurs when students respond to the arguments of other students by making arguments and counterarguments of their own. Interactive argumentation exposes students to a greater variety of ideas and may stimulate deeper thinking. Munneke et al. (2007) define interactive argumentation as argumentative discussions with at least two participants engaging in the discussion, and participants more or less equally contribute reasons and evidence for different viewpoints to build up a shared understanding of the issue at stake. Kim (2009) defines interactive argumentation as a special form of discussion in which participants engage in critical argumentation behaviors such as challenging, elaborating, and evaluating various arguments to resolve conflicts. Leitão (2000) describes interactive argumentation as having the potential to set off processes of knowledge building and distinguishes two important argumentative processes that can promote learning: justification of claims and counter argumentation.

Interactive argumentation has the major characteristics of fruitful argumentation indicated in pragma-dialectics and presumptive arguments, including the examination of an issue from multiple perspectives, counterarguments, justification, and the use of evidence to back up claims. Besides, interactive argumentation is unique in that it emphasizes the use of critical yet constructive and collaborative argumentation behaviors and discussions to deepen the understanding of different and opposing viewpoints regarding the issue at stake.

All three aforementioned types of dialectical argumentation indicate that dialectical argumentation is a social activity of reasoning that requires parties involved to

argue to solve differences of opinion. The critical role of questions in the process of argumentation in all three types of dialectical argumentation is also implied: questions can be used by discussion participants to challenge claims made by others as well as to help evaluate the validity of arguments.

Structure of Arguments

There are several models available for examining the structures of arguments. The most used model is the Toulmin model (2003), which consists of six fundamental elements: claim, data, warrant, backing, qualifier, and rebuttal. In the Toulmin model, an individual presents a claim they want their audience to accept, supported by facts or evidence and reasoning through a warrant. Backing provides additional support for the validity of the warrant, while the qualifier indicates the strength of the connection between the data and the warrant. Finally, the rebuttal presents exceptions that counter or invalidate the claim, evidence, or warrant.

However, the Toulmin model has some limitations. While it is useful in identifying the elements of an argument, it does not reveal much about the quality of the argument. Additionally, making distinctions between the claim, warrant, and backing can be difficult as they are not fixed (Harmon et al., 2015). Moreover, this model does not account for the dialogical nature of dialectical argumentation.

Another alternative model that can be used to analyze not only the structures of arguments but also the quality of arguments was developed by Kuhn (1991). According to Kuhn (1991), there are five key abilities that are essential for constructing a persuasive argument. These abilities include generating causal theories to support claims, providing evidence to support these theories, generating alternative theories, envisioning conditions

that could potentially undermine the theories one holds, and rebutting alternative theories. Kuhn (1991) asserts that an argument can only be considered strong if it encompasses all these components.

Challenges in Argumentation

Argumentation is crucial for problem-solving, particularly for ill-structured problem-solving. However, research has revealed that students face challenges in constructing cogent and coherent arguments (Jonassen, 2011). One of the major issues is the lack of consideration for alternative theories, counterarguments, and rebuttals, as pointed out by Jonassen (2011). Speaking of this, Jonassen (2011) commented that the lack of rebuttals and counter argumentation is "the most common weaknesses in argumentation" (p. 325). Furthermore, students often struggle to provide sufficient and relevant evidence to support their claims, as evidenced by Hyytinen et al. (2017). Kuhn and her colleagues (Felton & Kuhn, 2001, 2001; Kuhn, 2001; Kuhn & Udell, 2003) have found that pseudo evidence, which merely elaborates a theory rather than genuinely supporting it, is commonly used instead of proper evidence. Additionally, informal reasoning often leads people to take the correctness of their claims for granted (Felton & Kuhn, 2001, 2001; Kuhn, 2001; Kuhn & Udell, 2003) and forgo justifications for their claims and evidence, as noted by Reznitskaya et al. (2007). Considering the difficulties people face in argumentation, it is essential to support students in developing argumentation skills to promote interactive argumentation and better problem-solving performance.

Supporting Argumentation in Computer-Mediated Communication Environments

Interactive argumentation can be facilitated using computer-supported collaborative argumentation environments. Several tools have been developed to support interactive argumentation, including Belvedere (Suthers et al., 1995), SenseMaker (Bell, 2013), Drew (Baker et al., 2003), pro-con tables (Schwarz et al., 2003), Matrices (Suthers & Hundhausen, 2003), FLE3 (Oh & Jonassen, 2007), and Argumentaryum (Akpinar et al., 2015). These environments share some common features, including providing students with argumentation structures that require the presence of certain key components such as claim, data, warrant, backing, and rebuttal. The rationale for providing students with an argumentation format is that it may facilitate the development of argumentative dialogue and the collaborative exchange of ideas (Akpinar et al., 2015; Bell, 2013; van Bruggen et al., 2003).

In addition, these environments tend to constrain students' argumentation to a pre-defined set of post types and sentence openers. Constraints may be assigned together with note starters or sentence-openers, which can promote participants' metacognitive thinking and engage them in desired cognitive processes, such as considering other points of view. For example, participants in a study by Nussbaum et al. (2004) were asked to use note starters such as "on the opposite side," "I need to understand," and "my argument is" to begin their notes and encourage counterarguments.

Some findings support the effectiveness of constrained environments in encouraging argumentation behaviors. For example, Nussbaum et al. (2004) developed a constrained environment with note starters targeting counterarguments and found that it significantly increased the frequency of disagreement compared to a threaded forum.

Similarly, Oh and Jonassen (2007) found that students who were required to constrain their argumentation by post type labels and to use note starters generated more evidence posts, hypotheses, and hypothesis testing posts compared to students in a threaded forum.

However, such environments have also been found to have some partial effects and even negative effects. For example, note starters were found to be most useful for students with low degrees of curiosity or assertiveness (Nussbaum et al., 2004). Jeong and Joung (2007) found that using post type labels may inhibit the process of developing a deeper and more critical analysis of individual arguments, and students in constrained environments barely generated rebuttals and elaborations. Oh and Jonassen (2007) also found that the constrained environments led to no significant difference in the performance of argumentation and problem-solving, which they attributed to the short length of treatment as one of the factors for the intervention's ineffectiveness.

Despite efforts to support the cognitive dimension of interactive argumentation in computer-mediated communication environments, the social presence dimension remains relatively unexplored. Additionally, previous studies have hardly touched on the effects of question prompts to support argumentation behaviors during problem-solving in these environments.

Social Interactions

Theory Base

The importance of social interactions in learning and knowledge construction is well established in social constructivism. According to this approach, knowledge is not just passively transferred to individuals, but actively constructed by learners through their interactions with others (Brown et al., 1989; Lave & Wenger, 1991b; Vygotsky, 1978).

Other learning theories, such as social learning theory (Bandura & Walters, 1977), the community of practice (Lave & Wenger, 1991b), cognitive apprenticeship (Brown et al., 1989), and connectivism (Siemens, 2017), also emphasize the importance of social interactions to learning.

Sustained social interactions can lead to the formation of 'communities of practice' or communities of learning, where people "share a concern or a passion for something they do and learn how to do it better as they interact regularly" (Lave & Wenger, 1991b, p. 1). Tomkin et al. (2019) found that communities of practice can be an effective mechanism for meaningful learning activities, such as problem-solving, and can enhance students' engagement and participation in STEM. According to Pyrko et al. (2017), 'communities of practices' only work when individuals in such communities "think together" and "mutually guide each other through their understanding of the same problems in their area of mutual interest, and this way indirectly share tacit knowledge" (p.389).

Social interactions take many forms, but language is perhaps the most obvious. Vygotsky (1978) posited that language and culture are the means for people to experience, communicate, and understand reality. Language supports dialogues that trigger learning because "in the process of explaining, clarifying, elaborating, and defending our ideas and thoughts, we engage in cognitive processes such as integrating, elaborating, and structuring" (Pena-Shaff & Nicholls, 2004, pp. 244–245). During social interchanges, social discord catalyzes the knowledge construction process since contradictory or differing perspectives can result in a new or changed perspective (Anderson & Kanula, 1998).

Social constructivism emphasizes the role of collaboration and expert guidance during the knowledge-building and learning process. Vygotsk (1978) suggested that people learn best when they have reached their "zone of proximal development" (p. 85) - the competency level they are capable of reaching through collaboration with peers or from the guidance of experts.

In social constructivism, learning can be best facilitated through the design and implementation of tools and environments that foster meaning-making and discourse among communities of learners (Bruner, 1990; Engeness, 2021; Jonassen & Reeves, 1996; Vygotsky, 1978). Jonassen (1992) and Jonassen and Remidez (2005) argue that it is not specific knowledge but tools that support learners in constructing knowledge. In today's world, learners can use online tools like asynchronous online discussion forums to create meaning in their learning process. Asynchronous discussion forums offer valuable opportunities for online learners to construct knowledge by articulating, reflecting on, negotiating, and resolving their understanding of course content with both peers and instructors (Galikyan & Admiraal, 2019).

Social Interactions in Online Learning

Social interactions are just as important in online learning as they are in traditional face-to-face learning. As Stacey (2003) notes: "The social dimension of online interaction provides the basis of establishing an environment of trust and motivation for effective learning" (p. 138). A high level of social interactions in online learning environments can foster feelings of closeness, warmth, belonging, and mutual trust, which in turn encourages students to share their perspectives and collaborate to explore learning materials more readily (Rourke & Anderson, 2002). Furthermore, online

environments with high social interactions contribute to higher interactivity or higher quality of communication among participants (Gunawardena, 2017b).

Social interactions in online learning are promoted through social presence (Garrison et al., 1999). Social presence refers to the ability of participants "to project themselves socially and emotionally in a community of inquiry" (Garrison et al., 1999, p. 94) and "the degree to which a person is perceived as "real" in mediated communication" (Gunawardena & Zittle, 1997, p. 8). In asynchronous learning networks, social presence is constructed through accumulated interactive messages over time (Garrison et al., 1999).

However, due to the lack of social cues in text-based communications over the Internet, social presence tends to be low in online discussions (Akcaoglu & Lee, 2016; Gunawardena, 2017b). This can have a detrimental effect on learning and building a warm and trusting environment. For example, Hambacher et al. (2018) found that online discussions have the potential to devolve into exchanges of poorly-reasoned personal experiences and extended serial monologues instead of facilitating deep dialogues. To compensate for the lack of non-verbal cues and express their feelings, online learners often develop the ability to use emotions and parenthetical metalinguistic cues in written messages (e.g., hmmm, yuk) (Gunawardena, 1995, 2017b; Gunawardena & Zittle, 1997). This indicates that while the nature of the medium may make social presence seem incompatible, it can still be developed and cultivated.

Social presence is a crucial component of successful online learning, and various approaches can be taken to foster it. Drawing on the work of Garrison et al. (1999), Rourke et al. (1999) suggested that affective, interactive, and cohesive responses can help

to establish social presence in online learning environments. Affective responses involve using emotions, feelings, humor, and self-disclosure, while interactive responses include using features like "reply," quoting others' messages, asking questions, and expressing agreement. Cohesive responses involve using inclusive pronouns, addressing participants by name, and engaging in social functions like greetings and closures. These strategies promote social presence and can facilitate the social construction of knowledge in online discussions.

Additionally, the language used in online interactions can affect social presence. For example, Kaneyasu (2022) found that emoticons, when combined with specific linguistic features, can enhance social presence and increase the perception of intimate rapport. Communication styles that foster social presence include friendly, encouraging, and personalized posts (Fahy, 2003), as well as posts that acknowledge others' contributions, reference shared experiences, and invite others' viewpoints (Steinkuehler, 2002). Conversely, language styles that hinder social interactions include a lack of acknowledgment of others' contributions, the use of tricky questions or arguments, negative reactions to perceived contradictions, and wording that implies authority (Steinkuehler, 2002).

Cultivating social presence requires an understanding of the diverse social desires of participants, which can vary within and between cultures (Gunawardena, 2017b). To address these differences, Gunawarden (2017b) proposed six strategies for cultivating social presence in online learning environments with culture in mind, such as using self-introduction and self-disclosure to build relationships and trust, creating an inclusive learning community, establishing informal social spaces, designing activities for

interaction, including teacher presence, and orienting students to communication protocols and discussion etiquette.

Despite the availability of these strategies, evidence suggests that social presence is consistently low in online learning environments, leading to low social interactions, interactivity, critical thinking, and (co-)construction of knowledge. To support students' learning, especially during ill-structured problem-solving in computer-supported collaborative learning environments, social interactions must be actively facilitated.

Asynchronous Online Discussion Forums

An Overview of Asynchronous Online Discussion Forums

Asynchronous online discussion forums have gained popularity in higher education, especially in online and blended courses, providing several advantages such as increased accessibility and the creation of virtual space for students to exchange ideas and clarify their understanding (Bryce, 2014; Hrastinski, 2008). From a constructivist perspective, these forums offer learners opportunities to showcase their understanding of course content, engage in collaborative meaning-making with their peers, and integrate new knowledge, promoting higher-order thinking and knowledge construction (Galikyan & Admiraal, 2019).

The theory of social constructivism can be used to frame the use of asynchronous online discussion forums (Loncar et al., 2014). These forums enable social interactions that promote interactivity, which is a crucial factor affecting learning outcomes (Gunawardena, 2017a). Asynchronous online discussion forums connect students with each other and with their instructors, extending classroom activities and encouraging cooperative and collaborative learning (Schellens & Valcke, 2006).

Theoretically, interactions in asynchronous online discussion forums can promote higher-order thinking skills, critical thinking, problem-solving, and knowledge construction (Al-Husban & Almad, 2020; Jeong, 2003; Kirschner et al., 2004), leading to improved learning performance (Webb et al., 2004). Empirical studies have shown that effective asynchronous online discussions can help students develop higher-order thinking, deeper levels of critical thinking, and more advanced phases of knowledge construction (Afify, 2019; Moore & Marra, 2005; Rourke & Anderson, 2004). However, certain challenges can hinder students' meaningful learning activities in asynchronous online discussion forums, such as problem-solving.

Issues with Asynchronous Online Discussion Forums

Asynchronous online discussions offer students a valuable platform for collaboration and interaction, which can lead to knowledge construction. However, various challenges have been identified in facilitating meaningful learning through these discussion forums. One challenge is related to the nature of communication in this format. As online communication is primarily computer-mediated and often asynchronous and text-based, it lacks personal touch and non-verbal cues, making it difficult to make students feel connected and engaged (Al Tawil, 2019; Gunawardena, 1995; Gunawardena & Zittle, 1997). The absence of these cues can lead to limited student participation in online discussions, which is a common complaint of online students (An et al., 2009; Buelow et al., 2018; Hewitt, 2005; Osborne et al., 2018; Rovai, 2007).

In addition, it is more challenging for instructors to redirect discussions promptly and ensure that individual contributions are not ignored, unlike in face-to-face courses

(Moore & Marra, 2005). This can hinder the quality of discussions and knowledge construction. Another challenge is the quality of interactions. Interactions in online discussions may not always lead to quality interactivity, which can affect learning and knowledge construction (Aloni & Harrington, 2018; Angeli et al., 2003). Students may post the minimum number of messages and procrastinate in replying to others' postings, hindering timely and sustained communication (An et al., 2009; Ding, 2019; Fehrman & Watson, 2021; Hara et al., 2000). These issues can impede the exchange of ideas and perspectives necessary for meaningful learning. Furthermore, students in computer-supported collaborative environments for argumentation rarely engage in counterargument and rebuttal activities, even with strong instructional support (Oh & Jonassen, 2007; Snyder & Dringus, 2014).

Despite these constraints, creating meaningful learning opportunities in online learning and asynchronous online discussion forums is possible and essential (Howland et al., 2012). Pedagogical strategies that enhance social presence can help cultivate meaningful learning for students in online learning environments (Garrison et al., 1999).

Successful online learning occurs when learners are actively engaged in learning communities, and social presence plays a vital role in this process (Garrison et al., 1999). Enhancing social interactions and connections within social networks or learning communities is critical for nurturing and maintaining learning engagement and supporting critical argumentation and problem-solving (Siemens, 2017). However, further research is needed to explore how to enhance social presence in online learning environments.

Scaffolding in Asynchronous Online Discussion Forums

Several outstanding characteristics of scaffolding in asynchronous online discussion forums have been noted. Firstly, scaffolds in discussion forums tend to be constraint-based, where participants' posts are restricted to a specific set of message categories embedded within the discussion environment (e.g., Ak, 2016; Jeong & Joung, 2007; Oh & Jonassen, 2007; Verdú & Sanuy, 2014). Secondly, constraints in discussion forums are often accompanied by sentence openers (e.g., Ak, 2016; Nussbaum et al., 2004; Oh & Jonassen, 2007). Thirdly, scaffolding in discussion forums tends to focus on facilitating argumentation, higher-order thinking, and problem-solving (e.g., Choi et al., 2005; Hall, 2011; Henrikson, 2019; Jacob & Sam, 2010). However, studies on scaffolding collaborative engagement remain limited (e.g., Choi et al., 2008; Farrow et al., 2021; Lai & Law, 2006; Morris et al., 2010).

Scaffolding has demonstrated positive effects on students' learning in asynchronous online discussion forums. Scaffolding has been associated with better learning performance (Ak, 2016; Han et al., 2021), and one of the reasons for this is that scaffolding helps students to be more task-oriented (Ak, 2020). Furthermore, scaffolding may lead to higher learning satisfaction (Giacumo & Savenye, 2020; Han et al., 2021) and supports skills that are beneficial to problem-solving, such as critical thinking (Giacumo & Savenye, 2020), reasoning, and argumentation Oh & Jonassen, 2007; Özçinar, 2015). For example, Oh and Jonassen (2007) found that constraint-based argumentation scaffolding in asynchronous online discussions improved students' argumentation and problem-solving performance. The scaffolded discussion group

generated more evidence notes, hypothesis messages, hypothesis testing messages, and problem space construction messages than the non-scaffolded discussion group.

However, scaffolding in asynchronous online discussion forums does not always guarantee activities conducive to learning, such as engagement (e.g., Jacob & Sam, 2010), and producing rebuttals and counterarguments (Jeong & Joung, 2007; Oh & Jonassen, 2007). The incorrect timing to remove scaffolds (Han, Luo et al., 2021), the type of scaffolds, and the combination of more than one type of scaffolding (Giacumo & Savenye, 2020) also may lead to different effects of scaffolding on students' learning in discussion forums.

Problem-solving with Question Prompts in Asynchronous Online Discussion Forums

Asynchronous online discussion forums are characterized by asynchronicity and connectivity, according to Anderson (2003). Asynchronicity allows for reflection activities, while connectivity enables collaborative learning experiences (Anderson, 2003). These forums are designed to give students more time to process information and contribute thoughtfully to discussions, leading to mutual guidance through the understanding of learning content and tasks such as problem-solving (Bryce, 2014; Pyrko et al., 2017). The reflection and connectivity properties of asynchronous online learning align well with the characteristics of higher-order learning activities like problem-solving.

However, evidence of meaningful learning outcomes such as problem-solving, critical thinking, and higher levels of knowledge construction in asynchronous online discussion environments is limited. Some research has explored ways to support meaningful learning in these environments using strategies such as question prompts

(e.g., Choi et al., 2005; Ge et al., 2010; Hew & Knapczyk, 2007; Hong & Jacob, 2012; Kramarski, 2011; Oh & Jonassen, 2007).

There are some notable characteristics of using question prompts to support problem-solving in prior studies. Question prompts are typically designed to align with problem-solving steps to aid students in their problem-solving process. For example, in Ge et al.'s (2010) study, five problem-solving steps were introduced, including identifying the problematic situation, defining the problem, listing and evaluating alternative solutions, choosing, justifying, and implementing a plan, and evaluating the plan. Sample questions for each step of problem-solving in this study include, "What facts from this case suggest a problem?" (Step 1), "What do you already know about the problem?" (Step 2), "List at least two alternatives to solve the problem" (Step 3), "How will you implement this plan" (Step 4), and "How and when will you monitor the implementation of the plan?" (Step 5). Similarly, Hew and Knapczyk (2007) designed question prompts to align with problem-solving steps to assist practicum teachers in solving teaching problems encountered in the workplace. The four steps of problem-solving defined by Hew and Knapczyk (2007) are problem formulation, solution planning and generating, justifying and selecting solutions, and reflection on the solution.

Question prompts are also commonly designed to support cognitive skills related to problem-solving. Argumentation is a critical component of problem-solving, particularly for ill-structured problem-solving, and question prompts have been employed to support argumentation in synchronous online discussion forums. For example, Oh and Jonassen (2007) developed question prompts to support argumentation skills during ill-structured problem-solving in seven aspects of problem-solving, including problem

identification, hypothesizing cause, solution generation, verification, rebuttal, evidence, and elaboration. Another notable cognitive skill that question prompts have been used to support problem-solving in asynchronous online discussion forums is metacognition. For example, Kramarski (2011) supported students' metacognition during problem-solving by utilizing question prompts to aid students in understanding the problem before solving it, finding connections or activating prior knowledge to define the structural features of the provided problem and planning how to solve it, considering appropriate strategies to solve the given problem, and monitoring and evaluating their understanding of the problem-solving and solution. Elaboration questions (Choi et al., 2005; Hong & Jacob, 2012), counterargument questions (Choi et al., 2005), reflection questions (Kramarski, 2011), connection questions (Kramarski, 2011), evidence questions (Hong & Jacob, 2012), and evaluation questions (Hong & Jacob, 2012; Kramarski, 2011) are some types of question prompts that have been utilized to support metacognition during problem-solving in asynchronous online discussion forums.

Question prompts can serve as a cognitive scaffolding tool for students, and they can be presented in various ways. Some ways involve presenting question prompts as discussion tasks or asking students questions. For example, in a study by Hong and Jacob (2012), the lecturer moderated discussion forums and used Socratic questioning to scaffold students' problem-solving. These questions helped clarify key mathematical concepts and guide the discussions toward solutions. Other ways involve question prompts as part of an interactive environment. In a study by Choi et al. (2005), students were presented with situations they might encounter while discussing problem generations and solutions with their peers. Clicking on a situation allowed users to access

descriptions for generating effective questions, along with generic and specific examples of question prompts.

Using question prompts as a scaffolding strategy in online learning tends to show positive effects on students' learning. Since question prompts tend to be designed in alignment with problem-solving steps and skills crucial to problem-solving, such as argumentation and metacognition skills, they tend to be positively associated with higher problem-solving performance. For instance, Ge et al. (2010) found that question prompts significantly improved students' problem-solving performance in all the problem-solving steps in both initial and revised reports. Similarly, in a study by Hew and Knapczyk (2007), practicum teachers consistently reported that question prompts successfully guided them through the process of planning and carrying out interventions. Furthermore, question prompts tend to support students' reasoning. In a study by Kramarski (2011), the use of question prompts had positive impacts on students' knowledge and reasoning.

Question prompts may also modify students' behaviors to support problem-solving. For example, Choi et al. (2005) found that peer-questioning guidelines increased the frequency of student questioning behavior during online discussions. The online guidance served as "a starting point" to generate questions when students had difficulty asking questions. However, the guidance did not improve the quality of questions and thus the learning outcomes. The study also found that peer-generated adaptive questions served a critical role in facilitating learners' reflection. Additionally, the use of question prompts tends to enhance knowledge construction. Choi et al. (2005) and Kramarski (2011) found that the use of reflection prompts enabled students to contemplate and articulate gaps in their knowledge at a deeper level.

Despite the benefits of using question prompts, some concerns remain. For example, low levels of rebuttals are one concern. Social interactions play an important role in problem-solving but to the best of my knowledge, no research has investigated how using question prompts in combination with social presence enhancement strategies may change students' argumentation behaviors in support of problem-solving.

Research Challenges

Chapter 2's literature review highlights several research problems and challenges regarding effective support for students' ill-structured problem-solving in asynchronous online discussion environments. Firstly, argumentation is a critical component of ill-structured problem-solving, yet students tend not to engage in critical argumentation activities like generating counterarguments and rebuttals to construct meaning in discussion forums. Additionally, there is currently no unified community dedicated to exploring effective strategies for promoting meaningful argumentation behaviors in asynchronous online discussion forums. Secondly, question prompts hold promises to support target argumentation skills, but it remains unclear how question prompts can be used to trigger argumentation behavioral changes and whether any changes can occur. Thirdly, social interactions are crucial to problem-solving, but students tend to show low levels of engagement in online discussions. While research has focused on cognitive strategies to enhance problem-solving in online discussion forums, efforts to investigate how social presence when combined with other instructional cognitive strategies like question prompts can affect students' learning - particularly their argumentation and problem-solving - remain limited.

This study aims to fill the gaps by (1) examining how two components critical to problem-solving - argumentation and social interactions - may be supported in asynchronous online discussion forums through the use of question prompts to support argumentation behaviors and the use of social presence enhancement strategies; and (2) investigating their effects on students' argumentation behaviors, problem-solving processes, and problem-solving performance.

Chapter Summary

Chapter 2 provides definitions and descriptions of problems, questioning, question prompts, social presence, and argumentation in learning, both in general and in the context of asynchronous online discussion forums. The chapter argues that asynchronous online discussion forums are a favorable environment for collaborative ill-structured problem-solving, but prior research has shown that two critical components of problem-solving, argumentation, and social interactions, tend to be low in these environments. Furthermore, there is a lack of literature exploring how question prompts and the use of social presence enhancement strategies can support these components of problem-solving in asynchronous online discussion forums. This contrasts with the comprehensive literature on how argumentation and social interactions support problem-solving in general. The chapter argues that a more thorough examination is required to understand how ill-structured problem-solving in asynchronous online discussion forums can be effectively supported using question prompts and social presence enhancement strategies.

3. METHODOLOGY

Overview

This study aims to provide a detailed examination of students' argumentation behaviors, problem-solving processes, and problem-solving performance on asynchronous online discussion forums. To achieve this, four constructs were operationalized, including questioning, argumentation behaviors, social presence, and problem-solving. The study seeks to evaluate the effects of argumentation scaffolding using question prompts and social presence enhancement strategies on these constructs. The effects of the argumentation scaffolding and social presence enhancement strategies were measured quantitatively at three points (before, during, and after intervention) using discussion transcripts.

A between-groups experimental design, also known as a between-subjects design (Jhangiani et al., 2019), was used to investigate the effects of question prompt-based argumentation scaffolding in combination with social presence enhancement strategies on students' argumentation behaviors, problem-solving processes, and problem-solving performance. This design was selected because it allows for the examination of the relationship between independent variables and changes in dependent variables when multiple groups are involved in the study (Cresswell & Clark, 2017).

The students who participated in this study were randomly assigned to one of three study conditions: a) a control condition (condition 1) with no question prompts, b) a condition with question prompts only (condition 2), and c) a condition with both question prompts and social presence enhancement strategies (condition 3). Further details on

these conditions can be found in the Three Conditions of the Study section of this chapter.

Several variables were investigated to answer the research questions of this study. The independent variable was the three study conditions: the control condition (condition 1), the question prompt-based only condition (condition 2), and the question prompt and social presence enhancement strategy condition (condition 3). The dependent variables included students' argumentation behaviors, problem-solving processes, and problem-solving performance, which were evaluated through analysis of the discussion transcripts. Personal variables that could potentially affect the dependent variables, such as demographics, argumentativeness, and pre-test problem-solving performance, were included as covariates and control variables in the analysis to address the research questions.

The data collection process occurred over three time points. The first point was the pre-test, which took place in Week 1 of the course. During the pre-test, survey data on students' variables, argumentativeness, and self-reported problem-solving skills were collected, as well as students' first discussion posts of Week 1 to measure their pre-test problem-solving performance. The second point was the intervention, which occurred in Week 5. During this time, students' discussion posts in small discussion groups within each study condition were collected to evaluate their argumentation behaviors and problem-solving processes during discussions. The third point was the post-test, which took place in Week 6. During the post-test, students' first discussion posts were collected to measure their post-test problem-solving performance.

Throughout the treatment, students in all three conditions worked in small groups of three to four students in different "discussion breakout rooms" on Canvas, a web-based course management system. They worked together to diagnose and find solutions to the same problem regarding teacher presence on social media. Before the data collection began, problem scenarios were developed, and the length of the treatment was determined through collaboration with experts in problem-solving and the course instructors. To evaluate the appropriateness and potential bias of the problem scenarios, a focus group with undergraduate students majoring in education was conducted, followed by further feedback from experts and the course instructors. The overall research design can be seen in Table 3.1.

Table 3.1

Research Design

		Ill-structured Problem-solving		
Conditions	Recruitment	Pre-test	Intervention	Post-test
1. Condition 1	X	X_{pr}	X_1	X_{po}
2. Condition 2	X	X_{pr}	X_2	X_{po}
3. Condition 3	X	X_{pr}	X_3	X_{po}

Note.

Condition 1: Control condition

Condition 2: Question prompt-based only condition

Condition 3: Question prompt and social presence enhancement strategy condition

$X_{pr:}$ Individual problem diagnosis and solution assignment on a problem scenario four weeks prior to the treatment – 1st post (pre-test).

X_1: Small group discussions without the support of question prompts conducive to argumentation behaviors.

X_2: Small group discussions with the support of question prompts conducive to argumentation behaviors provided.

$X_{3:}$ Small group discussions with the support of social presence enhancement strategies besides the question prompts conducive argumentation behaviors provided.

$X_{po:}$ Individual problem diagnosis and solution assignment on a problem scenario one week after the treatment – 1^{st} post (post-test)

Research Context and Participants

The participants in this study were undergraduate students enrolled in two sessions of an online course titled "Empowering Learners with Technology" at a state university located in the Midwestern United States during the latter half of the spring semester in 2022. This course is designed to develop the skills of undergraduate students who plan to become teachers upon graduation, enabling them to use technology in student-centered ways to support meaningful learning. The course, delivered through Canvas, spans eight weeks, and typically has large enrollments across multiple sessions during the academic semesters, with an average of 35-40 students in each session. The course covers topics such as digital citizenship, professional online presence, and designing and facilitating learning with technology. Its major activities include weekly readings, weekly discussions with peers, and essay writing.

This course was chosen for the study for two reasons. First, it is conducted entirely online, and students are required to participate in weekly asynchronous online discussion forums. The study aimed to explore students' ill-structured problem-solving in such discussion environments. Second, the course aims to help future teachers use educational technologies in student-centered ways that support meaningful learning. The

treatment of this study, which included question prompts and social presence enhancement strategies, was designed to support online argumentation in a way that encourages students to generate more interactive argumentative messages. These prompts and strategies could provide a good example to these future teacher students of how online learning, in general, and problem-solving in asynchronous online discussion forums can be supported.

The students who agreed to participate in the study signed an online Qualtrics consent form, giving the researcher permission to use their discussion data from the three asynchronous online discussion forums in Week 1, Week 5, and Week 6, where they discussed how to solve issues presented in the scenarios for the research purposes of this study, and completed a personal profile survey. Students who did not participate in the study were those who did not complete either or both of the following: signing the online Qualtrics consent form and completing the online Qualtrics personal profile survey. The link to the Qualtrics form for consent and the survey was shared with all students in the two sessions of the course during the first day of their first module of the course in Spring 2022. Students who participated in the study were awarded five extra course credits, while those who chose not to participate were given an alternative assignment by the course instructors to also earn up to five extra course credits. Additionally, three students from each session of the course were randomly selected to receive a $50 Amazon gift card.

Random assignment was used to ensure that personal factors were equally distributed among conditions and groups, as recommended by Cresswell and Clark (2017). In order to anonymize students, each participant was assigned an ID number by

the researcher. These ID numbers were then used to randomly assign students to one of three conditions: the control condition, the question prompt-based only condition, or the question prompt and social presence enhancement strategy condition. Within each condition, students were then randomly assigned to small groups of 3 to 4 students.

Initially, 53 undergraduate students agreed to participate in the study by signing the consent form (see Appendix G) and completing the personal profile survey (see Appendix H). These 53 students were randomly assigned to one of the three groups: the control group (condition 1) had 18 students, the question prompt-based only condition (condition 2) had 17 students, and the question prompt and social presence enhancement strategy condition (condition 3) had 18 students. Each condition had 6, 5, and 6 groups respectively, with each group consisting of 3 to 4 participants.

During the data screening process, nine participants were eliminated from the sample because they did not participate in all three data collection points (i.e., the pre-test discussion, the treatment time, and the post-test discussion). As a result, the analysis to answer the research questions in this study was based on data obtained from the remaining 44 participants (see Table 3.2). Of these participants, the control condition (condition 1) consisted of 15 students, the question prompt-based only condition (condition 2) had 12 students, and the question prompt and social enhancement strategy condition (condition 3) had 17 students.

Table 3.2 presents an overview of the participants' general characteristics in this study, which were obtained from their personal profile survey (Appendix H) during the recruitment process. All the participants (44 students, 100%) were undergraduate students, and the majority of them were female (35 students, 79.5%). Most students fell

in the age range of 18 to 20 years old (39 students, 88.8%), and almost all of them reported English as their native language (43 students, 97.7%). Additionally, nearly all the students indicated that they took the course because it was a requirement for their major (41 students, 93.1%). Based on these demographic characteristics, the sample in this study was homogeneous. As a result, these variables were not included in the statistical analysis to address the research questions.

Table 3.2

General Characteristics of Participants by Conditions

	Condition			Total
	Condition 1 (n = 15)	Condition 2 (n = 12)	Condition 3 (n = 17)	(*N* = 44)
Gender				
Female	12 (80.0%)	11 (91.7%)	12 (70.6%)	35 (79.5%)
Male	3 (20.0%)	1 (8.33%)	5 (29.4%)	9 (20.5%)
Age				
18-20	15 (100.0%)	12 (100.0%)	12 (70.6%)	39 (88.8%)
21-25	0 (0.0%)	0 (0.0%)	4 (23.5%)	4 (9.1%)
26-30	0 (0.0%)	0 (0.0%)	1 (5.9%)	1 (2.3%)
Native language				
English	15 (100%)	12 (100%)	16 (94.1%)	43 (97.7%)
Other	0 (0.0%)	0 (0.0%)	1 (5.9%)	1 (2.3%)
Academic status				
Undergraduate	15 (100%)	12 (100%)	17 (100%)	44 (100%)
Other	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Reason for taking classes				

Required	13 (86.7%)	12 (100.0%)	16 (94.1%)	41 (93.2%)
Interested in it	2 (13.3%)	0 (0.0%)	1 (5.9%)	3 (6.8%)
Groups	6	5	6	17
Total	15 (34.1%)	12 (27.3%)	17 (38.6%)	44 (100%)

Note.

Condition 1: Control condition

Condition 2: Question prompt-based only condition

Condition 3: Question prompt and social presence enhancement strategy condition

Three Conditions of the Study

The students in this study participated in a weekly online group discussion, which took place on a text-based asynchronous threaded discussion board on Canvas, a web-based course management system. The discussion environments for the three conditions were identical but differed based on the treatment conditions of question prompts and social presence enhancement strategies. Students in all treatment conditions were required to (1) work in small pre-assigned groups of three to four students in a breakout room accessible only to them, (2) label each post using one of eight pre-defined categories of argumentation behaviors (*claims, agreeing, challenging, counter-challenging, integration, elaboration, making a concession,* and *supporting reasons*) as the subject heading for their post (see Appendix L), and (3) restrict the content of their post to address only one argumentation behavior at a time.

Previous studies have applied constraints to scaffold argumentation in online discussion forums (e.g., Cho & Jonassen, 2002; Jeong & Joung, 2007; Oh & Jonassen, 2007). According to Jeong and Joung (2007), message constraints and message labels assist students in maintaining a task-oriented discussion and seeing the structure of arguments when viewing the discussion thread. Such constraints are also argued to

promote students' metacognitive thinking and engage them in desired cognitive processes (Jonassen & Remidez, 2005; Nussbaum et al., 2004). For example, Nussbaum and his colleagues (2004) developed a constrained environment to encourage counterarguments and observed an increase in the expected behaviors among students who used their environment.

Control Group. In this condition, students did not receive a list of the question prompts or social presence enhancement strategies. Instead, they were provided with argumentation behavior categories and their descriptions and required to constrain their posts to those specific behaviors. For more information on this condition, please refer to Appendix J.

Treatment One – Question Prompt-based Only Condition. In addition to argumentation behavior categories and their descriptions, students in this condition were provided with a set of 19 question prompts (Appendix M), grouped by types of argumentation behaviors, to scaffold their interactive argumentation during ill-structured problem-solving. These prompts were adapted from Oh and Jonassen's (2007) deep reasoning question prompts, which are based on seven types of knowledge necessary for critical argumentation during ill-structured problem-solving: problem identification, hypothesizing cause, solution generation, verification, rebuttal, evidence, and elaboration.

This adaptation was based on Nussbaum and Schraw's (2007) finding that explicit instruction on how to rebut, synthesize, and evaluate alternative arguments enhances argument-counterargument integration. To further enhance interactive argumentation, the list of question prompts developed by Oh and Jonassen (2007) was adapted by adding questions to help students develop a compromise position and weigh alternative

arguments, in alignment with argumentation behaviors associated with co-meaning making such as counterargument, rebuttal, and counterargument-rebuttal integration (Appendix L).

The question prompts (Appendix M) were categorized by the researcher into eight groups in alignment with the pre-defined argumentation behaviors: *claims* (3 question prompts, questions 1-3), *agreeing* (1 question prompt, question 4), challenging (3 question prompts, questions 5-7), *counter-challenging* (1 question prompt, question 8), *integration* (2a, questions 9-10), *elaboration* (3 question prompts, questions 11-13), *making a concession* (1 question prompt, question 14), and *supporting reasons* (5 question prompts, questions 15-19). Details of the question prompts from Oh and Jonassen's (2007) study and those created in this study can be found in Appendix M. For further details on this condition, please refer to Appendix J.

Treatment Two – Question Prompt and Social Presence Enhancement Strategy Condition: In addition to the question prompts, students in this condition received social presence enhancement strategies. They were also provided with argumentation behavior types and the link to argumentation behavior descriptions, like the control condition. For further details on this condition, please refer to Appendix J.

Prior research has shown that the use of social presence inducing behaviors leads to productive interactive argumentation and elicits more responses from other participants compared to messages without such behaviors (Fahy, 2003; Kaneyasu, 2022). The provision of social presence enhancement strategies in this study aimed to validate previous findings and contribute to a better understanding of the impact of social presence on students' interactive argumentation and problem-solving.

The social presence enhancement strategies used in this study were based on the categories and indicators of social presence in computer-mediated conferencing environments originally proposed by Garrison et al. (1999) and refined in a social presence coding scheme developed by Rourke et al. (1999). Three out of the twelve social presence indicators proposed by Rourke et al. (1999) - the use of humor, continuing a thread, and expressing agreement - were not included as social presence enhancement strategies in this study. The use of humor was deemed unsuitable as students in online learning environments may not know each other well enough to use it, and its interrater reliability in Rourke et al. (1999) was only 0.24, which is considered unacceptable. As for continuing a thread, since students in the three conditions were expected to make multiple posts focusing on the threads of their interest while working in small groups of three to four students to solve the assigned problem, there was no need to advise students to use this social presence indicator as one of the social presence enhancement strategies. Expressing agreements was also not recommended as one of the social presence enhancement strategies since it was one of the argumentation behaviors they were required to label in their posts.

Rourke et al.'s (1999) expression of emotions was replaced using paralanguage features such as emoticons, emojis, exaggerated punctuation, or spelling to convey emotions. Swan and her colleagues (Swan, 2002, 2003; Swan & Shih, 2019) used this approach as an indicator of social presence. In another study by Lo (2008), the use of non-verbal communication, such as emoticons and emojis, was found to be effective in conveying emotions, similar to facial and body expressions in face-to-face communication.

In addition to the social presence indicators proposed by Rourke et al. (1999), this study also considers apologies, invitations, and challenging politely and responding to a question/challenge politely as indicators of social presence. Apology and invitations are among the thirteen peer-to-peer support indicators suggested by Fahy (2003) and Jeong (2006). Challenging politely and responding to a question/challenge politely are among the social presence enhancement strategies proposed by Kim (2009) to support interactive argumentation.

In total, this study employs 11 social presence enhancement strategies (Appendix N), categorized by the researcher into three categories identified by Garrison et al. (1999) and Rourke et al. (1999): 1) affective (four strategies, strategies 1-4), 2) supportive (four strategies, strategies 5-8), and 3) cohesive (three strategies, strategies 9-11).

Table 3.3 provides a summary of the three conditions of the study.

Data Sources, Instruments, Data Collection Procedures, Data Management and Analysis

Overview of Data Sources, Instruments, and Analysis

The research matrix, which includes the purposes, data sources, instruments, and analysis methods for each research question, is presented in Table 3.4.

Data Sources and Instruments

This study employed a variety of instruments to collect and analyze data. For a summary of the instruments used and their respective purposes, please refer to Table 3.5.

Table 3.3

Three Conditions of the Study

	Condition 1	Condition 2	Condition 3
Similarities			
Group size	3-4 students	3-4 students	3-4 students
Discussion activity	Label posts by argumentation behaviors adapted from work by Kim (2010)	Label posts by argumentation behaviors adapted from work by Kim (2010)	Label posts by argumentation behaviors adapted from work by Kim (2010)
Differences			
Treatment	Neither question prompts nor social presence enhancement strategies	Question prompts adapted from work by Oh and Jonassen (2007)	Question prompts adapted from work by Oh and Jonassen (2007) + Social presence enhancement strategies adapted from work by Rourke et al. (1999)

Table 3.4

Research Matrix

Research questions	Purposes	Data sources/Instruments/ Data Analysis
RQ1 How do argumentation behaviors in the discussion vary by the use of the scaffolds versus the use of the scaffolds together with social presence enhancement strategies, and no scaffolding?	To learn whether the treatment (question prompt-based only condition and question prompt and social presence enhancement strategy condition) support interactive argumentation.	Data Source: Students' messages posted on the online discussion board during treatment (Week 5) Instruments: Coding scheme for argumentation behaviors (Appendix L) Data Analysis: Content analysis, principal component analysis, ANOVA
RQ2 How do students' problem-solving processes in the discussion vary between the three groups?	To examine whether the treatment enhance students' problem-solving performance as measured by their participation in problem-solving processes.	Data Source: Students' messages posted on the online discussion board (Week 5) Instruments: Coding scheme for ill-structured problem-solving processes (Appendix O) Data Analysis: Content analysis, MANOVA

RQ3 How does the problem-solving performance vary between the three groups on a post-treatment problem-solving activity?	To examine whether the treatment has transfer effects on problem-solving performance.	Data Source: Post-treatment problem-solving scores, pre-treatment problem-solving scores, self-reported problem-solving skill scores, argumentativeness Instruments: Problem-solving performance rubric (Appendix P), personal profile survey (Appendix H) Data Analysis: Content analysis, ANCOVA

Table 3.5

Instruments and Purposes

Instruments	Purposes
Argumentative Scale (Infante & Rancer, 1982) (Section 1, Appendix H)	• To measure students' level of argumentativeness • Assign students into conditions and within-condition groups if needed. • Covariates in analyzing the effects of the treatment on students' problem-solving performance
Self-reported Problem-solving Skills (Ge, 2001) (Section 2, Appendix H)	• To measure students' self-reported problem-solving skills • Assign students into conditions and within-condition groups if needed
Demographic information (gender, age, native language, academic status, reason for taking the class) (Section 3, Appendix H)	• Control variables in analyzing the effects of the treatment on argumentation behaviors, and problem-solving processes and performance
Validation Tool for Problem Scenarios (Appendix A)	• To validate the ill-structured nature of problem scenarios
Argumentation Behavior Coding Scheme adapted from the work by Kim (2010) (Appendix I)	• To analyze students' argumentation behaviors in online discussion posts
Problem-Solving Processes Coding Scheme adapted from the work by Ge (2001) (Appendix O)	• To analyze students' problem-solving processes in online discussion posts
Ill-structured Problem-Solving Rubric adapted from the work by Ge (2001) (Appendix P)	• Measure students' problem-solving performance in the pre- and post-treatment posts • Assign students into conditions and within-condition groups (pre-test scores) if needed

To investigate the impact of question prompt-based argumentation scaffolds and social presence enhancement strategies on students' argumentation behaviors, problem-solving processes, and problem-solving performance, data were collected from various sources. Firstly, participants' responses to the personal profile survey (Appendix H) conducted during the recruitment period (Weeks 1-3) were collected. Secondly, participants' messages posted on the online discussion boards during the intervention (Week 5) were analyzed. Finally, participants' pre- and post-treatment discussion first posts (Week 1 and Week 6) were examined using different instruments and analysis methods.

Personal Profile Survey. To collect potentially relevant personal variables prior to treatment, an online Qualtrics questionnaire (Appendix H) was utilized. The personal profile survey was conducted during the recruitment period, lasting from the first week to the third week of the course. The survey consists of 45 items divided into three sections. The first section (Section 1, Appendix H) includes twenty items designed to measure respondents' level of argumentativeness using the 20-item Argumentative Scale developed by Infante and Rancer (1982). The second section (Section 2, Appendix H) consists of 20 items on students' self-rated problem-solving skills, adopted from the self-report questionnaire on problem-solving skills developed by Ge (2001). Lastly, the third section (Section 3, Appendix H) contains five items for gathering demographic information such as gender, age, native language, academic status, and reason(s) for taking the class. The responses to the personal profile survey were evaluated and used to assess how individual differences among participants may impact outcome variables.

Argumentativeness. To measure an individual's tendency to approach or avoid argumentative situations, the 20-item Argumentative Scale developed by Infante and Rancer (1982) was used with a 5-point Likert-type scale ranging from 'never or almost never true' to 'always or almost always true'. The Argumentative Scale yields two separate scores: the tendency to approach and the tendency to avoid argumentative situations, representing two separate variables for argumentativeness. The sum of 10 question items (2, 4, 7, 9, 11, 13, 15, 17, 18, 20) represents the tendency to approach argumentative situations, and the sum of the other 10 items (1, 3, 5, 6, 8, 10, 12, 14, 16, 19) represents the tendency to avoid. High scores indicate a strong tendency. Questions 1 to 20 in Appendix H are the items used for these two variables. Infante and Rancer (1982) reported Cronbach's alpha coefficients of .91 and .86 for the tendency to approach argumentative situations and the tendency to avoid, respectively, indicating good internal consistency of the scale.

***Self-reported Problem-solving Skill*s**. The self-reported questionnaire on problem-solving skills (Section 2, Appendix H) was adopted from Ge's (2001) work, which was based on the research of Schoenfeld (1985) and Hong (1998). The questionnaire aimed to gather information on students' self-rating of their problem-solving skills and consisted of 20 statements grouped into four areas, with each area comprising five questions. The four areas are: (a) interpreting and problem representation (questions 21-25), (b) developing solutions and monitoring solution processes (questions 26-30), (c) making justifications and evaluating problem-solving processes (questions 31-35), and (d) students' specific strategies for solving a problem (questions 36-40). Participants were asked to rate each question on a 1-5 Likert scale, with 1 indicating

"Never" and 5 indicating "Always." The maximum score for each question area is 25 points, and the minimum score is 5 points. Therefore, the maximum average score for each problem-solving skill area is 5, while the minimum average score for a problem-solving area is 1. High scores indicate strong problem-solving skills in a particular area.

Online Postings. Online messages posted by students during the treatment period were the primary data source in this study. Prior to coding, pseudonyms in the form of IDs were created and assigned to participants' names. This measure ensured that the two coders who worked on the study were blind to the students' names and conditions, enhancing the reliability of coding.

The two coders used two coding schemes - one for argumentation behaviors (Appendix L) and the other for problem-solving processes (Appendix O) - to code the online discussion messages posted by students during the treatment. This coding process aimed to quantify the frequency of students' argumentation behaviors and problem-solving processes.

Argumentation Behaviors. The coding scheme used in this study to analyze argumentation behaviors was adapted from the work of Kim (2009). Kim's coding scheme was designed to capture important argumentation behaviors observed during interactive argumentation where two arguers in two opposite roles (supporter or opponent) exchanged opinions on a controversial issue. The scheme consists of seven argumentation behaviors, including *challenging, counter-challenging, integration, elaboration, and agreeing,* as well as *proposing a supportive* or *opposing theory*. Kim (2009) reported intercoder reliability of .86 and .83 using Cohen's kappa coefficient and

kappa coefficients for argumentation behaviors, respectively. These reliability values were considered acceptable, as they were above .70.

However, in the current study, students were not assigned specific roles, and therefore the behaviors of proposing a supportive theory and proposing an opposing theory were removed from the coding scheme. Instead, three new argumentation behaviors were added: *claims, making a concession,* and *supporting reasons*. Claims are a key component in argumentation, according to Toulmin's (2003) model, and have been used in prior studies to classify students' argumentative messages. Concession is recognized as a key feature of critical argumentation, as it helps increase or decrease the acceptability of a controversial standpoint for the listener or reader (Keefer et al., 2000; Resnick et al., 1993). *Supporting reasons* was also coded as one of the argumentation categories in prior studies (Cho & Jonassen, 2002; Jonassen & Cho, 2011; Munneke et al., 2007; Nussbaum & Kardash, 2005; Oh & Jonassen, 2007) since *supporting reasons* with evidence is crucial to construct cogent arguments (Hyytinen et al., 2017).

The coding scheme adopted for this study encompasses eight argumentation behaviors, which are listed in Appendix L. The primary objective of this coding scheme is to capture significant argumentation behaviors that may emerge during interactive discussions where participants present reasons and evidence to support their positions on how to solve an ill-structured problem.

Problem-solving Processes. The coding scheme used in this study, as presented in Appendix O, was adapted from the scoring rubrics for measuring ill-structured problem-solving processes created by Ge (2001). Ge (2001) identified four major ill-structured problem-solving processes and their corresponding problem-solving activities. The first

process, *problem representation*, includes four indicators: defining the problem, generating subgoals, identifying relevant information (known factors and constraints), and seeking needed information. The second process, *solution generation*, involves selecting or developing solutions with explicit explanations. The third process, making *justification*, involves two indicators: constructing arguments and providing evidence. The fourth and final process, *solution evaluation*, includes two indicators: evaluating solutions and assessing alternative solutions.

According to Jonassen (1997), one of the most critical aspects of ill-structured problem-solving is determining the nature of the problem or identifying an appropriate problem space among competing options. To do this, problem solvers must examine the context from which the problem arises and determine the problem's nature. Therefore, the coding scheme for problem representation in this study includes two indicators: *defining the problem* and *determining the problem space*, which are characteristic of problem representation, according to Jonassen (1997). The coding scheme for problem representation does not use the activity of generating subgoals by Ge (2001). The newly added indicator, defining problem space, encompasses two indicators of problem representation proposed by Ge (2001): identifying relevant information (known factors and constraints) and seeking needed information. Therefore, the two indicators of problem representation in Ge's (2001) coding scheme, which are *identifying relevant information* (known factors and constraints) and *seeking needed information*, were removed and replaced by *defining problem space*.

The final coding scheme consists of four problem-solving processes with a total of seven indicators of ill-structured problem-solving processes, as listed in Appendix O.

The coding scheme aims to capture critical ill-structured problem-solving processes that may be observed during online discussions.

Pre-test and Post-test. In this study, students' first individual posts in Week 1 (four weeks before the intervention) and Week 6 (the week immediately after the intervention) were used as another data source. Pre-test and post-test first posts were utilized to assess students' problem-solving performances at two different time points. To measure students' performance in the pre-test and the post-test, two researchers scored everyone's pre-test and post-test first posts using the ill-structured problem-solving performance rubric (Appendix P) without knowing the participants' identity.

The problem-solving performance rubric utilized in this study was adapted from Ge's (2001) rubric. While Ge's rubric assigns different scores for each indicator of each problem-solving process, resulting in different total scores for each process, I assigned each process the same total score since each process is equally important to overall problem-solving performance. The rubric aims to evaluate the quality of key processes of ill-structured problem-solving demonstrated in students' performance. Previous works by Ge (2001) and Oh and Jonassen (2007) also assessed students' individual problem-solving performance by evaluating the quality of students' individual problem-solving processes in their written assignments. Refer to Appendix P for the rubric used in assessing students' ill-structured problem-solving performance.

In this study, the problems assigned to students for the pre-test and post-test assignments differed (refer to Appendix I and K for the pre-test and post-test problems, respectively). All the problem-solving scenarios and tasks (pre-test discussion, during-intervention discussion, and post-test discussion) were developed by the researcher in

collaboration with the course instructors, committee members, and feedback from the focus group. The ill-structured nature of all the problems was validated using an instrument adapted from Ge's (2001) work (refer to Appendix A).

Data Collection Procedures

There were six major phases of this study: 1) Pre-work, 2) Pilot-testing, 3) Recruitment, 4) Pre-test, 5) Intervention, and 6) Post-test.

Phase 1: Pre-work. This phase involved identifying a suitable course for the study's purpose, determining the intervention's duration, and designing and developing problem-solving scenarios. The researcher collaborated with the chair of the dissertation committee and another committee member, both experts in online learning and designing meaningful learning with technology, to select a course. Once a course was selected, the researcher worked with the course instructors and the committee members to determine the intervention's length and which modules to use for the intervention. The researcher also sought feedback from them on the problem-solving scenarios developed. The researcher and course instructors used a validation tool for the problem-solving scenario materials (Appendix A) to assess the scenarios' appropriateness for the course. The revised problem scenarios were shared with the course instructors and two committee members for their feedback before the pilot-testing phase.

Phase 2. Pilot testing. After the pre-work phase, a pilot test was conducted to assess the suitability of the real-life problem scenarios designed for the study, including those for the pre-test, intervention, and post-test. An email containing a Qualtrics recruitment survey link was sent via the Listserv for undergraduate students in the College of Education at a large Mid-western university to all undergraduates majoring in

education, including students enrolled in the same course as the study but in different sections taking place in the first half of the Spring 2022 semester. The email invited ten students to participate in a 45-minute-long focus group and offered each participant a $25 Amazon gift card as compensation for their time (see Appendix B for the recruitment email). Six students expressed their interest, but only four attended the Zoom focus group conducted by the researcher. The focus group followed the focus group protocol (Appendix D) and lasted 45 minutes. The transcript of the focus group was analyzed by the researcher to make corresponding revisions to the problem scenarios (see a sample of the transcript in Appendix E). The revised problem scenarios were then shared with the course instructors and the chair of the committee for further feedback, revisions, and final approval to be used in the course and for the intervention.

Phase 3: Recruitment. Recruitment for the study began in the first week of the semester and continued until the end of the third week, with the assistance of the course instructors who announced the study in the course announcements on Canvas LMS. The announcement included a link to the Qualtrics online consent form (Appendix G), which contained a description of the research purpose, the tasks and procedures involved in the study, and assurances that the identities of the participants would remain anonymous in any reporting of the data. Students provided their full name, email address, and consent to participate by allowing the researchers to use their discussion data from Week 1, Week 5, and Week 6, as well as completing a personal profile survey (Appendix H).

Participating students were awarded 5 extra course credits for their involvement, and three students from each session were randomly selected to receive a $50 Amazon

gift card. For students who chose not to participate, an alternative assignment was provided to earn up to 5 extra course credits.

Phase 4: Pre-test (Pre-test Problem-solving Essay). Students' initial posts in the Week 1 discussion forum were considered as their pre-test problem-solving essays (refer to Appendix I for details about the pre-test assignment). The outcomes obtained from their first posts were utilized to assess their problem-solving performance in the pre-test.

Phase 5: Treatment (Small Group Discussions). During the study, students were divided into small groups and participated in group discussions in breakout rooms. Each breakout room had instructions for the small group discussion activity. All students received the same problem-solving tasks and instructions. However, small groups in the treatment conditions received either question prompts for each argumentation behavior or both question prompts and social presence enhancement strategies, while small groups in the control condition received neither.

All students were required to (1) introduce themselves, share their views on the problem representations and their justifications for their position, and engage in dialogue with their discussion partners by Thursday of Week 5/Module 5, and (2) continue the discussion by checking their discussion breakout rooms daily during the study week and responding to their partners' posts. All discussion posts had to be completed by Sunday at midnight.

The instructors and researcher observed the discussions but did not intervene to avoid any possible confounding effects. However, if students had any questions or concerns, they could post them on the discussions or other communication channels such as emails, and the instructors and researcher would provide relevant replies.

The study focused on a real-life problem related to teacher presence on social media, which was a complex and ill-structured problem. The participants were expected to develop their arguments for solving the problem while working with their group members. The problem-solving tasks can be found in Appendix J.

Phase 6: Post-test (Post-Problem-solving Essay). Following the small group discussion, students were required to submit an individual problem-solving essay on a cyberbullying problem that was posted as the initial post for Week 6 discussion forum. Please refer to Appendix K for more details about the post-test task. The essay evaluated students' problem-solving skills and served as the basis for the post-test results.

Data Cleaning and Management

The quantitative data collected from the Qualtrics questionnaire was downloaded and loaded into R Studio (RStudio Team, 2020). The data was cleaned by accounting for and removing missing cases and outliers. Descriptive statistics were calculated to understand the frequencies and tendencies in the data, including the tendency to approach or avoid argumentative situations, self-reported problem-solving skills, and participants' demographics.

The qualitative data from the discussion posts during the treatment, pre-test, and post-test assignments were combined into three Excel files for each data collection point. The data was cleaned by adding additional words in brackets to increase the readability of sentences or to clarify meaning where necessary and by writing out all abbreviations and acronyms as full words. The cleaned data was then imported into MAXQDA for coding in accordance with coding schemes for argumentation behaviors and problem-solving

processes. Each participant was assigned a respondent ID in both the quantitative and qualitative datasets.

Data Analysis

To examine argumentation behaviors, ill-structured problem-solving processes in the small group discussions, and students' performance in pre-and-post tests, we used quantitative content analysis to analyze the discussion transcripts and students' answers in the pre-and-post tests. Content analysis allowed us to transfer qualitative data into quantitative data through coding by multiple coders (Drisko & Maschi, 2016; Krippendorff, 2018).

Argumentation Behaviors. To analyze the impacts of question prompt scaffoldings and social presence enhancement strategies on students' argumentation behaviors, we employed the coding scheme of argumentation behaviors adapted from the work by Kim (2009) to conduct content analysis and quantify the frequency of each argumentation behavior demonstrated in students' discussion posts (see Appendix L).

Problem-solving Processes. We also employed quantitative content analysis to analyze the discussion transcripts and determine the frequency of each problem-solving process represented in the online discussions. To do this, we used a coding scheme based on the work by Ge (2001) (see Appendix O).

Problem-solving Performance. This study used the problem-solving performance rubric, adapted from Ge's (2001) work, to analyze students' problem-solving performance scores before and after the small group discussion board. Please refer to Appendix P for the rubric.

Coding Procedure. The procedures for content analysis of argumentation behaviors and problem-solving processes in the study were similar, except for the coding schemes used. The study employed two coders to ensure that the coding was reliable and to minimize subjectivity and inconsistency in coding. One of the coders is the author of the study, and the other is a Ph.D. in instructional technologies and learning systems design who is familiar with content analysis.

The coding process involved several steps, including discussing and reaching a consensus on how to interpret the coding schemes, coding a test sample of 10 discussion posts independently to establish initial inter-coder reliabilities, meeting to discuss the coding process, clarifying misunderstandings, and resolving disagreements. After this, the coders worked independently to code meaning units by classifying them into the appropriate categories on MAXQDA. Finally, the coding results were compared, and any disagreements were resolved through communication between the two coders.

Similarly, the content analysis procedure for assessing students' problem-solving performance in the pre-and post-test also involved discussing and reaching a consensus on how to interpret the rubric, assessing a test sample of 10 posts independently to establish inter-coder reliabilities, meeting to discuss the coding process, clarifying misunderstandings, and resolving disagreements, and then assessing students' problem-solving performance individually. The coding results were compared, and any disagreements were resolved through communication between the two coders.

Overall, the study employed rigorous procedures for content analysis, which helped to ensure the reliability and validity of the coding process.

Argumentation Behaviors. During the treatment, all students in the three conditions were required to label their posts based on the types of argumentation behavior before submitting them. However, it was observed that students tended not to do so, and only 43 out of 138 messages obtained from students' discussions were labeled, which represents only 31.2% of the total messages. Moreover, upon analyzing the labeled messages, it was found that most of them were either mislabeled (5, 11.6%) or contained multiple argumentation behaviors (29, 67.4%). Hence, it was problematic to treat each posting as a unit of analysis for argumentation behaviors since a single posting from an individual, labeled or unlabeled, may contain more than one argumentation behavior, while some postings may be just an extension of previous processes.

To address this issue, the two coders in this study opted to use a 'thematic unit' or 'meaningful unit' as a unit of analysis for argumentation behaviors rather than treating each individual message as a unit of analysis. For instance, when a student's message conveyed multiple argumentation behaviors, it was divided into several behaviors, while two or more messages from an individual student used to construct a single behavior were combined as one meaningful unit. This approach aligns with prior studies (e.g., Baisley-Nodine et al., 2018; Tang & Hew, 2020)), which followed Merriam's (2001) recommendation that meaning should be the main focus of communication. Table 3.6 provides examples of argumentation behaviors that were coded from the data in this study.

Table 3.6

Examples of Argumentation Behaviors[1] *in the Study*

Argument behavior types	Description	Examples
Claims	Making conclusions or statements about the problem/ cause of the problem/problem constraints/ solution(s) to the problem etc., that the author wishes the audience to believe	I personally think that one of the possible causes for this behavior on Jane's social media is the feeling of needing to stick up for what she believes in and to make what she sees as a positive difference (P4).
Agreeing	Expressing agreement with the preceding argument made by their discussion partner	Hi xxx. I like how you said though she is able to express herself and share what is important to her, she isn't considering how it could affect the people in her community (P7).
Challenging	Providing a counterargument that attempt to challenge, falsify, or undermine an argument made by their discussion partner	I personally agree (…) but I also think that teachers should be able to be themselves and show who they are in their teaching and things such as social media (P4).
Counter-challenging	Providing a rebuttal that rebuts their partner's challenge	Although I do concur with you regarding the sentiment that if a student, who is apart of the LGBTQ+ community, were to see her liking content that is not supportive, they may feel hurt, I want to

[1] Agreeing, challenging, counter-challenging, integration, and elaboration are argumentation behaviors adopted from Kim, B. (2009). *The effects of prompts-based argumentation scaffolds on peer-led interactive argumentation*. [Doctoral Dissertation, University of Missouri-Columbia]. MOspace. https://mospace.umsystem.edu/xmlui/bitstream/handle/10355/6858/research.pdf?sequence=3

		urge you to think deeper about the message that it sends to students to shut down one's thoughts and beliefs. I often have to remind myself that what one considers offensive, another may not; therefore, what were the posts she was liking? (….) (P29).
Integration	Integrating primary and opposing lines of reasoning, suggesting a creative solution, or illustrating exceptions or conditions based on the examination of both primary and opposing lines of reasoning made by students and their partners	I do respect your position, and truly understand where you are coming from, and I must admit, it is important to consider, so I appreciate your sentiments, and it did make me think and do further research and have a conversation with my aunt about what she would think or do (P30).
Elaboration	Elaborating one's preceding argument with reasons or evidence (e.g., personal beliefs, experience, expert opinions, research findings, etc.) or asking a question seeking additional information on a preceding statement	(….) First, everyone can see Jane's content because her account is public, including her co-workers, students, and their parents (P10).
Making a concession	Acknowledging a point from the opposition	Hi xxxx! Something you said in your post stood out to me that was different from mine but is still true (….) (P26).
Supporting reason	Providing scholars' work, personal experience, individual beliefs, research findings, or data to support the claim	One of the biggest "don't" from the websiteThe Dos and Don'ts of Social Media for Teachers (Knoll, 2017) is sharing peronsal pictures that would include drinking alcohol (….) (P1).

The inter-rater reliabilities of Cohen's Kappa were generated using ReCal2 by Freelon (n.d.) for students' argumentation behaviors, including *claims, agreeing, challenging, counter-challenging, integration, elaboration, making a concession,* and *supporting reasons*. The values obtained were 0.64, 0.76, 0.92, 0.74, 0.65, 0.63, 0.65, and 0.83, respectively, indicating substantial reliabilities. For further details on the inter-rater reliabilities for argumentation behaviors, please refer to Appendix R.

Problem-solving Processes. In this study, a thematic unit or meaningful unit was also used as a classification method for problem-solving processes. If a student's message conveyed more than one problem-solving process, it was divided into several processes. Conversely, if two or more messages from a single student were used to construct a single process, they were combined as one meaningful unit. Table 3.7 provides examples of problem-solving processes that were coded from the data in this study.

The interrater reliabilities for students' problem-solving processes in *problem representation, solution generation, justification,* and *solution evaluation* were determined using Cohen's Kappa interrater reliability coefficient, which was generated from ReCal2 by Freelon (n.d.). The interrater reliabilities were 0.65, 0.72, 0.66, and 0.71, respectively, indicating substantial reliabilities. For further information on interrater reliabilities for problem-solving processes, please see Appendix S.

Table 3.7

Examples of Problem-solving Processes[2] *in the Study*

Processes	Indicators	Examples
Problem representation	- Statements that define the problem. - Statements that determine the context and the nature of the problem.	I think a potential cause for her behavior regarding interacting in questionable ways on social media would be simply her not thinking of all of the potential outcomes from her posts (P24).
Solution generation	- Statements that select or suggest solutions and elaboration on how it is/they are linked to and/or will address the cause(s) of the problem.	I feel that Jane's social media should be private if she is liking, sharing, and reposting posts about controversial things on social media (P11).
Justification	- Arguments to support why the solution(s) is/are selected. - Evidence to support the arguments	Jane needs to separate her school life with her personal life and by keeping her accounts public, this means that essentially she is allowing any coworker, employer, parents or students to follow her without actually "following" her (P35).
Solution evaluation	- Statements that describe the consequences/effectiveness/benefits/pros and cons/side effects of the proposed solution relative to all of the important causes, issues, and/or constraints.	Overall, I feel that when seeking for a true "solution", keeping your personal life private on social media, and creating a public account for your professional presence is the best option. The other ideas I provided, are seen to me personally as more of "stepping stones" to the solution, rather than solutions themselves (P4).

[2] Adapted from Ge, X. (2001). Scaffolding students' problem-solving processes on an Ill-structured task using question prompts and peer interactions [Unpublished doctoral dissertation]. Pennsylvania State University

	- Statements that assess the viability of alternative solutions relative to key issues and constraints associated with (the causes of) the problem.	

Alignment of Research Questions and Data Analysis Techniques

Question 1.

RQ1. How do argumentation behaviors in the discussion vary by the use of the scaffolds versus the use of the scaffolds together with social presence enhancement strategies, and no scaffolding?

Question 1 was analyzed using content analysis (Drisko & Maschi, 2016; Krippendorff, 2018). Specifically, the coding scheme for argumentation behaviors (see Appendix L) was used to characterize students' argumentation behaviors during group work. Descriptive statistics were calculated to describe the patterns of argumentation behaviors that emerged from the data. To compare argumentation behaviors across conditions, this study used the frequency of these behaviors.

To investigate differences in argumentation behaviors across conditions, a principal component analysis (PCA) was conducted to determine whether the proposed argumentation behaviors could be categorized into distinct groups. An ANOVA analysis was then performed, with the three conditions of the study serving as the independent variable. The dependent variables were the loading scores of principal components identified from the PCA.

Question 2.

RQ2. How do students’ problem-solving processes in the discussion vary between the three groups?

To answer Question 2, content analysis was used to characterize students' problem-solving processes during group work. The coding scheme for ill-structured problem-solving processes (see Appendix O) was employed for this purpose. Descriptive

statistics were calculated to describe the patterns of problem-solving processes that emerged from the data. To compare problem-solving processes across conditions, the frequency of these processes was used in the analysis.

To investigate differences in problem-solving processes across conditions, a MANOVA analysis was conducted. The independent variable was the three conditions of the study. The dependent variables were the frequency of the four pre-defined problem-solving processes/behaviors.

Question 3.

RQ3. How does the problem-solving performance vary between the three groups on a post-discussion problem-solving activity?

To answer Question 3, content analysis and ANCOVA analysis were used. Students' problem-solving performance after the discussion was characterized using the rubric for ill-structured problem-solving performance (Appendix P). Descriptive statistics were calculated for each criterion to describe the patterns of problem-solving performance that emerged from the data.

To investigate the differences in problem-solving performance across conditions, an ANCOVA analysis was conducted. The independent variable was the three conditions of the study. The dependent variable was the total score of individuals' problem-solving performance. The covariate variables were students' pre-test problem-solving performance, their tendency to approach argumentative situations, their tendency to avoid argumentative situations, and new variables for students' argumentation behaviors obtained from PCA. Table 3.8 summarizes the data analysis methods used to address each research question in this study.

Table 3.8

Data Analysis

Research Questions	Data Analysis Methods
RQ1 How do argumentation behaviors in the discussion vary by the use of the scaffolds versus the use of the scaffolds together with social presence enhancement strategies, and no scaffolding?	• Content analysis • Principal component analysis • ANOVA
RQ2 How do students' problem-solving processes in the discussion vary between the three groups?	• Content analysis • MANOVA
RQ3 How does the problem-solving performance vary between the three groups on a post-discussion problem-solving activity?	• Content analysis • ANCOVA

Validity and Reliability

The study's internal validity and credibility were minimally threatened by the testing effect, as the pre-test and post-test involved students' own reasoning and justifications on provided problems, without a right or wrong answer. To further minimize threats to internal validity or credibility, and reliability, triangulation techniques were utilized, including the use of multiple theories, multiple sources of data (discussion transcripts and pre/post-test results), and triangulating analysts. Random grouping was also employed to minimize individual differences and selection bias to internal validity. Participants were randomly assigned to the three different conditions to evenly distribute personal variables (extraneous variables) among the groups. While random assignment

does not guarantee full control over personal characteristics that may affect outcome variables, these variables were obtained prior to treatment to control for them statistically.

To assess the level of agreement between the two coders, Cohen's Kappa interrater reliabilities (Cohen, 1960) were calculated using ReCal2, a tool developed by Freelon (n.d.). The interrater reliabilities for pre-test problem-solving performance ranged from 0.70 to 0.86 (see Appendix Q), while those for argumentation behaviors ranged from 0.64 to 0.83 (see Appendix R). For problem-solving processes, the interrater reliabilities ranged from 0.66 to 0.72 (see Appendix S), and for pre-test problem-solving performance, they ranged from 0.68 to 0.77 (see Appendix T). All interrater reliability coefficients indicate substantial agreement between the coders.

In addition to ensuring the validity and reliability of the study, we provided a detailed and comprehensive description of our methodology and results to ensure their external validity and transferability. Moreover, since the ethics of the investigator are directly linked to the validity and reliability of a study (Merriam & Tisdell, 2015), we followed ethical considerations throughout the study.

Ethical Considerations

To ensure the utmost ethical conduct of this study, several steps were taken. First, the Institutional Review Board (IRB) guidelines and codes of ethics were strictly adhered to. Second, all research participants were given informed consent forms prior to data collection. Third, to protect the privacy of the participants, all student names in the collected data were anonymized. Fourth, the data was stored in a password-protected folder on a secure storage OneDrive software maintained by the researcher's affiliated institution, accessible only to the researcher and another coder. Additionally, to ensure

the voluntary participation of the students and to provide equal opportunity for all students to earn the same five extra course credits, an alternative option was developed by the course instructors for students who did not wish to participate in the study.

Chapter Summary

This chapter provides an overview of the research context, participants, sample, data collection, and data analysis strategies employed in this study. The research was conducted over two sessions of an 8-week-long online course hosted on the Canvas LMS platform at a large Mid-Western University in the latter half of Spring 2022. The study participants completed a survey on their argumentativeness, self-reported problem-solving skills, and demographic information, and granted permission for the researcher to use their discussion data from Week 1, Week 5, and Week 6 for research purposes.

4. RESULTS

Overview

This chapter begins with the results related to students' argumentativeness and self-reported problem-solving skills obtained from students' personal profile survey and pre-test problem-solving performance based on students' first posts of the Week 1 discussion board. After that, the chapter presents the findings in relation to the effects of the question prompt scaffold with or without the social presence enhancement strategies on students' argumentation behaviors and problem-solving processes during small group discussions, followed by the examination of the transfer effects of the treatment on students' post-test problem-solving performance and the summary of the chapter.

This chapter presents the results in relation to the three research questions of the study. The study's results are based on data obtained from 44 participants who participated in all three time points of data collection: the pre-test time, in which they completed the personal profile survey and discussed problem scenario 1; the intervention time, during which they participated in small group discussions to discuss problem scenario 2; and the post-test discussion, during which they had posts addressing problem scenario 3. Out of the 44 participants, the control condition (condition 1) consisted of 15 students, the question prompt-based only condition (condition 2) had 12 students, and the question prompt and social enhancement strategy condition (condition 3) had 17 students. The students in this study shared homogeneous demographic characteristics in terms of gender, native language, reasons for taking the course, education level, and age. Therefore, these variables were not utilized in the statistical analysis to answer the research questions of the study.

Students' Argumentativeness and Problem-solving Characteristics Before the Treatment

Argumentativeness

Students' argumentativeness data was collected from students' personal profile survey (Section 1 - Appendix H) conducted during the recruitment. Students' argumentativeness was measured through the use of the 20-item 5-point Likert-type argumentative scale developed by Infante and Rancer (1982). The scale yields two separate scores representing two separate variables for argumentativeness: the tendency to approach arguments and the tendency to avoid arguments. The higher the score is, the stronger the tendency is.

Table 4.1. summarizes individuals' argumentativeness that may influence their problem-solving performance and the descriptive statistics of individuals' argumentativeness across the conditions. Descriptively, overall, students' tendency to avoid argumentative situations (M = 3.49, SD = 0.64) is higher than students' tendency to approach argumentative situations (M = 2.85, SD = 0.65). The same trend is consistently seen across the conditions. The average score for students' tendency to avoid arguments is M = 3.59, M = 3.41, M = 3.46 for conditions 1, 2, and 3 correspondingly, while the average score for students' tendency to approach arguments is M = 2.60, M = 2.95, and M = 2.99 respectively.

The Cronbach's alpha coefficients of the tendency to approach argumentative situations and the tendency to avoid argumentative situations in this study are a = 0.83 and a = 0.86 respectively, indicating a good internal consistency of each of the measures of the scale, which is consistent with the Cronbach's alpha coefficients for the measures

of the scale by Infante and Rancer (1982). In this study, the correlation coefficient between the tendency to approach arguments and the tendency to avoid arguments is r = -0.63 and significant at $t(42) = -5.36$, $p < .001$. This significant and moderate correlation between these two variables indicates that they should be used as covariates in the analysis to address the research questions of this study with caution to avoid multicollinearity issues.

Table 4.1

Participants' Argumentativeness[3] *Across Conditions: The Tendency to Approach and Avoid Arguments*

		Condition			Total
		Control (n = 15)	QP (n = 12)	QPSPES (n = 17)	(*N* = 44)
Approaching	*M*	2.60	2.95	2.99	2.85
Arguments[a]	*SD*	0.70	0.48	0.67	0.65
	Median	2.40	2.85	3.00	2.80
	Min	1.60	2.30	1.90	1.60
	Max	3.70	3.80	4.10	4.10
	Alpha				0.83
Avoiding	*M*	3.59	3.41	3.46	3.49
Arguments[b]	*SD*	0.59	0.73	0.60	0.643
	Median	3.70	3.40	3.44	3.42
	Min	2.60	2.44	2.40	2.40
	Max	4.70	4.50	4.70	4.70
	Alpha				0.86

Note.

[a]Used 5-point Likert scale, ranging from 1-5, to measure the variable. Higher scores indicate a greater tendency to approach arguments.

[3] Adopted from Infante, D.A., & Rancer, A.S. (1982). A conceptualization and measure of argumentativeness. *Journal of Personality Assessment*, *46*(1), 72-80.

[b]Used 5-point Likert scale, ranging from 1-5, to measure the variable. Higher scores indicate a greater tendency to avoid arguments.

In order to investigate whether there were any significant differences in argumentativeness across the study conditions that could potentially affect the research findings, a MANOVA test was conducted. Prior to the test, the assumptions related to the homogeneity of covariance matrices, multivariate normality, and multivariate outliers were checked and found to be met. The results of the MANOVA test indicated that there were no significant differences in students' argumentativeness across the three conditions of the study ($V = 0.09$, $F(4, 82) = 0.95$, $p = 0.44$).

Self-reported Problem-solving Skills

The data for students' self-reported problem-solving skills were collected from students' personal profile survey (Section 2 - Appendix H) conducted during the recruitment. Students' self-reported problem-solving skills were measured through the use of a 20-item 5-point Likert-type instrument developed by Ge (2001). The instrument yields four separate scores representing four separate areas of problem-solving skills: *problem representation, solution generation, justification,* and *students' specific strategies for solving a problem*. The maximum score for each problem-solving skill area is 25 points and the minimum score is 5 points. Consequently, the maximum average score for each problem-solving skill area is 5 and the minimum average score for a problem-solving area is 1. High scores indicate strong skills in a specific area of problem-solving. This study reported students' average scores in students' self-rated problem-solving skills in those four problem-solving areas.

Table 4.2 summarizes the participants' self-reported problem-solving skills across conditions. Overall, the means for students' self-*reported problem representation,*

solution generation, justification, and *problem-solving strategies* were 3.76 (*SD* = 0.72), 3.72 (*SD* = 0.60), 3.54 (*SD* = 0.73), and 3.29 (*SD* = 0.73), respectively. Descriptively, *problem representation* ranked highest in students' self-reported problem-solving skills (*M* = 3.76), followed by *solution generation* (*M* = 3.72), *justification* (*M* = 3.54), and *problem-solving strategies* (*M* = 3.29).

Cronbach's alpha coefficients of students' *problem representation, solution generation, justification,* and *problem-solving strategies*-in this study were *a* = 0.79, *a* = 0.53, *a* = 0.76, and *a* = 0.65 respectively, indicating weak to moderate internal reliabilities. The alpha coefficients for students' self-reported problem-solving skills in this study were quite similar to those found in the study by Ge (2001), who developed the scale. Ge (2001) found that the internal consistency coefficients in her study were weak to moderate. The Cronbach's alpha coefficients in the study by Ge (2001) were *a* = .66, *a* = .69., *a* = .72, and *a* = .58 for *problem representation, solution generation, justification,* and *problem-solving strategies* respectively.

Table 4.2

Participants' Self-reported Problem-solving Skills[4]

		Condition			Total
		Condition 1 (n = 15)	Condition 2 (n = 12)	Condition 3 (n = 17)	(*N* = 44)
Problem representation[a]	*M*	3.75	3.75	3.62	3.76
	SD	0.78	0.78	0.82	0.72
	Median	3.6	3.6	3.80	3.8
	Min	2.4	2.4	2.00	2.00
	Max	5.00	5.00	4.8	5.00
	Alpha				0.79
Solution generation[b]	*M*	3.69	3.72	3.74	3.72
	SD	0.58	0.73	0.54	0.60
	Median	3.80	3.80	3.80	3.80
	Min	2.40	2.40	2.80	2.40
	Max	4.60	5.00	4.6	5.00
	Alpha				0.53
Justification[c]	*M*	3.48	3.48	3.64	3.54
	SD	0.67	0.86	0.73	0.73
	Median	3.60	3.30	3.60	3.60
	Min	2.40	2.20	2.60	2.20
	Max	4.60	5.00	5.00	5.00
	Alpha				0.76
Strategies[d]	*M*	3.13	3.48	3.28	3.29
	SD	0.66	0.63	0.86	0.73

[4] Adopted from Ge, X.(2001). *Scaffolding students' problem-solving processes in an ill-structured task using question prompts and peer interactions*. [Doctoral Dissertation, Pennsylvania State University]. PennState Elecronic Theses and Dissertations for Graduate School. https://etda.libraries.psu.edu/files/final_submissions/6665

Median	3.20	3.50	1.80	3.30
Min	1.40	2.60	3.20	1.40
Max	4.00	5.00	4.60	5.00
Alpha				0.65

Note.

Condition 1: Control condition

Condition 2: Question prompt-based only condition

Condition 3: Question prompt and social presence enhancement strategy condition

[a, b, c, d] Used 5-point Likert scale, ranging from 1-5, to measure the variable. Higher scores indicate a greater self-perceived problem-solving skill in a certain area (*problem representation, solution generation, justification,* and *problem-solving strategies*)

As shown in Table 4.3, the inter-correlations between self-reported problem-solving skills range from $r = 0.48$ to $r = 0.62$, and all are statistically significant at $p < 0.01$ or $p < .001$. The significant correlations indicate that these self-reported problem-solving skills should be treated with caution when used as covariates in the analysis to address research question 3 to avoid multicollinearity issues.

Table 4.3

Intercorrelations for Self-reported Problem-solving Skills

	Problem representation	Solution generation	Justification	Strategies
Problem representation	-	0.48**	0.62***	0.46**
Solution generation	-	-	0.61***	0.59***
Justification	-	-	-	0.60***

Note.

**$p < 0.01$, ***$p < 0.001$

To examine if there were any significant differences in students' self-reported problem-solving skills across the conditions, which may potentially confound the results of the research questions, I conducted a MANOVA test. Prior to the test, I checked the assumptions related to the homogeneity of covariance matrices, multivariate normality, and multivariate outliers. The results of the MANOVA test showed that there was no difference in students' self-reported problem-solving skills across the three conditions of the study ($V = 0.18$, $F(8, 78) = 0.95$, $p = .49$).

Pre-test Problem-solving Performance

The data for students' pre-test problem-solving performance were collected before the treatment and from students' first post in the Module 1 discussion board. The pre-test problem-solving performance was measured using the problem-solving performance rubric (Appendix P), adapted from the work by Ge (2001). The rubric evaluates the quality of four key problem-solving processes: *problem representation, solution generation, justification,* and *solution evaluation*. The performance score for each problem-solving process can be 1, 3, or 5, with 1 representing "not satisfied" performance, 3 representing "satisfied" performance, and 5 representing "very satisfied" performance. Students' overall pre-test problem-solving performance score is the average of all performance scores in the four key problem-solving processes. Higher scores indicate stronger pre-treatment problem-solving performance in general. The Cohen's Kappa inter-rater reliabilities generated from ReCal2 by Freelon (n.d.) for students' pre-test problem-solving performance in *problem representation, solution generation, justification,* and *solution evaluation* are 0.78, 0.86, 0.72, and 0.70, respectively,

indicating substantial reliabilities. For further details on inter-rater reliabilities for pre-test problem-solving performance, see Appendix Q.

Table 4.4 summarizes the pre-test problem-solving performance of participants in each problem-solving process category, their general problem-solving performance, and their distribution across the conditions. As shown in Table 4.4, the means for students' pre-test *problem representation, solution generation, justification,* and *solution evaluation* are 3.73 (*SD* = 1.06), 3.64 (*SD* = 0.94), 2.68 (*SD* = 1.22), and 2.00 (*SD* = 1.10), respectively. Descriptively, students' pre-test problem-solving performance followed the same trend as found in their self-reported problem-solving skills, in which *problem representation* ranked highest in students' problem-solving skills (*M* = 3.76), followed by *solution generation* (*M* = 3.72), *justification* (*M* = 3.54), and *strategies* (*M* = 3.29). The pre-test overall problem-solving performance of students is measured by the average of their pre-test problem-solving skills and has a mean of 3.01 (*SD* = 0.68). The Cronbach's alpha coefficient of students' pre-test problem-solving performance in this study was 0.48, indicating poor internal consistency.

To investigate whether there were any significant differences in the overall pre-test problem-solving performance across conditions, I conducted an ANOVA test, using the overall pre-test problem-solving performance score as the dependent variable. Prior to the test, ANOVA assumptions, such as homogeneity, normal distribution, and univariate outliers, were checked, and all the assumptions were met. The results of the ANOVA test showed that there were no significant differences across conditions in terms of students' overall pre-test problem-solving performance ($X^2 = 3.59$, $df = 2$, $p = .17$).

Table 4.4

Participants' Pre-test Problem-solving Performance by Condition

		Condition			Total
		Condition 1 (n = 15)	Condition 2 (n = 12)	Condition 3 (n = 17)	(*N* = 44)
Problem representation[a]	*M*	4.07	3.33	3.71	3.73
	SD	1.03	0.78	1.21	1.06
	Median	5.00	3.00	3.00	3.00
	Min	3.00	3.00	1.00	1.00
	Max	5.00	5.00	5.00	5.00
Solution generation[b]	*M*	3.67	3.50	3.71	3.64
	SD	0.98	0.91	0.99	0.94
	Median	3.00	3.00	3.00	3.00
	Min	3.00	3.00	3.00	3.00
	Max	5.00	5.00	5.00	5.00
Justification[c]	*M*	2.73	2.17	3.00	2.68
	SD	1.28	1.34	1.00	1.22
	Median	3.00	2.00	3.00	3.00
	Min	1.00	1.00	1.00	1.00
	Max	5.00	5.00	5.00	5.00
Solution evaluation[d]	*M*	2.20	1.83	1.94	2.00
	SD	1.01	1.34	1.03	1.10
	Median	3.00	1.00	1.00	1.00
	Min	1.00	1.00	1.00	1.00
	Max	3.00	5.00	3.00	5.00
Overall pre-test PS performance[e]	*M*	3.17	2.71	3.09	3.01
	SD	0.72	0.58	0.67	0.68
	Median	3.50	2.5	3.0	3.00

Min	2.00	2.00	2.00	2.00
Max	4.00	4.00	4.00	4.00
Alpha				0.48

Note.

Condition 1: Control condition

Condition 2: Question prompt-based only condition

Condition 3: Question prompt and social presence enhancement strategy condition

[a, b, c, d] Used a rubric with scores of 1, 3, and 5 to measure the variable. Higher scores indicate a greater pre-treatment problem-solving skill in a certain area (*problem representation*, *generating solution*, *justification*, and *solution evaluation*)

[e] Used the average of all four problem-solving skills. Higher scores indicate strong pre-treatment problem-solving skills in general.

Overall, the results of the personal profile survey indicated that before the treatment, there were no significant differences across conditions regarding students' argumentativeness, their self-reported problem-solving skills, and their pre-test problem-solving performance.

Effects of the Scaffolds on Argumentation Behaviors and Problem-solving Processes during Small Group Discussions

This section presents the findings on the impact of the question prompt-based argumentation scaffold and social presence enhancement strategies on students' argumentation behaviors and problem-solving processes during small group discussions. The analysis begins with descriptive statistics on the discussion posts used to code students' argumentation behaviors and problem-solving processes, followed by an examination of the effects of the scaffolds.

Table 4.5 displays the number of messages and word count of students' messages during Week 5 of the course, which was the treatment week. The study participants contributed a total of 138 posts during the discussions. Condition 3 had the highest number of posts (60 posts, 43.47%), followed by condition 1 (50 posts, 36.23%) and condition 2 (28 posts, 20.29%). Condition 1 had the lowest number of posts (38 posts, 23.75%). On average, students in condition 3 had the most messages per student (3.53 posts), followed by students in condition 1 (3.33 posts). Condition 2 had the lowest average number of posts per student (2.33 posts).

Table 4.5

Number of Discussion Posts and Word Count by Condition

		Condition			Total
		Condition 1(n = 15)	Condition 2 (n = 12)	Condition 3 (n = 17)	(*N* = 44)
Posts	n	50	28	60	138
	M	3.33	2.33	3.53	3.14
	SD	1.95	1.15	1.50	1.64
	MD	4.00	2.00	3.00	3.00
	Min	1.00	1.00	2.00	1.00
	Max	8.00	7.00	7.00	8.00
Word Count	n	9,855	3,939	11,173	24,967
	M	657	328	657	567.43
	SD	541	249	362	426.81
	MD	611	267	522	396.5
	Min	106	50	162	50.00
	Max	1,924	1,013	1,500	1,924

Note.

Condition 1: Control condition

Condition 2: Question prompt-based only condition

Condition 3: Question prompt and social presence enhancement strategy condition

Effects of the Scaffolds on Argumentation Behaviors during Small Group Discussions

RQ1: How do argumentation behaviors in the discussion boards vary by the use of the scaffold versus the use of the scaffold together with social presence enhancement strategies and no scaffolding?

This section reports the effects of the question prompt-based argumentation scaffold, with and without social presence enhancement strategies, on students' argumentation behaviors. To quantify students' argumentation behaviors, the online postings generated during Week 5 of the course's small group discussions were collected and coded using a coding scheme adapted from Kim's (2009) argumentation behavior coding scheme (Appendix L). Cohen's Kappa interrater reliabilities, generated using ReCal3 by Freelon (n.d.), ranged from 0.64 to 0.92, indicating substantial reliabilities. Refer to Appendix R for further details on interrater reliabilities for argumentation behaviors.

This section commences with descriptive statistics on the frequency of students' argumentation behaviors across conditions. Subsequently, the results of the principal component analysis used to reduce the dimensions of argumentation behaviors are presented. Lastly, an ANOVA analysis is conducted to investigate whether any differences exist in the reduced dimensions of students' argumentation behaviors across conditions.

An Overview of Argumentation Behaviors across Conditions. Table 4.6 shows the number of coded units for each type of argumentation behavior and their percentages

across conditions. In total, there were 555 coded units. Across conditions, *elaboration* (215, 38.70%) had the most coded units, followed by *claims* (208, 37.50%), and *agreeing* (85, 15.3%). The argumentation behavior with the least coded units was *integration* (2, 0.36%), followed by *counter-challenging* (3, 0.54%), *making a concession* (4, 0.72%), and *challenging* (9, 1.62%), and *supporting reasons* (29, 5.23%).

In terms of similarities across conditions, Table 4.6 shows that the types of argumentation behaviors with the most coded units are *claims* (n = 76, 38.78% for condition 1; n = 42, 36.52% for condition 2; n = 90, 36.89% for condition 3) and *elaboration* (n = 75, 38.27% for condition 1; n = 44, 38.26% for condition 2; n = 96, 39.34% for condition 3), followed by *agreeing* (n = 27, 13.78% for condition 1; n = 19, 16.52% for condition 2; n = 39, 15.98% for condition 3). According to Table 4.6, the types of argumentation behaviors with the least coded units are *integration* (n = 1, 0.51% for condition 1; n = 0, 00.00% for condition 2; n = 1, 0.41% for condition 3), *counter-challenging* (n = 0, 00.00% for condition 1; n = 0, 0.00% for condition 2; n = 3, 1.23% for condition 3), *making a concession* (n = 0, 0.00% for condition 1; n = 3, 2.61% for condition 2; n = 1, 0.41% for condition 3), *challenging* (n = 3, 1.53% for condition 1; n = 2, 1.74% for condition 2; n = 4, 1.64% for condition 3), and *supporting reasons* (n = 14, 7.14% for condition 1; n = 5, 4.35% for condition 2; n = 10, 4.10% for condition 3).

Regarding differences across conditions, Table 4.6 shows that one notable difference is that condition 3 has coded units for all types of argumentation behaviors, while condition 1 does not have any evidence of *counter-challenging* and *making a concession,* and condition 2 does not have any coded units for *counter-challenging* and *integration*.

Table 4.6

Coded Units for Argumentation Behaviors[5] *Across Conditions*

		Condition			Total
		Condition 1(n = 15)	Condition 2 (n = 12)	Condition 3 (n = 17)	(*N* = 44)
Claims	n	76 (38.78%)	42 (36.52%)	90 (36.89%)	208 (37.5%)
	M	5.07	3.5	5.29	4.73
	SD	3.88	3.00	2.69	3.23
	Median	4.00	3.00	5.00	4.00
	Min	1.00	1.00	1.00	1.00
	Max	13.00	12.00	9.00	13.00
Agreeing	n	27 (13.78%)	19 (16.52%)	39 (15.98%)	85 (15.3%)
	M	1.80	1.58	2.29	1.93
	SD	1.57	1.68	1.72	1.64
	Median	2.00	1.00	2.00	2.00
	Min	0.00	0.00	1.00	0.00
	Max	5.00	6.00	7.00	7.00
Challenging	n	3 (1.53%)	2 (1.74%)	4 (1.64%)	9 (1.62%)
	M	0.2	0.17	0.24	0.20
	SD	0.56	0.39	0.44	0.46
	Median	0.00	0.00	0.00	0.00
	Min	0.00	0.00	0.00	0.00
	Max	2.00	1.00	1.00	2.00
Counter-challenging	n	0 (0.00%)	0 (0.00%)	3 (1.23%)	3 (0.54%)
	M	0.00	0.00	0.18	0.07

[5] Argumentation behavior coding scheme adopted from the work by Kim, B. (2009). *The effects of prompts-based argumentation scaffolds on peer-led interactive argumentation*. [Doctoral Dissertation, University of Missouri-Columbia]. MOspace. https://mospace.umsystem.edu/xmlui/bitstream/handle/10355/6858/research.pdf?sequence=3

	SD	0.00	0.00	0.53	0.33
	Median	0.00	0.00	0.00	0.00
	Min	0.00	0.00	0.00	0.00
	Max	0.00	0.00	2.00	2.00
Integration	n	1 (0.51%)	0 (0.00%)	1 (0.41%)	2 (0.36%)
	M	0.07	0.00	0.06	0.05
	SD	0.26	0.00	0.24	0.21
	Median	0.00	0.00	0.00	0.00
	Min	0.00	0.00	0.00	0.00
	Max	1.00	0.00	1.00	1.00
Elaboration	n	75 (38.27%)	44 (38.26%)	96 (39.34%)	215 (38.7%)
	M	5.00	3.67	5.65	4.89
	SD	3.70	3.34	3.33	3.49
	Median	4.00	3.00	5.00	4.00
	Min	1.00	0.00	1.00	0.00
	Max	12.00	13.0	11.00	13.00
Making a	n	0 (0.00%)	3 (2.61%)	1 (0.41%)	4 (0.72%)
concession	*M*	0.00	0.25	0.06	0.09
	SD	0.00	0.46	0.24	0.29
	Median	0.00	0.00	0.00	0.00
	Min	0.00	0.00	0.00	0.00
	Max	0.00	1.00	1.00	1.00
Supporting	n	14 (7.14%)	5 (4.35%)	10 (4.10%)	29 (5.23%)
reasons	*M*	0.93	0.42	0.59	0.66
	SD	1.22	0.79	0.94	1.01
	Median	0.00	0.00	0.00	0.00
	Min	0.00	0.00	0.00	0.00
	Max	4.00	2.00	3.00	4.00

Total	n	196 (100%)	115 (100%)	244 (100%)	555 (100%)
	M	13.1	9.58	14.4	12.6
	SD	9.76	8.17	6.92	8.35
	Median	13	9	12	10
	Min	2	1	5	1
	Max	33	33	28	33

Note.

Condition 1: Control condition

Condition 2: Question prompt-based only condition

Condition 3: Question prompt and social presence enhancement strategy condition

Argumentation Behavior Reduction. Before examining potential differences in students' argumentation behaviors across conditions, the possibility of reducing the number of argumentation behaviors was explored using principal component analysis (PCA).

Before conducting PCA, I examined the suitability of the argumentation behavior frequency data for this kind of data dimension reduction. The correlation matrix (see Table 4.7) shows that argumentation behaviors are weakly to strongly correlated with one another, ranging from r = -0.01 to r = 0.86. Furthermore, Bartlett's test of sphericity using the data supports the rejection of the null hypothesis that argumentation behaviors are not correlated, $X^2 = 144.24$, $p < .001$, suggesting that PCA is appropriate. In addition, the KMO measure of sampling adequacy is 0.63 for both the raw data and the correlation matrix, indicating the mediocre suitability of the data for PCA.

To determine the optimal number of principal components to retain, an eight-component PCA model was conducted. The results in Table 4.8 indicate that the first

three components account for most of the overall variance (73% of the total). Therefore, the first three components may be retained.

Table 4.7

Correlation Matrix for the Argumentation Behavior Frequency Data

	CL	AR	CH	CCH	INT	ELA	CON
AR	.66						
CH	-.01	.02					
CCH	-.16	-.08	.36				
INT	.05	-.06	.14	.62			
ELA	.86	.78	-.04	-.13	.07		
CON	-.07	.21	.03	-.07	-.07	.03	
REA	.52	.43	.15	.14	.18	.41	-.05

Note. CL: *Claims;* AR: *Agreeing*; CH: *Challenging*; CCH: *Counter-challenging*; INT: *Integration*; ELA: *Elaboration*; CON: *Making a concession*; REA: *Supporting reasons*

A closer examination of the first three components in Table 4.8 reveals that component 1 loaded well with four argumentation behaviors, which are *claims, agreeing, elaboration,* and *supporting reasons*. Component 2 has good loadings of three argumentation behaviors, including *challenging, counter-challenging*, and i*ntegration*. However, component 3 only consists of one argumentation behavior, which is *making a concession*. Since the primary purpose of using PCA is to compress the data or reduce the number of variables used in the analysis, having a variable as a component is not aligned with the use of PCA. Therefore, a three-component structure in which *making a concession* is the only item that loads well with component 3 is not supported. Other component structures, such as a four-component structure or a five-component structure, were also tested, but no simple structure of components emerged.

Table 4.8

Principal Component Analysis with Eight Principal Components

	Factor loadings on components							
	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
CL	.92	-.04	-.17	-.03	.12	.19	.20	.20
AR	.86	-.08	.23	.04	.11	-.34	-.26	.08
CH	.02	.55	.37	-.70	.20	.15	-.05	-.01
CCH	-.12	.89	.07	.14	.05	-.36	.22	.01
INT	.06	.80	-.12	.47	.08	.29	-.19	.02
ELA	.93	-.06	-.04	.10	.25	.04	.09	-.24
CON	.06	-.15	.92	.31	-.13	.13	.09	.01
REA	.65	.33	-.08	-.17	-.66	.03	-.01	-.04
Proportion variance	.36	.23	.14	.11	.07	.05	.03	.01

Note.

CL: *Claims*; AR: *Agreeing*; CH: *Challenging*; CCH: *Counter-challenging*; INT: *Integration*; ELA: *Elaboration*; CON: *Making a concession*; REA: *Supporting reasons*

PC: Principal component

The results from the PCA test without oblique rotations for two components showed a simple structure of components. At the cutoff point of .40, *claims, agreeing, elaboration,* and *supporting reasons* were found to load strongly onto component 1 (loading values of 0.92, 0.85, 0.93, and 0.66, respectively) and *challenging, counter-challenging,* and *integration* loaded well onto component 2 (loading values of 0.57, 0.89, and 0.80, correspondingly). The correlations between the two components were found to be weak *(r* = -0.04) (see Table 4.9).

Table 4.9

Pattern and Structure Coefficients Based on Principal Component Analysis without Oblique Rotations

Item	Argumentation behaviors	PC1	PC2
1	CL	.92	-.04
2	AR	.85	-.05
3	CH	.03	.57
4	CCH	-.10	.89
5	INT	.08	.80
6	ELA	.93	-.04
7	REA	.66	.33
Correlations (with CP2)		-.04	
Mean (SD)		3.05 (2.08)	0.11 (0.26)
Range		1 - 33	0 - 4
Cronbach's alphas		.83	.57

Note.

CL: *Claims*; AR: *Agreeing;* CH: *Challenging*; CCH: *Counter-challenging*; INT: *Integration*; ELA: *Elaboration*; REA: *Supporting reasons*

PC: Principal component

Table 4.9 shows that component 1 is composed of *elaboration, claims, agreeing,* and *supporting reasons,* which I consider to be the lower level of interactive argumentation. In contrast, component 2 includes *counter-challenging, integration,* and *challenging,* which I view as the higher level of interactive critical argumentation. Component 1, therefore, can be referred to as '*lower level interactive argumentation* (LLIA)' and component 2 as '*higher level interactive argumentation* (HLIA).' The Cronbach's alpha for component 1 is high (a = .83), indicating good internal consistency,

whereas the Cronbach's alpha coefficient for component 2 is a = .57, below the acceptable threshold of .7.

Since the original argumentation behaviors, excluding *making a concession* (which did not load well with either of the two new variables), can be reduced into two new variables (LLIA and HLIA) based on the results of the PCA with oblique rotation, subsequent analyses in this study used the loading score of these two principal components as new variables to describe students' argumentation behaviors.

Descriptive statistics for the sum of coded units of argumentation behaviors related to each of the new categories of argumentation behaviors are presented in Table 4.10. Overall, small group discussion posts were dominated by LLIA (537 coded units, 97.46%). This pattern was consistent across all conditions, with LLIA accounting for 96.70% to 98.21% of all coded units for argumentation behaviors. Among the conditions, condition 3 had the highest number of coded units for HLIA (8 coded units, 3.29%), whereas condition 1 had the lowest number of coded units for HLIA (2 coded units, 1.79%).

Differences in Lower Level and Higher Level Interactive Argumentation Behaviors across Conditions. ANOVA was conducted to investigate the impact of the treatment on the two new categories of argumentation behaviors. The independent variable was the three conditions of the study. The dependent variables were two new categories of argumentation behaviors identified in the PCA: lower level interactive argumentation behaviors (LLIA) and higher level interactive argumentation behaviors (HLIA). Prior to the test, ANOVA assumptions related to univariate outliers, homogeneity of variances, and normality were checked.

Table 4.10

Higher Level Interactive Argumentation and Lower Level Interactive Argumentation

		Condition			Total
		Condition 1(n = 15)	Condition 2 (n = 12)	Condition 3 (n = 17)	(*N* = 44)
HLIA		192 (97.96%)	110 (98.21%)	235 (96.70%)	537 (97.46%)
		12.8	9.17	13.82	12.20
LLIA		4 (2.04%)	2 (1.79%)	8 (3.29%)	14 (2.54%)
		0.23	0.17	0.47	0.31
Total	n	196 (100%)	112 (100%)	243 (100%)	551 (100%)
	M	13.1	9.3	14.2	12.5

Note.

Condition 1: Control condition

Condition 2: Question prompt-based only condition

Condition 3: Question prompt and social presence enhancement strategy condition

LLIA: *Lower level interactive argumentation* (*claims, agreeing, elaboration, supporting reasons*)

HLIA: *Higher level interactive argumentation* (*challenging, counter-challenging, integration*)

The minimum and maximum thresholds based on the mean and the standard deviation were used to identify univariate outliers. There were no univariate outliers for LLIA data. However, one univariate outlier was found for HLIA. When looking closely at the observation with the outlier, I saw that that observation showed evidence of HLIA in more than one argumentation behavior, while other observations either had no evidence of HLIA or had evidence of HLIA in no more than one argumentation behavior. Therefore, the observation was retained in the analysis as it reflected the rare nature of HLIA data, and the decision was made to avoid the potential loss of important information.

Levene's tests indicated that the assumption of homogeneity was met, with non-significant results for LLIA ($F(2, 41) = 1.74$, $p = .19$) and HLIA ($F(2, 41) = 0.83$, $p = .44$). However, Shapiro-Wilk normality tests revealed that both LLIA and HLIA data significantly deviated from normal distribution ($W = .92$, $p < .01$ and $W = .48$, $p < .001$ for LLIA and HLIA, respectively).

Given the violation of normality assumption and the unequal condition sizes, a non-parametric test was utilized to examine the significant differences in LLIA and HLIA across conditions. Kruskal-Wallis tests (Table 4.11) revealed that there were no significant differences on LLIA and HLIA across conditions ($X^2 = 2.95$, $df = 2$, $p = .23$, $\eta^2 = .02$ and $X^2 = 1.99$, $df = 2$, $p = .37$, $\eta^2 = .00$ for LLIA and HLIA, respectively).

Table 4.11

Kruskal-Wallis Tests for LLIA and HLIA Across Conditions

	X^2	*df*	*p*	*η2*
LLIA	02.95	2	0.23	0.02
HLIA	1.99	2	0.37	.00

LLIA: *Lower level interactive argumentation* (*claims, agreeing, elaboration, supporting reasons*)

HLIA: *Higher level interactive argumentation* (*challenging, counter-challenging, integration*)

In conclusion, to address Research Question 1, the eight argumentation behaviors identified through coding students' discussion posts with the argumentation behavior coding scheme developed by Kim (2009) (Appendix L) were reduced to two components or variables, namely *lower level interactive argumentation* (LLIA) and higher level interactive argumentation (HLIA), using PCA. LLIA consists of *claims*, *elaboration, agreeing,* and *supporting reasons,* while HLIA comprises *challenging, counter-challenging,* and *integration*. *Making a concession* did not load well with either of the

two components and was thus not included in the two newly created variables or any subsequent analysis. An ANOVA test was then conducted using the two new variables resulting from PCA as the dependent variables and the conditions students were randomly assigned to as the independent variable. The ANOVA test results showed that there was no significant difference in students' LLIA and HLIA across conditions. However, it is worth noting that students in condition 3 demonstrated all types of argumentation behaviors, whereas students in the other two conditions did not show evidence of all argumentation behaviors, particularly those related to HLIA. Moreover, students in condition 3 had a higher percentage of HLIA than students in the other two conditions.

Effects of the Scaffolds on Problem-solving Processes during Small Group Discussions

RQ2. How do students' problem-solving processes in the discussion vary between the three groups?

In this section, we report on the effects of the question prompt-based argumentation scaffold, with and without social presence enhancement strategies, on students' problem-solving processes during small group discussions. To quantitatively measure these processes, we coded the online postings generated by participants during the Week 5 small group discussions, using a coding scheme for problem-solving processes adapted from Ge (2001) (see Appendix O). Interrater reliabilities for students' problem-solving processes in *problem representation, solution generation, justification,* and *solution evaluation* were generated using Cohen's Kappa in ReCal2 by Freelon (n.d.). The reliabilities for these processes were substantial, ranging from 0.65 to 0.72 (see Appendix S for further details on interrater reliabilities).

This section begins with a description of the frequency of students' problem-solving processes across conditions, followed by a MANOVA analysis to determine whether there were any differences in problem-solving processes between conditions.

An Overview of Problem-solving Processes across Conditions. Table 4.12 displays the number of coded meaningful units for problem-solving processes and their percentages across the conditions. In total, 716 coded units were identified. Among the problem-solving processes, *problem representation* had the highest number of coded units (255, 35.60%), followed by *solution generation* (211, 29.50%), and *justification* (172, 24.00%). The problem-solving process with the least coded units was *solution evaluation* (78, 10.90%).

Regarding similarities across the conditions, Table 4.12 reveals that *problem representation* received the most coded units (n = 87, 35.51% for condition 1; n = 60, 48.00% for condition 2; n = 108, 31.21% for condition 3), followed by *solution generation* (n = 70, 28.57% for condition 1; n = 34, 27.20% for condition 2; n = 107, 30.93% for condition 3), *justification* (n = 59, 24.08% for condition 1; n = 20, 16.00% for condition 2; n = 93, 26.88% for condition 3), and *solution evaluation* (n = 29, 11.84% for condition 1; n = 11, 8.80% for condition 2; n = 38, 10.98% for condition 3).

Concerning differences across the conditions, Table 4.12 reveals that condition 3 had more average coded units in all problem-solving processes than the other two conditions. Additionally, condition 2 consistently had the fewest average coded units in all problem-solving processes compared to the other two conditions. The average coded units for problem representation were M = 5.80, M = 5.00, and M = 6.35 for condition 1, condition 2, and condition 3, respectively. The average coded units for *solution*

generation were *M* = 4.67, *M* = 2.83, and *M* = 6.29 for condition 1, condition 2, and condition 3, respectively. The average coded units for *justification* were *M* = 3.93, *M* = 1.67, and *M* = 5.47 for condition 1, condition 2, and condition 3, respectively. The average coded units for *solution evaluation* were *M* = 2.00, *M* = 1.33, and *M* = 2.24 for condition 1, condition 2, and condition 3, respectively.

Table 4.12

Distribution of Coded Units for Problem-solving Processes[6] *Across Conditions*

		Condition			Total
		Condition 1 (n = 15)	Condition 2 (n = 12)	Condition 3 (n = 17)	(*N* = 44)
Problem representation	n	87 (35.51%)	60 (48.00%)	108 (31.21%)	255 (35.60%)
	M	5.80	5.00	6.35	5.80
	SD	3.19	3.10	3.53	3.27
	Median	5.00	4.50	6.00	5.00
	Min	1.00	1.00	1.00	1.00
	Max	14.00	10.00	13.00	14.00
Solution generation	n	70 (28.57%)	34 (27.20%)	107 (30.93%)	211 (29.50%)
	M	4.67	2.83	6.29	4.80
	SD	3.75	2.86	3.55	3.65
	Median	4.00	3.00	6.00	4.00
	Min	0.00	0.00	1.00	0.00
	Max	12.00	11.00	12.00	1200
Justification	n	59 (24.08%)	20 (16.00%)	93 (26.88%)	172 (24.00%)
	M	3.93	1.67	5.47	3.91
	SD	3.73	1.61	5.14	4.17

[6] Adapted from Ge, X. (2001). *Scaffolding students' problem-solving processes on an Ill-structured task using question prompts and peer interactions* [Unpublished doctoral dissertation]. Pennsylvania State University

	Median	3.00	1.00	4.00	2.50
	Min	0.00	0.00	0.00	0.00
	Max	13.00	5.00	17.00	17.00
Solution	n	29 (11.84%)	11 (8.80%)	38 (10.98%)	78 (10.90%)
evaluation	*M*	2.00	1.33	2.24	1.88
	SD	2.20	1.72	2.36	2.12
	Median	1.5	1.00	2.00	1.00
	Min	1.00	1.00	0.00	0.00
	Max	8.00	6.00	8.00	8.00
Total	n	245 (100%)	125 (100%)	346 (100%)	716 (100%)
	M	16.30	10.400	20.40	16.30
	SD	11.70	7.59	12.80	11.70
	Median	15.00	9.50	17.00	13.50
	Min	3.00	1.00	6.00	1.00
	Max	47.00	30.00	50.00	50.00

Note.

Condition 1: Control condition

Condition 2: Question prompt-based only condition

Condition 3: Question prompt and social presence enhancement strategy condition

Differences in Problem-solving Processes across Conditions. MANOVA was conducted to examine the effect of the treatment on students' problem-solving processes during small group discussions. The independent variable was the three conditions of the study. The dependent variables were the frequency of each of the students' problem-solving processes during small group discussions. Prior to the test, assumptions related to the homogeneity of covariance matrices, multivariate normality, and multivariate outliers were checked.

Mahalanobis Distance (MD) was used to identify outliers in the multivariate data. Results indicated that no outliers existed in our multivariate data for *problem representation, solution generation, justification,* and *solution evaluation,* with Mahalonobis distances ranging from .42 to 14.31 with a Chi-square cutoff value of 18.45 (p = .999 and df = 4).

Table 4.13 presents the variance-covariance matrices related to the problem-solving processes students engaged in during small group discussions across the three conditions of the study. The diagonal elements of Table 4.13 reveal that the variances for *problem representation* were quite similar (10.17, 9.63, and 12.49 for conditions 1, 2, and 3 respectively) across the conditions, with a variance ratio of about 1.30, which is below the threshold of 2. Similarly, the variances for *solution generation* were quite similar (14.10, 8.15, and 12.60) across conditions, with a variance ratio of about 1.73, which is also below the threshold of 2. However, the variances for *justification* (13.92, 2.61, and 26.40) and *solution evaluation* (5.21, 1.53, and 5.57) were significantly different across conditions, with variance ratios of about 9.96 and 3.64 respectively, both of which are above the threshold of 2. Table 4.13 also reveals that the covariances between pairs of problem-solving processes were different across conditions, indicating a violation of the homogeneity of covariances. For instance, the covariances between *problem representation* and *justification* were 8.70, 2.00, and 10.70 for conditions 1, 2, and 3 respectively, with a covariance ratio of 5.35, which is above the threshold of 2. In conclusion, we can infer that the assumption of the homogeneity of covariances was violated.

Table 4.13

Homogeneity of Covariance Matrices for Problem-solving Processes during Small Group Discussions across Conditions

		PR	SG	JU	SE
Condition 1	PR	10.17	7.21	8.70	4.34
	SG	7.21	14.10	13.12	6.33
	JU	8.70	13.12	13.92	6.85
	SE	4.34	6.33	6.86	5.21
Condition 2	PR	9.63	5.55	2.00	1.55
	SG	5.55	8.15	3.94	3.08
	JU	2.00	3.94	2.61	1.70
	SE	1.55	3.08	1.70	1.53
Condition 3	PR	12.49	7.83	10.70	5.29
	SG	7.83	12.60	13.54	5.80
	JU	10.70	13.54	26.40	10.63
	SE	5.29	5.80	10.63	5.57

Note.

Condition 1: Control condition

Condition 2: Question prompt-based only condition

Condition 3: Question prompt and social presence enhancement strategy condition

PR: *Problem representation*; SG: *Solution generation*; JU: *Justification*; SE: *Solution evaluation*

The results of the three multivariate normality tests show that the dependent variables (*problem representation*, *solution generation*, *justification*, and *solution evaluation*) do not follow a multivariate normal distribution within conditions ($W = 0.84$, $p < .05$; $W = 0.64$, $p = <.001$; and $W = 0.88$, $p < 0.05$ for conditions 1, 2, and 3 respectively). In other words, the assumption of multivariate normality is violated.

To test for differences in problem-solving processes across conditions, a MANOVA model with Pillai's trace was used. This test is considered to be the most powerful and robust statistic for general use, especially for departures from assumptions (Scheiner, 2020). Table 4.14 shows that, using Pillai's trace, there was no significant difference in problem-solving processes across the three conditions of the study, $V = 0.20$, $F(8, 78) = 1.07$, $p = 0.39$, $\eta^2 = .10$. Since the omnibus F multivariate test results were insignificant, no further analysis was conducted.

Table 4.14

Multivariate Analysis for Problem-solving Processes Across Conditions

	Pillai's trace	*df*	*F*	*p*	$\eta^2 = .02$
Multivariate Test	0.20	8, 78	1.07	0.39	.10

In conclusion, to address research question 2, we used the frequency of four problem-solving processes identified by coding students' discussion posts using the problem-solving process coding scheme developed by Ge (2001) (Appendix O) as the dependent variable in the MANOVA test, while the three conditions of the study that students were randomly assigned to were used as the independent variable. The results of the MANOVA test showed no significant difference in students' problem-solving processes, as measured by the frequency of each problem-solving process in students' posts, across the conditions. However, it is worth noting that students in condition 3 had a higher average number of coded units for all problem-solving processes than students in the other two conditions, with students in condition 2 having the lowest average number of coded units for all problem-solving processes.

Post-test Problem-solving Performance

RQ3. How does the problem-solving performance vary between the three conditions on a post-discussion problem-solving activity?

In this section, the transfer effects of the question prompt-based argumentation scaffold with and without social presence enhancement strategies on students' post-test problem-solving performance are reported. The data for students' post-test problem-solving performance was collected the following week of the treatment and from students' first post in the Module 6 discussion board. Students' post-test problem-solving performance was measured through the problem-solving performance rubric (Appendix P) adapted from the work by Ge (2001). The problem-solving performance rubric evaluates the quality of four key problem-solving processes: *problem representation, solution generation, justification,* and *solution evaluation*. The performance score for each problem-solving process can be 1, 3, or 5 in which 1 represents 'not satisfied' performance, 3 for 'satisfied' performance, and 5 for 'very satisfied' performance. Students' overall post-test problem-solving performance score is the average of all the performance scores in four key problem-solving processes. Higher scores indicate stronger post-treatment problem-solving performance in general.

The Cohen's Kappa interrater reliabilities generated from ReCal2 by Freelon (n.d.) for students' post-test problem-solving performance in *problem representation, solution generation, justification,* and *solution evaluation* are 0.77, 0.71, 0.73, and 0.68 respectively, indicating substantial reliabilities. For further details on interrater reliabilities for post-test problem-solving performance, see Appendix T.

This section starts with the descriptive statistics of the students' problem-solving performance in each problem-solving process and their overall performance across conditions. Following that is the analysis of covariance (ANCOVA) to examine if there were any differences in post-test problem-solving performance across conditions. This current study used the average post-test problem-solving performance as the dependent variable in the ANCOVA analysis.

An Overview of Students' Post-test Problem-solving Performance. Table 4.15 summarizes the participants' post-test problem-solving performance in each problem-solving process category, as well as their overall problem-solving performance and distribution across the conditions. As shown in Table 4.15. the means for students' post-test *problem representation*, *solution generation*, *justification*, and *solution evaluation* are $M = 3.57$ ($SD = 1.07$), $M = 3.41$ ($SD = 0.82$), $M = 2.50$ ($SD = 1.05$), and $M = 2.04$ ($SD = 1.30$), respectively. Descriptively, students' post-test problem-solving performance follows the same trend as found in their self-reported problem-solving skills and pre-test problem-solving performance, with *problem representation* ranking highest in students' problem-solving process ($M = 3.58$), followed by *solution generation* ($M = 3.41$), *justification* ($M = 2.50$), and *solution evaluation* ($M = 2.04$). Students' post-test overall problem-solving performance was measured by the average of students' post-test problem-solving skills and had a mean of 2.89 ($SD = 0.60$).

Table 4.15

Participants' Post-test Problem-solving Performance by Conditions

		Condition			Total
		Condition 1 (n = 15)	Condition 2 (n = 12)	Condition 3 (n = 17)	(*N* = 44)
Problem representation[a]	*M*	3.67	3.50	3.47	3.55
	SD	0.98	0.91	1.12	1.00
	Median	3.00	3.00	3.00	3.00
	Min	3.00	3.00	1.00	1.00
	Max	5.00	5.00	5.00	5.00
Generating solution[b]	*M*	3.00	4.00	3.47	3.55
	SD	0.00	1.04	0.87	0.99
	Median	3.00	4.00	3.00	3.00
	Min	3.00	3.00	3.00	1.00
	Max	3.00	5.00	5.00	5.00
Justification[c]	*M*	2.2	2.5	2.65	2.45
	SD	1.01	1.24	0.79	1.00
	Median	3.00	3.00	3.00	3.00
	Min	1.00	1.00	1.00	1.00
	Max	5.00	5.00	3.00	5.00
Evaluation[d]	*M*	1.53	1.67	3.00	2.14
	SD	1.41	0.99	1.00	1.32
	Median	1.00	1.00	3.00	1.00
	Min	1.00	1.00	1.00	1.00
	Max	5.00	3.00	5.00	5.00
Overall Post-test Problem-solving Performance[e]	*M*	2.60	2.92	3.15	2.89
	SD	0.57	0.63	0.55	0.60
	Median	3.00	2.5	3.00	3.00

	Min	2.00	2.00	2.00	2.00
	Max	4.00	4.00	4.00	4.00

Note.

Condition 1: Control condition

Condition 2: Question prompt-based only condition

Condition 3: Question prompt and social presence enhancement strategy condition

[a, b, c, d] Used a rubric with scores of 1, 3, and 5 to measure the variable. Higher scores indicate a greater post-treatment problem-solving performance in a certain area of problem-solving (*problem representation, solution generation, justification,* and *solution evaluation*)

[e] Used the average performance score of all the four problem-solving processes. Higher scores indicate stronger post-treatment problem-solving performance in general.

Differences in the Post-test Problem-solving Performance across Conditions. To investigate potential significant differences in overall post-test problem-solving performance across the study's conditions while controlling for pre-test problem-solving performance, students' tendency to argue, students' tendency to avoid arguments, and two types of argumentation behaviors (HLIA and LLIA), a factorial analysis of covariance (ANCOVA) was conducted. The dependent variable was overall post-test problem-solving performance, and the independent variable was the three conditions of the study. Covariates included pre-test problem-solving performance, two types of argumentation behaviors (HLIA and LLIA), students' tendency to argue, and students' tendency to avoid arguments.

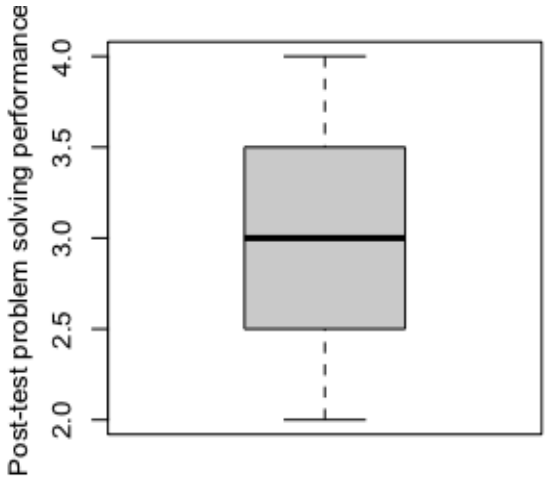
Before conducting the ANCOVA analysis, assumptions related to univariate outliers, homogeneity, univariate normality, linearity between the dependent variable and covariates, independence of the covariate and independent variable (treatment effect), and homogeneity of regression slopes were assessed.

Figure 4.1 indicates that there are no outliers in the post-test problem-solving performance data. The homogeneity assumption was tested using Levene's test and found to be non-significant: $F(2, 41) = 0.17$, $p = .85$. However, the Shapiro-Wilk normality test demonstrated a significant deviation from normal distributions ($W = .91$, $p < .01$). A multiple linear regression was conducted to check the linearity between the dependent variable and covariates. The result revealed some level of linearity, but only a significant correlation between HLIA and post-test problem-solving performance was found.

The independence assumption of the covariates and the independent variable was assessed through descriptive statistics and statistical analysis presented in Table 4.1, Table 4.2, and Table 4.4. The results show that there were no significant differences across conditions in terms of students' argumentativeness, pre-test problem-solving performance, and argumentation behaviors. An ANOVA test was conducted to explore the interaction between the three conditions of the study and the covariates. The results indicated no significant interactions ($F(2, 26) = 0.18$, $p = 0.84$ for the pre-test problem-solving and the three conditions of the study; $F(2, 26) = 2.09$, $p = 0.14$ for LLIA and the three conditions of the study; $F(2, 26) = 0.83$, $p = 0.45$ for HLIA and the three conditions of the study; $F(2, 26) = 0.11$, $p = 0.89$ for the tendency to avoid arguments and the three conditions of the study; and $F(2, 26) = 0.11$, $p = 0.89$ for the tendency to argue and the three conditions of the study), indicating no violation of homogeneity of regression assumption. Overall, all the ANCOVA assumptions except for normal distributions were met.

Figure 4.1

Boxplot for the Overall Post-test Problem-solving Performance



Despite the violation of the normal distribution assumption, ANCOVA was still performed because it is known to be robust against non-normality. The results of ANCOVA with backward elimination are presented in Table 4.16. The table shows that HLIA has a significant positive correlation with post-test problem-solving performance ($F(1, 40) = 5.34$, $p = 0.03$). Notably, the table also shows that the conditions of the study to which students were assigned have a significant effect on the post-test problem-solving performance score ($F(2, 40) = 3.45$, $p = 0.04$).

Table 4.16

Analysis of Covariance for Post-test Problem-solving Performance Across Conditions

	Sum of Squares	*df*	Mean Square	*F*	*p*	$\eta^2 = .02$
HLIA	1.67	1	1.67	5.34	0.03*	0.12
Conditions of the study	2.15	2	1.08	3.45	0.04*	0.15
Residuals	11.31	36	0.31			

Note.

LLIA: *Lower level interactive argumentation*

HLIA: *Higher level interactive argumentation*

Table 4.17 displays the adjusted group means, their confidence intervals, and the standard errors. The adjusted means for conditions 1, 2, and 3 are 2.60 at 95% CI [2.31, 2.89], 2.96 at 95% CI [2.63, 3.29], and 3.12 at 95% CI [2.84, 3.39], respectively. Notably, condition 3 has the highest adjusted group mean for post-test problem-solving performance scores, followed by condition 2, and condition 1.

Table 4.17

Adjusted Means for Post-test Problem-solving Performance Across Conditions

Condition	Adjusted means	95% CI	SE
Condition 1	2.60	2.31, 2.89	0.14
Condition 2	2.96	2.63, 3.29	0.16
Condition 3	3.12	2.84, 3.39	0.14

Note.

Condition 1: Control condition

Condition 2: Question prompt-based only condition

Condition 3: Question prompt and social presence enhancement strategy condition

A Tukey pairwise contrast post-hoc comparison test was utilized to determine which adjusted means differed. Table 4.18 displays the results of the post-hoc comparisons, which include three comparisons: condition 1 vs. condition 2, condition 3 vs. condition 2, and condition 3 vs. condition 1. The results reveal that students in condition 3 exhibited significantly higher post-test problem-solving performance scores than those in condition 1 ($t = 2.59$, $p = 0.03$), indicating a positive correlation between the question prompts used in conjunction with social presence enhancement strategies and students' post-test problem-solving performance. Notably, there were no significant

differences in the post-test problem-solving performance scores between condition 1 and condition 2 or between condition 2 and condition 3.

Table 4.18

Post-hoc Comparisons for Post-test Problem-solving Performance Across Conditions

	Estimate	SE	t	p
Condition 1 vs. Condition 2	-.35	0.22	-1.63	0.24
Condition 3 vs. Condition 2	.16	0.21	0.75	0.74
Condition 3 vs. Condition 1	.52	0.20	2.59	0.03*

Note.

Condition 1: Control condition

Condition 2: Question prompt-based only condition

Condition 3: Question prompt and social presence enhancement strategy condition

In conclusion, to address research question 3, the first posts of students in the Module 6 discussion board were collected. Their post-test problem-solving performance was measured using the problem-solving performance rubric (Appendix P), adapted from the work by Ge (2001). An ANCOVA test was conducted to determine whether there were any differences in the post-test problem-solving performance across the conditions assigned to students. The post-test problem-solving performance scores were the dependent variable, the conditions assigned to students were the independent variable, and students' pre-test problem-solving performance and two types of argumentation behaviors were the covariates. The results of the ANCOVA test indicated that there were differences in the post-test problem-solving performance across conditions, and the post-hoc comparisons revealed a significant difference in the adjusted mean in the post-test

problem-solving performance between condition 1 and condition 3. Specifically, students in condition 3 had significantly higher post-test problem-solving performance scores than those in condition 1. Additionally, the ANCOVA test indicated a positive association between HLIA during the treatment and the post-test problem-solving performance.

Chapter Summary

This chapter presents the results in relation to the three research questions of this study. Overall, with a one-week-long treatment, this study did not detect any significant differences across conditions in terms of students' argumentation behaviors and problem-solving processes during small group discussions. However, this study did register positive improvement in students' post-test problem-solving performance in the treatment conditions. It is worth noting that the difference in post-test problem-solving performance scores between the control condition and the question prompt and social presence enhancement strategy condition was significant. There is a consistent trend in this study that the group that received both the cognitive scaffold (question prompts) and the social presence enhancement strategies performed better than the other two conditions in terms of the diversity of argumentation behaviors during discussions, higher level interactive argumentation behaviors during discussions, problem-solving processes during discussions, and post-test problem-solving performance.

5. DISCUSSION AND IMPLICATIONS

Overview

This chapter provides a comprehensive summary of the study's findings and discusses the crucial outcomes for enhancing knowledge of the effects of the question prompt scaffold and social presence enhancement strategies on various aspects of students' ill-structured problem-solving in asynchronous online discussions. These aspects include students' argumentation behaviors, problem-solving processes, and performance. The chapter comprises five sections, which are as follows: (1) Summary and discussion of the findings, (2) implications, (3) limitations of the study, (4) recommendations for future research, and (5) conclusion.

Summary and Discussion of Findings

This study investigated the effects of using question prompt-based argumentation scaffolds with or without social presence enhancement strategies on students' argumentation behaviors during discussions, problem-solving processes, and post-treatment performance. Specifically, the study sought to compare the impact of question prompts alone versus those combined with social presence enhancement prompts. The question prompts were designed to encourage students to engage in a variety of argumentation behaviors, particularly interactive argumentation behaviors that involve considering multiple perspectives, such as *challenging, counter-challenging, integration,* and *making a concession,* during asynchronous online discussions. The social presence enhancement prompts were intended to encourage students to produce posts that demonstrate social presence indicators and contribute to building a supportive and welcoming discussion environment.

The study was based on the assumption that collaborative problem-solving relies on interactive argumentation and social interactions and that supporting these two components critical to problem-solving could enhance students' problem-solving performance. Participants were assigned to one of three study conditions: a control group (condition 1), a group using question prompts alone (condition 2), and a group using both question prompts and social presence enhancement strategies (condition 3).

Below is the summary of the study's key findings and their discussion.

Question One: Effects of the Question Prompt-based Scaffold on Argumentation Behaviors

The first research question in this study focused on the effects of question prompt-based argumentation scaffolds, with or without social presence enhancement strategies, on students' argumentation behaviors. These behaviors were measured by coding the frequency of each argumentation behavior present in students' small group online discussion posts. A total of eight argumentation behaviors were coded for this analysis (see Appendix L). To facilitate comparisons of the differences in argumentation behaviors across conditions, principal component analysis (PCA) was used to reduce the dimensions of the eight behaviors to two principal components: *lower level interactive argumentation behaviors* (LLIA) and *higher level interactive argumentation behaviors* (HLIA) (see Table 4.10). The LLIA category included *claims, elaboration, agreeing, and supporting reasons*, while the HLIA category consisted of *challenging, counter-challenging,* and *integration*. The behavior of *making a concession* did not load well with either category; as a result, its data was not used in the statistical analysis. However, its descriptive statistics were presented and discussed (see Table 4.9).

Finding One: The Question Prompt-based Scaffold, with or without the Social Presence Enhancement Strategies, did not result in Statistically Significant Effects on Students' Argumentation Behaviors during Small Group Online Discussions. The results of this study indicated that the use of the question prompt-based scaffold, with or without social presence enhancement strategies, did not lead to any statistically significant differences across conditions in terms of students' LLIA and HLIA. It is not uncommon to observe that scaffolding in asynchronous online discussion forums does not always yield the desired effects on students' learning (e.g., Jeong & Joung, 2007; Oh & Jonassen, 2007). There may be several reasons for the failure to detect the impacts of the question prompt scaffold and social presence enhancement strategies on argumentation behaviors in this study.

One noteworthy factor to consider is the short treatment time of seven days. Previous studies (e.g., Kim, 2009; Oh & Jonassen, 2007; Tawfik et al., 2018) have demonstrated that it can be challenging to observe intervention impacts or to alter individuals' argumentation behaviors within a brief time frame. For instance, Oh and Jonassen's study (2007) involved a two-week training period, which was significantly longer than the current study. Nevertheless, they did not find any effect of argumentation scaffolds on students' argumentation performance, and they suggested that the two-week period might be insufficient to enhance students' argumentation skills. Dawson and Carson (2017), on the other hand, observed significant impacts on their students' argumentation skills, but their treatment lasted four weeks. This implies that students may require more extended scaffolding periods to effectuate changes in their argumentation behaviors.

Second, student engagement may be another significant factor. Students learn best when they are actively involved in the learning process. However, merely placing students in groups and introducing scaffolds does not always guarantee that they will be more motivated to work with others or use the scaffold to achieve learning outcomes (Ge & Land, 2004; Lavrinenko et al., 2019). In this study, the students in condition 2 showed the lowest level of engagement, as measured by the average number of posts per student (M = 3.3, M = 2.3, and M = 3.53 for condition 1, condition 2, and condition 3 respectively) (Table 4.5). The low level of engagement of students in condition 2 was clearly a contributing factor to the ineffectiveness of the question prompt-based scaffold in supporting argumentation behaviors for these students. Among the three conditions of the study, students in condition 3 demonstrated the highest level of engagement, as measured by the average number of posts (M = 3.53). As a result, students in condition 3 had the highest frequency of average coded units for all argumentation behaviors and for both LLIA and HLIA. In fact, students in condition 3 demonstrated evidence for all eight argumentation behaviors, while students in the other two conditions showed evidence for only six out of eight argumentation behaviors. The argumentation behaviors students in condition 1 and condition 2 did not demonstrate were those related to HLIA, such as *counter-challenging* (0.0% for both conditions), *integration* (0.0% for condition 2), and *making a concession* (0.0% for condition 1).

Overall, the study suggests that student engagement is a critical factor in the effectiveness of scaffolds in promoting argumentation behaviors. Therefore, educators should consider implementing strategies that promote student engagement in order to maximize the benefits of scaffolds in the learning process.

Finding Two: Students' Argumentation during the Small Group Discussions was Dominated by Lower Level Interactive Argumentation Behaviors and Higher Level Interactive Argumentation Behaviors were Rare. Across all conditions, almost all of the coded units for argumentation behaviors (97.46%) were attributed to *lower level interactive argumentation* (LLIA), while evidence of *higher level interactive argumentation* (HLIA) was rare, comprising only 2.54% of the coded units (Table 4.6). Within the LLIA category, *claims* and *elaboration* were the most frequently observed behaviors, followed by *agreeing* and *supporting reasons* (Table 4.6). All argumentation behaviors within the HLIA category (*challenging*, *counter-challenging*, and *integration)* were consistently low to non-existent across all conditions (Table 4.6).

While this study was not able to classify *making a concession* as either LLIA or HLIA due to its poor loading with either of the two components (Table 4.8), *making a concession* is commonly viewed as evidence of critical discussion (Keefer et al., 2000). In order to make a concession, students must counter-challenge their own original arguments, suggesting that it can be viewed as one of the HLIA. However, like other HLIA, *making a concession* was not a common argumentation behavior in students' discussions.

Further details and discussions of each argumentation behavior within these two groups are presented below.

Claims and Elaboration. According to the study, students across all three conditions generated a significant number of arguments related to *claims* (condition 1: 38.78%, condition 2: 36.52%, condition 3: 36.89%) and *elaboration* (condition 1: 38.27%, condition 2: 38.26%, condition 3: 39.34%) (Table 4.6). This finding is consistent

with previous research conducted by Anwar and Susanti (2019), Dawson and Carson (2017), and Sekerci and Canpolat (2017), which also revealed that students tend to focus on presenting their positions. The reason behind this tendency is that when answering problem-solving questions, students are required to state their positions in the form of claims, which must then be justified by elaborations (Cho & Jonassen, 2002).

Agreeing. The study findings revealed that the third most common argumentation behavior among students across all three conditions was *agreeing* with others (condition 1: 13.78%, condition 2: 16.52%, condition 3: 15.98%) (refer to Table 4.6). One possible explanation for this trend is that students may tend to agree with others to avoid conflicts. This observation is in line with prior research that indicates that in asynchronous online discussion forums, students may intentionally agree with one another to avoid social conflicts (e.g., Cho & Jonassen, 2002; Oh & Jonassen, 2007). Another plausible explanation is that students may agree with a solution to the problem merely to meet the minimum number of postings required. This finding is consistent with a study by Koehler et al. (2020), which demonstrated that students may agree because it is easier to agree and be viewed as having participated in the discussion. Additionally, *agreeing* with others is one of the supportive indicators of social presence (Fahy, 2003), and students may have used this behavior to create a supportive discussion environment for their groups.

It should be noted, however, that the quality of the *agreeing* arguments across conditions was not high when considering other argumentation behaviors. Students across all three conditions tended not to extend their *agreeing* arguments with substantial reasons, evidence, or counterarguments to their original arguments, as evidenced by the low levels of *challenging* (1.62% across conditions), *counter-challenging* (0.54% across

conditions), *integration* (0.36% across conditions), *supporting reasons* (5.23% across conditions) and *making concessions* (0.72% across conditions) (refer to Table 4.6). In other words, the students in this study tended to reiterate their agreement with comments made by their group members without adding any extensions to *higher level interactive argumentation* (HLIA). These findings are similar to those of Toledo's (2006) study, which showed that students in asynchronous online discussions tended to answer one another with phrases such as "I agree" or "That's what I think" without following their agreement behavior with arguments that demonstrate critical thinking skills to push the discussion to new depths.

Supporting Reasons. While evidence and data are crucial in supporting the development of coherent arguments (Erduran et al., 2015), this study found that students across all conditions demonstrated a low level of using evidence during argumentation (condition 1: 7.14%, condition 2: 4.835%, condition 3: 4.10%) (Table 4.6). These observations highlight one of the weaknesses students face in making coherent arguments, a finding that is consistent with previous studies (e.g., Kuhn & Modrek, 2018; Oh & Jonassen, 2007; Stein & Miller, 2019). As a result, educators and instructors should consider pedagogies that can support students in using evidence to back up their claims.

There are several reasons why students may have underperformed in this argumentation behavior. First, they tended not to support their claims with evidence. Additionally, students may have mistaken elaborations for genuine evidence, leading them to provide insufficient or irrelevant evidence. This phenomenon is known as the use of "pseudo evidence," where descriptions are used to elaborate an argument instead of relying on factual information cited from reliable sources (Kuhn & Udell, 2003; Hyytinen

et al., 2017; Kuhn & Modrek, 2018). Another possible explanation is that students may have taken the correctness of their claims for granted, leading them to overlook the importance of using examples and evidence to justify their claims. This challenge related to argumentation is consistent with findings from Kuhn and her colleagues (e.g., Felton & Kuhn, 2001, 2001; Kuhn, 2001; Kuhn & Udell, 2003).

Challenging and Counter-challenging Behaviors. The study found that students in all three conditions exhibited very low levels of engagement in *challenging* others' arguments (condition 1: 1.753%, condition 2: 1.74%, condition 3: 1.64%) (refer to Table 4.6). They also showed minimal response to a challenging argument by *counter-challenging* (condition 1: 0.00%, condition 2: 0.00%, condition 3: 1.23%). These results are consistent with previous studies (Ding et al., 2018; Snyder & Dringus, 2014), which have found that students infrequently engage in counterarguments and rebuttals. For instance, Dawson and Carson (2017) reported that students seldom offered rebuttals.

Several possible reasons could account for these findings. Firstly, *challenging* others' arguments and responding to counterarguments to bolster one's original argument are "the most common weaknesses in argumentation" (p.325) that students tend to struggle with, as noted by Jonassen (2011). Consequently, students are more likely to make declarative statements such as *claims* and *elaboration*, rather than delving deeper into the discussions with *higher level interactive argumentation* behaviors (HLIA) such as *challenging* and *counter-challenging* other ideas, which was also observed in the study by Snyder and Dringus (2014).

A second possible reason for the low engagement in *challenging* and *counter-challenging* others' arguments is students' disposition towards argumentation. The results

from the personal profile survey show that students consistently scored lower in approaching arguments (condition 1: $M = 2.60$, condition 2: $M = 2.95$, condition 3: $M = 2.99$) than in avoiding arguments (condition 1: $M = 3.59$, condition 2: $M = 3.41$, condition 3: $M = 3.46$) (refer to Table 4.1). This negative disposition toward argumentation has been found to be a contributing factor to the infrequent use of *challenging* and *counter-challenging* behaviors in previous studies (Albe, 2008; Grooms et al., 2018). When students rarely engage in *challenging* and *counter-challenging* arguments, they may lack the skills to demonstrate these behaviors.

A third possible reason for the scarcity of evidence related to *challenging* and *counter-challenging* behaviors is students' unwillingness to rebut each other in asynchronous online discussions. Although no nationality information was collected in this study, it can be tentatively inferred that almost all students in the study come from Western cultures, as 97.7% of the students (43/44 students) used English as their native language. Despite Western culture placing emphasis on discussing conflicts in knowledge beliefs, it seems that the willingness of students to engage in spirited arguments is unfortunately not a common feature of asynchronous online discussions in American classroom culture. Nussbaum and Bendixen (2003) confirmed students' disposition to avoid arguments as part of the American classroom culture, citing the desire to maintain warm relationships as one of the reasons.

Another possible reason for the scarcity of evidence related to *challenging* and *counter-challenging* behaviors is the students' potential lack of domain-specific knowledge. Although topics about digital citizens and digital leaders were covered in Module 4 of this class, a week of study may not be enough to equip students with

sufficient domain knowledge to discuss complicated topics like teachers' social media presence. When students lack adequate knowledge to add value to the conversation, their critical arguments suffer (Valero Haro et al., 2022; Yeong, 2021). Prior studies have confirmed the importance of domain-specific knowledge for the generation of critical argumentation behaviors (e.g., Valero Haro et al., 2022; Yeong, 2021).

The absence of *challenging* and *counter-challenging* argumentation behaviors in all conditions of this study is likely due to the task design. Kim (2009) discovered that when there is disagreement on a given issue, students tend to put in more effort to challenge and counter-challenge arguments made by others. Moreover, in role-playing situations where students take on the role of supporter or opponent of an issue, they feel more comfortable challenging their discussion partners. In this study, the discussion tasks allowed students to examine the scenario from multiple perspectives instead of limiting arguments to supporting or arguing against Jane Doe's social media presence (see Appendix J). Students were not assigned roles as proponents or opponents, and the task instructions did not emphasize the use of challenging and counter-challenging argumentation behaviors to achieve persuasive goals. Nussbaum (2005) found that emphasizing persuasive goals encouraged students to engage in more opposing interactions. The lack of role assignments, absence of disagreement requirements on the given issue, and failure to integrate persuasive goals into the task design could explain why students did not exhibit *challenging* and *counter-challenging* behaviors across the conditions in this study.

The low levels of *challenging* and *counter-challenging* seen in this study may also have resulted from low levels of participation in the discussion environment. For

instance, in condition 2, students had an average of 2.3 posts (Table 4.10), with 2 posts being the minimum requirement each week. This suggests that students tended to meet the minimum requirements of the discussion assignment, rather than actively engaging in the discussion. Low participation in asynchronous online discussions is well-documented in the literature (e.g., Du et al., 2022; Hew et al., 2010). This low level of participation could have made it challenging to create a trusting, warm, and comfortable environment, which, in turn, affected students' willingness to critique their peers' ideas and be open to receiving critiques from others (Rourke & Anderson, 2002).

Integration and Making a Concession. Similar to the low levels of *challenging* and *counter-challenging* behaviors, levels of integrating multiple lines of reasoning made by the student and their partner(s) to suggest a creative solution (*integration*) (condition 1: .51%, condition 2: 0.00%, condition 3: 0.41%) (Table 4.11), and acknowledging an opposing point made by their partner(s) as true (*making a concession*) (condition 1: 0.00%, condition 2: 2.61%, condition 3: 0.41%) (Table 4.11) were also low to non-existent across conditions. I suspect that these two argumentation behaviors are intertwined with *challenging* and *counter-challenging* behaviors since they require the presence of different and/or opposing points of reasoning. Since evidence of *challenging* and *counter-challenging* behaviors was low, it negatively affected the presence of *integration* behavior and *making a concession* behavior in students' discussion posts.

Finding Three: **Argumentation among Students in Question Prompt and Social Presence Enhancement Condition during the Small Group Discussion was More Co-constructive than that in the Other Two Conditions.** While no significant differences in argumentation behaviors were found across the different conditions, it is

worth noting that students in the question prompt and social presence enhancement strategy condition (condition 3) demonstrated a greater diversity of argumentation behaviors than their peers in the other two conditions, despite the short treatment period. Students in this condition exhibited evidence of all eight argumentation behaviors, while students in the other two conditions only demonstrated evidence of six out of eight. The argumentation behaviors that students in conditions 2 and 3 did not demonstrate were related to HLIA, such as *counter-challenging* (0.0% for both conditions), *integration* (0.0% for condition 2), and *making a concession* (0.0% for condition 1) (see Table 4.11).

According to Liu et al. (2019), students co-construct knowledge through critical discourse interactions. Students in condition 3 had more evidence of critical discourse than those in the other two conditions, as evidenced by the presence of all argumentation behaviors. Therefore, it is reasonable to infer that argumentation among students in the social presence enhancement condition (condition 3) was somewhat more co-constructive than among students in the other two conditions.

Question Two: Effects of Question Prompt-based Scaffolding with or without Social Presence Enhancement Strategies on Students' Problem-solving Processes during Small Group Discussions

The second research question investigated the effects of the question prompt-based argumentation scaffold with or without social presence enhancement strategies on students' problem-solving processes during small-group discussions, as represented by the frequency of each problem-solving process evidenced in their discussion messages.

Finding Four: The Question Prompt-based Scaffold with or without the Social Presence Enhancement Strategies did not Have any Statistically Significant

Effects on Students' Problem-solving Processes during Small Group Online Discussions. This study found no significant differences across conditions in terms of students' problem-solving processes during discussions. The non-significant correlations of the question prompt scaffold with or without social presence enhancement strategies on students' problem-solving processes during small group discussions were inconsistent with previous studies (e.g., Ge & Land, 2003; Oh & Jonassen, 2007), which found positive and significant impacts of question prompts on students' problem-solving. For instance, Oh and Jonassen (2007) found partial effects of their constraint-based argumentation scaffolds on students' problem-solving processes. Specifically, scaffolded students in their study performed better than control group students in problem hypothesis testing, but there were no significant differences in other problem-solving processes. Ge and Land (2003) found that students who received question prompts significantly outperformed those who did not receive question prompts in all problem-solving processes. There are several plausible explanations for the inconsistency between the findings of this study and those of previous studies.

Firstly, it is possible that student argumentation behaviors during the discussions impacted their problem-solving processes. Argumentation is a critical aspect of problem-solving and is known to predict student problem-solving (Kim et al., 2022; Pratiwi et al., 2019). For instance, Oh and Jonassen (2007) found that students who received argumentation scaffolds posted more evidence notes than the control group and performed better in problem hypothesis testing. In this study, since there were no significant differences across conditions in terms of LLIA and HLIA, it is unsurprising

that there were no significant differences across conditions in terms of problem-solving processes during the discussions.

Secondly, the degree of exposure to the scaffolds may also need to be taken into account. Students in conditions 2 and 3 were instructed to use the provided question prompts with or without social presence enhancement strategies to guide their posts. However, it is uncertain to what extent the students in these conditions actually used these scaffolds to direct their discussions with their peers to solve the problem. Furthermore, to prevent any potential confounding effects of the instructor and researcher's presence on the discussions, they were observers of the discussions and did not participate in the discussions. As a result, the students in the treatment conditions were not prompted to use the scaffolds. In the study by Ge and Land (2003), where the use of question prompts had positive effects on all problem-solving processes, students were frequently reminded to refer to the question prompts while solving the problem. Similarly, in the study by Oh and Jonassen (2007), students in the question prompt condition were reminded to use the prompts through a pop-up window that displayed relevant question prompts for the chosen knowledge type related to problem-solving.

Another possible explanation for the lack of significant differences in students' problem-solving processes across conditions could be related to their engagement during discussions, as measured by the average number of posts. Students in condition 2 posted fewer messages on average (M = 2.3) compared to those in condition 1 (M = 3.3) (see Table 4.5). Although students in condition 3 had the highest average number of posts (M = 3.53), it was not substantially higher than that of students in condition 1 (see Table 4.5). I speculate that the number of posts may indicate the level of social interactions

among students in the different conditions. According to social constructivism perspectives (e.g., Bandura & Walters, 1977; Lave & Wenger, 1991a; Vygotsky, 1978), social interactions foster meaningful learning activities, such as problem-solving. Through social interactions, individuals can "think together" and "guide each other" to better understand and solve problems. The fact that students' level of engagement or social interactions in the scaffolded conditions was not substantially higher (condition 3), or even lower (condition 2), than that of students in the control condition may explain why no significant differences in students' problem-solving processes were detected across conditions in this study.

Finding Five: Students were More Engaged in Certain Problem-solving Processes than Others. The data indicated that *problem representation* and *solution generation* received more coded units than *justification* and *solution evaluation*, with *solution evaluation* receiving the fewest coded units. This trend was also reflected in students' self-reported problem-solving skills, pre-test problem-solving performance, and post-test problem-solving performance, with *problem representation* and *solution generation* receiving higher scores than *justification* and *solution evaluation*, and *solution evaluation* receiving the lowest score.

One plausible explanation for this observation is that students may be more comfortable with identifying the problem and suggesting solutions than justifying and arguing for their preferred solutions and against other alternative solutions, particularly when strong justifications and solution evaluations require using examples and evidence. Providing justifications with examples and evidence and evaluating solutions are skills

that students tend to struggle with, as found in the literature (e.g., Hyytinen et al., 2017; Kuhn & Udell, 2003; Reznitskaya et al., 2007).

It is worth noting that this observation is consistent with findings from previous studies (e.g., Ge & Land, 2003; Oh & Jonassen, 2007), which have reported lower scores for *justification* and *solution evaluation*. This highlights the need for further investigations into practices and pedagogies that could effectively support problem-solving for students, particularly those related to *justification* and *solution evaluation*.

Another explanation for why *problem representation* and *solution generation* had a higher presence than *justification* and *solutions evaluation* could be attributed to students' argumentation behaviors during discussions. Making *justification* and *solution evaluation* require critical argumentation behaviors such as *challenging, counter-challenging,* and *supporting reasons*, which can be considered higher level problem-solving skills. However, given the low evidence of HLIA in this study, it is understandable that the evidence of problem-solving processes in *justification* and *solution evaluation* is limited.

Question Three: Transfer Effects of the Question Prompt-based Scaffold on Problem-solving Performance

The third research question examined whether the question prompt-based argumentation scaffold, with or without social presence enhancement strategies, had any transfer effects on students' post-test problem-solving performance. The students' performance was represented by their average scores across all the problem-solving categories, including *problem representation, solution generation, justification,* and *solution evaluation.*

Finding Six: The Question Prompt-based Scaffold, with or without the Social Presence Enhancement Strategies, Positively Affected Students' Post-test Problem-solving Performance. Students in condition 3, who had the question prompt scaffold combined with social presence enhancement, had a significantly higher post-test problem-solving performance score than students in condition 1. Although there were no significant differences in performance between condition 3 and condition 2, or between condition 2 and condition 1, it is worth noting that the average post-test performance score was higher in condition 3 than in condition 2, and higher in condition 2 than in condition 1. In general, the use of the question prompt scaffold improved students' post-test problem-solving performance, which was greater when combined with social presence enhancement prompts.

These results provide partial support for previous studies that have shown improvements in students' ill-structured problem-solving performance as a result of the question prompt-based argumentation scaffold (e.g., Kim, 2009; Oh & Jonassen, 2007; Ge and Land, 2004). One possible explanation for this positive effect is that the question prompts directed students' attention to important information they might have otherwise overlooked, such as alternative solutions and their viability. The results also confirm the benefit of social presence support on students' problem-solving performance, as seen in the literature (e.g., Kim, 2009).

However, it is important to interpret this study's post-test problem-solving performance results with caution. To represent overall problem-solving performance, the performance scores of the four types of problem-solving processes were summed and averaged for statistical analysis. Therefore, the problem-solving performance score does

not necessarily reflect the performance quality across all four problem-solving processes. In fact, the most influential factors in determining the problem-solving performance score across the conditions were *problem representation* and *solution generation* (Table 4.15), indicating that students tended to identify and reach conclusions quickly rather than justify their proposed solutions and consider alternative solutions and their viability, as noted by Schoenfeld (2014).

Finding Seven: Higher Level Interactive Argumentations Had a Positive and Significant Effect on Students' Post-test Problem-solving Performance. HLIA was found to be related to better post-test problem-solving performance scores. Despite the fact that students, particularly in online learning environments, seldom engage in HLIA, such as *challenging* and *counter-challenging*, this study provides evidence that HLIA is crucial to improving students' problem-solving abilities. It is not surprising to see that HLIA was positively and significantly correlated with students' post-test problem-solving performance scores. This is because HLIA enables conflicting ideas to be discussed in depth and multiple problem representations and competing solutions to be explored, as noted in previous studies (Cho & Jonassen, 2002; Ertmer et al., 2011; Snyder & Dringus, 2014).

Implications

Theoretical Implications

Scaffolding. This study adds to our understanding of why scaffolding is necessary but not sufficient for desirable learning outcomes, such as improved critical argumentation skills and problem-solving performance. Firstly, during small group discussions, students lacked argumentation skills, particularly HLIA, to solve problems,

as seen in their argumentation behaviors. This issue is well-documented in the literature (e.g., Safari & Meskini, 2015). Secondly, students showed a reluctance to engage in argumentative situations, as indicated by the results of the personal profile survey. Thirdly, placing students in small groups and providing them with cognitive scaffolding did not guarantee their active participation in collaborative problem-solving activities. This finding aligns with the results of Ge and Land's (2004) study, which found that putting students in groups did not always lead to engagement in problem-solving processes. Furthermore, students tended to focus more on *problem representation* and *solution generation* rather than *justification* and *evaluation* of alternative solutions and the viability of the preferred solutions with evidence and data. This study demonstrated that the benefits of cognitive scaffolding were more effective and consistent when supported by students' social interactions.

Social Presence. The significance of social interactions in learning is well-established in various learning theories, such as social constructivism (Brown et al., 1989; Lave & Wenger, 1991; Vygotsky, 1978), social learning theory (Bandura & Walters, 1977), a community of practice (Lave & Wenger, 1991), cognitive apprenticeship (Brown et al., 1989), and connectivism (Siemens, 2017). Previous studies have found that social interactions in online learning can be promoted through social presence (Garrison et al., 1999).

The current study focuses on providing social presence enhancement strategies in conjunction with the question prompt-based argumentation scaffold to support students' argumentation during collaborative problem-solving. We consistently observed and even recorded significant improvements in students' argumentation behaviors and problem-

solving during discussions and after the intervention. This was due to the introduction of social presence enhancement strategies, indicating that social presence can be supported in asynchronous online discussion environments through simple strategies. These include introducing social presence enhancement strategies that students can use and encouraging them to use these strategies during discussions with their peers.

Practical Implications

The present study demonstrates that introducing a cognitive scaffold, such as question prompts, to support different types of argumentation behaviors during ill-structured problem-solving is essential in enhancing argumentation behaviors, collaborative ill-structured problem-solving during asynchronous online group discussions, and individual ill-structured problem-solving. However, the study also highlights the importance of social presence enhancement scaffolds, as the combination of both was more effective and consistent. Hence, creating a social presence in asynchronous online discussion forums is necessary to support students' interactive argumentation and meaningful learning activities, such as problem-solving.

The study identifies the lack of demonstration of HLIA during students' small group discussions. Since argumentation, particularly HLIA is crucial to ill-structured problem-solving, instructors and instructional designers in asynchronous online classes can use this finding to design learning tasks and pedagogical strategies that promote HLIA to support students' problem-solving processes and performance.

In integrating the use of question prompts and social presence enhancement strategies into students' discussions, it is crucial to consider the treatment duration. Multiple discussions spanning several weeks may be necessary to see significant changes

in students' argumentation behaviors and problem-solving performance. The study and literature suggest that a short one-week treatment may not be enough to observe treatment impacts on students' argumentation behaviors and problem-solving performance. A previous study by Dawson and Carson (2017) demonstrated significant impacts on students' argumentation skills with a four-week treatment. Instructors and instructional designers may need to implement scaffolding with an extended time frame to observe potential changes in students' argumentation behaviors, leading to improvements in their problem-solving performance.

Limitations of the Study and Suggestions for Future Research

The study has several methodological limitations that need to be acknowledged. First, the sample size was relatively small ($N = 44$), which could increase the risk of under-powering the study and difficulty in detecting effects through inferential statistical analysis. For instance, the study failed to identify any effect of scaffolds on students' lower and higher levels of interactive critical argumentation behaviors across the conditions during small group discussions. However, it is unclear whether this result was due to the small sample size or whether the scaffolds genuinely had no impact on the outcome variables. As a result, observed differences across conditions during the discussion and after the treatment were mostly descriptive rather than statistically significant. Future research with larger sample sizes is necessary to confirm the current study's findings.

Second, the intervention was conducted in the fifth week of an eight-week course, which could have affected the study outcomes. By this point, students might have already established social relationships with their peers, and their sense of social presence in the

course might have already been established. If the students had a low sense of social presence in the course before the intervention, providing them with social presence enhancement strategies and putting them into small groups may not have increased their engagement in making arguments with their peers to solve problems. This could have led to the inability to detect the effects of question prompt-based scaffolding used in combination with social presence enhancement strategies when there might have been an actual effect. Future research could introduce cognitive scaffolding in combination with social presence scaffolding earlier in the course to determine if the introduction of social presence enhancement strategies could lead to more participation in collaborative argumentation, problem-solving processes during discussions, and better problem-solving performance.

Third, the study findings should not be over-generalized beyond the current research context. Although the findings provide insights into students' argumentation behaviors, problem-solving processes, and problem-solving performance in this particular course with pre-service teachers, they may not be generalizable to all types of online courses and online students.

Fourth, the high attrition rate (17%) of this study (9 out of 53 participants lost across time periods) could have biased the findings. For instance, after screening incomplete data, group D in condition 2 was left with only one member, which could have affected the results. To avoid this issue in future studies, the implementation of the intervention could be started earlier.

Fifth, the study highlights the need for valid and reliable assessment tools to analyze argumentation behaviors in asynchronous online learning environments. Previous

studies have heavily relied on Toulmin's model to analyze interactive argumentation, despite its inadequacy for this task. The current study attempted to adapt a coding scheme based on prior research, but its reliability (Cronbach's $\alpha = .57$) was not satisfactory, particularly for the *making a concession* behavior. Thus, further refinement of the coding scheme is necessary to develop an assessment tool with higher reliability. Additionally, future studies may produce different outcomes if the *making a concession* behavior could be included as part of an argumentation behavior category.

Sixth, the one-week treatment period in this study may have been too short to detect treatment effects on outcome variables. An extended treatment period, such as the four-week treatment period used in Dawson and Carson's (2017) study, could lead to different outcomes.

Seventh, this study solely used students' discussion data for content analysis and did not examine their perceptions of how the scaffolds influenced their cognitive and social interactions. Future research could use qualitative data from interviews, focus groups, or in-depth case studies to gain insights into the influence of scaffolds on students' cognitive and social interactions.

This study found a low frequency of HLIA, such as *challenging*, *counter-challenging*, and *making a concession*, during collaborative problem-solving. However, the study did not examine how these argumentation behaviors develop in a small group online discussion setting. When students argue to learn in groups, their argumentation behaviors are influenced by each other and by the perceived social presence. Future research should focus on developing an understanding of the trajectory of argumentation

behaviors and how social presence factors foster these behaviors in a small group online discussion setting.

Conclusions

Problem-solving skills are among the most sought-after soft skills by employers (National Association of Colleges and Employers, 2022), and they are equally important in solving everyday problems. Therefore, education should focus on supporting students' problem-solving skills, whether in-person or online. Asynchronous online discussion forums are designed to support meaningful learning activities like problem-solving. However, few studies have explored the impact of question prompts as a scaffolding strategy, either with or without social presence enhancement strategies, to support interactive argumentation during collaborative problem-solving in asynchronous online discussions.

This study aimed to investigate the effects of question prompts as a scaffolding strategy, used with or without social presence enhancement strategies, on students' argumentative behaviors, problem-solving processes, and performance. Data were gathered from students' discussion posts within small groups, as well as individuals' first posts after the intervention. Qualitative content analysis was used to quantify the frequency of argumentation behaviors and problem-solving processes during discussions and to evaluate students' post-test problem-solving performance. The study identified two categories of argumentation behaviors: LLIA and HLIA, using principal component analysis to reduce the dimension of argumentation behaviors.

The study conducted ANOVA to explore the differences across conditions in terms of argumentation behaviors, MANOVA to investigate the differences in problem-

solving processes during discussions, and ANCOVA to examine the differences in post-test problem-solving performance across conditions. The outcome variables were the loading score of each newly identified argumentation category (LLIA and HLIA), the frequency of students' problem-solving processes during discussions, and post-test problem-solving performance scores. Descriptive statistics were also used to better understand the data and interpret the findings from statistical analysis.

The main findings of the study were: (1) the scaffolds did not significantly impact students' LLIA and HLIA or their problem-solving processes during small group discussions, (2) using question prompt scaffolds, with or without social presence enhancement strategies, tended to have positive transfer effects on students' post-test problem-solving performance, but the effect was only significant when the cognitive scaffold was used in combination with social presence enhancement strategies, and (3) HLIA was a significant predictor of students' post-test problem-solving performance scores.

The examinations of the impacts of the question prompt scaffold in combination with or without social presence enhancement strategies on students' argumentation behaviors and problem-solving processes during discussions and problem-solving performance after the intervention has contributed to the understanding of how students engage in collaborative problem-solving activities in asynchronous online discussion forums, areas of challenges students face to solve problems successfully, and the design of pedagogical strategies which may lead to the improved problem-solving practices during asynchronous online discussion forums for online students in the future.

APPENDICES

APPENDIX A: VALIDATION TOOL FOR THE PROBLEM SCENARIO[7]

Features	Responses			Comments
1. Is the problem relevant to the class (ISLT-2467)?	Yes	Somewhat	No	
2. Does the problem require the use of concepts and principles related to digital citizenship?				
3. Is the problem complex?				
4. Will the problem have multiple perspectives?				
5. Will the problem have multiple solutions?				
6. Does the problem solution call for justifications/argumentation?				
7. Can the problem-solving task be completed within a week-long discussion?				
8. Does the problem need to be modified? If yes, how? Please write the comment in the space provided?				

[7] Adopted from Ge, X. (2001). *Scaffolding students' problem-solving processes in an ill-structured task using question prompts and peer interactions*. [Doctoral Dissertation, Pennsylvania State University]. PennState Elecronic Theses and Dissertations for Graduate School. https://etda.libraries.psu.edu/files/final_submissions/6665

APPENDIX B. FOCUS GROUP RECRUITMENT EMAIL

Title: Invitation to education research participation

My name is Minh Pham, a Ph.D. candidate from the School of Information Science and Learning Technologies. I am looking for students who are over 18 years old and currently an undergraduate who is/was enrolled in a course related to the meaningful integration of technologies in education to participate in my focus group. I have designed three controversial real-life problem scenarios related to digital divide, teacher online presence, and cyberbullying to implement in discussion board forums for undergraduate pre-service teacher students to investigate how students solve problems in asynchronous online discussion forums. I would like to invite you to participate in a one-hour long focus group on Zoom to learn whether those problems are appropriate to use.

The first 10 to 12 students that contact me via email (minhpham@mail.missouri.edu) will get to participate and receive financial compensation ($25 Amazon gift card). All information collected in this focus group is completely confidential. Name and any data that can identify you will not be revealed.

If you are interested in participating or have questions, please contact me at minhpham@mail.missouri.edu. Thank you for your consideration!

Minh

APPENDIX C: CONSENT FORM FOR THE FOCUS GROUP

INFORMED CONSENT FORM FOR A RESEARCH FOCUS GROUP

University of Missouri, Columbia

Title of project: "Evaluating the Appropriateness of Real-life Problem Scenarios for Undergraduate Class Online Discussions"

IRB Project Number: 2089022

Principal Investigator: Ms. Minh Pham

Ph.D. Candidate, School of Information Science and Learning Technologies

College of Education

University of Missouri-Columbia

Phone: (573) 673-0672

Email: mtpr3d@umsystem.edu

Advisor: Dr. Rose Marra

You are being invited to take part in a research focus group conducted via Zoom. You must be 18 years of age or older. Your participation is voluntary, and you may stop being in this study at any time. The purpose of this focus group is to explore the potential issues with three real-life problem scenarios related to digital divide, teacher's problem-solving, and cyberbullying which have been developed for undergraduate pre-service teacher students to discuss and to improve them. These problem scenarios are part of the study on the effects of question prompt-based scaffolding and problem-solving enhancement on students' argumentation and ill-structured problem-solving. You are being asked to provide your opinions on the content and language of the problem

scenarios and keep the focus group discussion information confidential. Your participation should last up to one hour. For your time and effort, we will be offering compensation in the amount of $25 Amazon gift card. The information you provide will be kept confidential and only the research team will have access.

If you have questions about this study, you can contact the University of Missouri researcher at 573-673-0672 or via email at minhpham@mail.missouri.edu. If you have questions about your rights as a research participant, please contact the University of Missouri Institutional Review Board (IRB) at 573-882-3181 or muresearchirb@missouri.edu. The IRB is a group of people who review research studies to make sure the rights and welfare of participants are protected. If you want to talk privately about any concerns or issues related to your participation, you may contact the Research Participant Advocacy at 888-280-5002 (a free call) or email muresearchrpa@missouri.edu.

You can ask the researcher to provide you with a copy of this consent for your records, or you can save a copy of this consent if it has already been provided to you. We appreciate your consideration to participate in this study. By providing your first and last name and Mizzou email address, you consent to participate.

Please provide your first and last name

Please profile your Mizzou email address

APPENDIX D. FOCUS GROUP PROTOCOL

Focus Group Protocol

The Goal:

The goal of the focus group is to understand the appropriateness of three problem scenarios which have been designed for asynchronous online group discussions in an online 3 credit hour, 8-week course. Students enrolled in this course are undergraduate pre-service teacher students. The course aims to help students with models and strategies for integrating technology into the teaching and learning process with a focus on transformative meaningful learning instead of passive technology use. The problem scenarios aim to engage students in the course with real-life complex problem-solving activities. The results of the focus group will help identify potential issues with the problem scenarios.

Participants:

10-12 undergraduate students from a session of the same course and/or a similar course will be recruited for this focus group. If permitted by participants, the session will be recorded for analysis.

Note: Each participant will receive an online $25 Amazon gift card as incentive for the focus group participation on Zoom in compensation for their time.

Moderators:

Minh Pham – the PI of the study.

Tentative Meeting Date and Time:

11a. m. -12. 00 p.m., Feb 21

Meeting Tool:

Zoom meeting

Conducting process:

The conducting process and related interview questions will be addressed as following: introduction message with the goal of the focus group, ground rules, problem scenario introduction, and interview questions regarding the appropriateness of the problem scenarios which have been designed for asynchronous online group discussions in an online 3 credit hour, 8-week course.

***Introduction Message*:**

Hello everyone and thank you for participating the focus group today. My name is Minh Pham, and I will be the moderator for today's focus group. The purpose of this focus group is to learn about the appropriateness of three problem scenarios. Students enrolled in this course are undergraduate pre-service teacher students. The course aims to help students with models and strategies for integrating technology into the teaching and learning process with a focus on transformative meaningful learning instead of passive technology use. The problem scenarios aim to engage students in the course with real-life complex problem-solving activities. The results of the focus group will help identify potential issues with the problem scenarios.

All of you have been invited to participate because you are students who are taking one of the sessions of the course or taking similar courses on how to create meaningful learning with technology.

It is my/our expectations that your opinions and experiences will help me/us learn more about whether the problem scenarios are appropriate and can engage students in discussions. After the focus group, the information we discussed will be analyzed and

findings will be used to make necessary changes to the problem scenarios to make sure that the problems are interesting and neutral for students to solve. Your personal information will not be connected to the results of this focus group.

I am passing around/sharing with you a consent form. By signing these forms, you are agreeing to participate in the focus group and to keep our discussion confidential. If you feel uncomfortable for any reason signing these forms, you are free to leave at any time. Please take a moment to read them over. If you have any questions, please let me know.

Before we begin, I would like to go over a few ground rules for the focus group. These are in place to ensure that all of you feel comfortable sharing your experiences and opinions.

Ground Rules:

1. *Confidentiality* – As per the consent form, please respect the confidentiality of your peers. The moderator will only be sharing the information anonymously with relevant committee members and published works.
2. *One Speaker at a Time* – Only one person should speak at a time in order to make sure that we can all hear what everyone is saying.
3. *Use Respectful Language* – In order to facilitate an open discussion, please avoid any statements or words that may be offensive to other members of the group.
4. *Open Discussion* – This is a time for everyone to feel free to express their opinions and viewpoints. There will be no right or wrong answers.

5. *Participation is Important* – It is important that everyone's voice is shared and heard in order to make this the most productive focus group possible. Please speak up if you have something to add to the conversation!

Before we look at the problem scenarios and discuss, may I have your permission to record our meeting.

Problem Scenarios and Interview Questions:

The first problem for students to solve on the discussion board with the whole class is:

Digital (Use) Divide and Beyond

Harvey is a 11-year-old Black fifth grader, attending an elementary school in a rural area in the mid-west, USA. The nearest public library he can have access to is 6 miles away from his home. He is the fourth kid in a family of six K-12 school age children. His school has resumed face to face education since the beginning of this academic school year (2021-2022). Academically, Harvey is failing behind his peers. His homework assignments are either not completed or poorly completed. If the assignments are paper-based open ended questions or paper-based math problem, he tends to return it. If the homework assignment requires some research or is technology-based homework, very likely he either does not complete it or submits it late. He also tends not to proofread or check his answers. He rarely participates in discussion forum boards to discuss homework assignments with his peers. Only 25% of his homework assignments are completed on time. Harvey has access to an iPad provided by the school and can bring it home. His parents reported that since the outbreak of the pandemic, they have been provided the Internet access for free through the school district. However, they also

reported it is hard for them, timewise, to help their children use technology and deal with internet problems such as the speed, reliability of quality of internet connection. In class, his classmates complain that Harvey contributes little to nothing when they are assigned to work together on technology-based group projects such as designing and coding a video game or creating a short video clip. When allowed to use iPad to play educational games or do research projects in class, he also tends to search for content and videos related to entertainment video games instead of working on assigned activities.

Task 1. Please answer all the following questions in your first post in the discussion. The first post is due on due on the first day of Week 1.

1. From reading the case, what are the issues that Harvey seems to be having?
2. What might be contributing to, or causing the issues Harvey is facing? Please list the most likely cause(s) and support each with justifications and evidence.
3. Imagine you were Harvey's teacher, what could you do to help Harvey? As you think about this, specify what your goal would be in any help or intervention you might provide. Please justify your solution(s) with evidence.
4. What are other potential solutions?
5. Of all the potential interventions you have identified, which do you think is best and why?

Task 2. In the following posts, please make meaningful comments on others' posts and replies to others' messages to further understand the problem and possible solutions. When possible, provide support for your posts from class readings or other sources.

Interview Questions:

1. How would you describe the content of this problem scenario? Interesting or boring? Acceptable or unacceptable? etc.

2. How would you describe the language of this problem scenario? Neutral or biased? Off-putting or acceptable? etc.

3. What do you think about the clarity of the questions?

4. If you could make a modification to the problem scenario or the question prompts, what would it be?

Prompts during the interview:

"Could you explain further?"

"Could you give an example of what you mean?"

"I don't understand."

"Tell me more about that…"

For the second problem for students, students will work in groups of three to identify the problem and propose the solutions. The problem scenario is:

Teacher Social Media Presence

Jane Doe is a science teacher in a large middle school in the Mid-West, USA. She loves to share every moment of her life on social media: date nights, holidays pics, etc., She also tends to like, share, and re-posts, or "like" controversial content on social media (e.g., climate change, gun control). Jane, however, does not post actual comments on these controversial social media posts.

Tasks:

In the first post, introduce yourselves, try to get to know your partner, and post your first idea about your views on the appropriateness or inappropriateness of Jane's social media behavior and provide a justification for your position. Make your first post no later than (the first day of Week 4).

In the following posts, discuss with your partner to address the following questions:

- What are the possible causes of the behavior with the use of social media by Jane Doe. Please list the most possible cause(s) and support your hypothesis with argument and evidence.
- What do you think teachers should do to create a positive online presence on social media so that they can establish their personal brand and at the same time be viewed as a professional leader in their career? Please justify your positions.
- What else do you think teachers could do relative to creating a positive online presence? Of all the solutions you have identified, which do you think is the best and why?

Interview Questions:

1. How would you describe the content of this problem scenario? Interesting or boring? Acceptable or unacceptable? etc.

2. How would you describe the language of this problem scenario? Neutral or biased? Off-putting or acceptable? etc.

3. What do you think about the clarity of the questions?

4. If you could make a modification to the problem scenario or the question prompts, what would it be?

Prompts during the interview:

"Could you explain further?"

"Could you give an example of what you mean?"

"I don't understand."

“Tell me more about that…”

The third problem for students to solve on the discussion board with the whole class is:

Cyberbullying

Alex is a 17-year-old, attending a large high school in the Midwest, USA. Alex is an outstanding student in all aspects: academics, music, and sports. At the beginning of this year, Alex came out to his family and a few of his close friends at school as gay, and slowly he has become more comfortable embracing his identity. Recently, one of his close friends outed Alex to other at school without Alex’s consent and knowledge in an Instagram private chat room. Since then, these persons have started to post all kinds of untrue information about Alex relative to his identity as a gay man. One such posting that was circulated to many at the school, contained a photoshopped image of Alex that portrayed him in a degrading way. Comment made on this image were both hurtful and demeaning.

Imagine you are the Extended Educational Experiences (EEE) teacher to both Alex and your daughter. A few days ago, your daughter blurted out Alex’s sexual orientation information and showed you all circulating social media comments and pictures about Alex.

Please answer all the following questions in your first post in the discussion. The first post is due on the first day of Week 5.

1. How would you describe the behavior of those that were posting this content about Alex? Acceptable? Not acceptable? Describe the behaviors as being acceptable or not and provide a justification for your position.

2. What are the possible causes of the behavior with the use of social media by Alex's schoolmates? Please list the most possible cause(s) and support your hypothesis with argument and evidence.

3. As a teacher, what do you think you can do that can address this type of use of social media? Explain as well what the goal would be of your actions, and justify your positions.

4. What else do you think you could do relative to this situation? What do you think is the most viable thing you could do, and why?

Interview Questions:

1. How would you describe the content of this problem scenario? Interesting or boring? Acceptable or unacceptable? etc.

2. How would you describe the language of this problem scenario? Neutral or biased? Off-putting or acceptable? etc.

3. What do you think about the clarity of the questions?

4. If you could make a modification to the problem scenario or the question prompts, what would it be?

Prompts during the interview:

"Could you explain further?"

"Could you give an example of what you mean?"

"I don't understand."

"Tell me more about that…"

Conclusion:

Thank you for participating in today's focus group. **Is there something that we haven't talked about that we should consider in these problem scenarios and question prompts? (**Pause…). If you think of any additional thoughts or comments that you would like to share, please contact me at minhpham@mail.missouri.edu. (The gift card will be emailed to you within a couple of days). Thanks a lot everyone!

APPENDIX E. FOCUS GROUP TRANSCRIPT

FOCUS GROUP TRANSCRIPT (Sample)

Interviewer: So if you haven't had time to take a look at those scenarios, then please take a look at the scenarios, so I have three problem scenarios and they are meant to be controversial scenarios so students feel like they want to make arguments and challenge the arguments with other fellow students in discussion forums.

Interviewer: Okay, so before we go to the questions, then please take a look at the first scenario, and then the final question prompts.

Interviewer: Once you have done reading the first problem scenario and the questions for that scenario, then please let me know so that we can go ahead with the questions today.

Interviewer: Okay awesome. Thank you. So the first question I have is, how would you describe the content of this problem scenario? Interesting or boring? Acceptable or unacceptable?

P1: It's probably a problem that his parents can't really help him when he needs help it said that they report it hard for them to help their child time wise like they don't have time, so they can't really like watch him do his work, so he gets distracted and plays games.

Minh Pham: Okay awesome. Thank you! what do you think P2?

P2: Um a problem I saw was that he doesn't have Internet access outside of school so it's hard for him to use the Internet at home. And then also it seems like he's having problems with like digital citizenship so like he does have educational games and stuff, but when he can use his iPad or device he doesn't use it wisely.

Interviewer: Okay, thank you.

Interviewer: I think I have misguided you so I don't need you to analyze the problem for me. So what I want to see is when I present these problem scenarios for student, I want to make sure that the language and the content in these problems would not make anyone defended. I would like to see if there are stereotypes embedded in the problem scenarios, if you think the language may be offensive or something like that.

Interviewer: So I want students to feel comfortable to share their ideas and they will not take offense at the language or the content.

Interviewer: So do you see any stereotype that somebody will take it personally.

P3: I don't think any one would necessarily take it personally.

P4: I don't think anybody will take it personally. It's kind of just like a vague description and all that it really says is like he's falling behind and he doesn't have like access to Wifi and that's not really like specific or its stereotype or anything like that.

P1: So I don't think yeah. I completely agree with that, too, I don't I don't think there's anything wrong.

Interviewer: Awesome. Thank you!

Interviewer: OK, the next question I have is how would you describe the language of this problem scenario? Neutral or biased? Off-putting or acceptable?

P1: I think it's pretty neutral like there's not really anything in it that's biased or anything like that.

P2: Yeah I agree, I didn't see any words that stuck out to me that would make me think that there was any bias, but I think it's neutral.

Interviewer: Okay, so I think we are good, with the prom scenario, what about the question problems.

Interviewer: What do you think about that clarity of the questions?

P1: I think they're clear and easy to understand and there'll be like easy to answer as a group or individually.

P2: Frankly, I really like how they're broken up into like smaller parts, rather than having like a long question.

P2: I also like the question about what is the most likely causes since there's no really right or wrong answer so there's a lot of room for more ideas, rather than just one.

Interviewer: Okay awesome. Thank you so much.

Interviewer: What do you think about the clarity of the questions, P3?

P3: Um I think they're good questions. I don't think there are like a waste of time. I feel like they're good questions that would be that could like bring good conversations.

Interviewer: Okay awesome. Thank you!

Interviewer: So the last question for this scenario. It is, if you could make a modification to the problem scenario or the question prompts, what would it be?

P4: I would say, like. Yes, it depends on like if you're doing this like individually or like in a group, because I thought the only way, you can make it controversial is if you're like comparing your answer to somebody else's. Or if you're like add a question that tells people to come up with like multiple solutions and compare them to like which one is better and, like the reasons that they're better I think those are the only ways to really like make it controversial in that aspect.

Interviewer: Okay awesome. Thank you.

Interviewer: Do you guys want to add something?

P1: I think what she said was really good um yeah I think something like a comparison so, then you can see other people's ideas, who make it more controversial but yeah. That was really good she said.

P2: yeah I agree with both of them.

P3: Same here.

APPENDIX F. INTERVENTION RECRUITMENT MATERIALS

Announcement Title (Announcement 1): Opportunity to be part of an educational research study (and get extra points)

Opportunity to be part of an educational research study

Good morning, Everyone!

My name is Minh Pham, a Ph.D. candidate from the School of Information Science and Learning technologies, University of Missouri, Columbia. I would like to invite you to participate in my research study. The purpose of my study is to explore effective instructional strategies used to support students' real-life problem-solving skills on asynchronous discussion forums. The findings of this research will be used to help instructors develop effective learning strategies and support problem-solving skills in online discussion forums.

Your participation in my research involves letting your discussion board activity data used in my dissertation and completing a personal profile survey. I would like to use your required coursework discussion activities of Week 1, Week 5, and Week 6 for my research study. Your discussion board participation is part of your required coursework, and you will not be doing it for research. You only participate after you have consented to and completed the survey. You will be awarded 5 extra points for your participation.

All records and information collected in this study are completely confidential. Name, student email, and any data that can identify you will not be revealed. Results of this research will be presented and published in aggregate form with no personal identifiers. You can make requests to me to see the study results once the study is completed.

If you are interested, please read and sign the consent form and complete the survey. The survey will take 5-7 minutes to complete. The survey aims to measure your argumentativeness, problem-solving skills, and demographic information.

If you have question, please contact me at minhpham@mail.missouri.edu.

Best,

Minh

Announcement Title (Announcement 2): Research request: Participate in an educational research study (and get extra points and have your name in a raffle for one of the 3 $50 dollar gift cards)

Hi, Everyone!

I would like to reach out to you again to invite you to have your work in this class used in my research study. This is a chance to see how your work and responses in discussion boards can make contributions to the design and development of effective instructional strategies for online learning. You can make requests to me to see the study results once the study is completed.

Your participation in my research involves letting your required coursework data in Weeks 1, 5, and 6 of the class used in my dissertation study and your completion of the survey. You will be provided with 5 extra course points in compensation for your participation in this research study. Your name will be also entered in a raffle to win one of 3 $50 Amazon gift cards. There are 3 $50 Amazon gift cards for students in each class

where the participant recruitment for this study is conducted. Raffle winners will be notified privately by Week 5 of your class.

If you are interested, please read, and sign the consent form and complete the survey. The consent form and the survey take about 7 minutes to complete.

If you have question, please contact me at minhpham@mail.missouri.edu.

Best,

Minh

APPENDIX G. CONSENT FORM

Consent to Participate in a Research Study

Title of project:

The effects of question prompt-based scaffolding and social presence enhancement on students' argumentation and ill-structured problem-solving

IRB application number: 2088843

Principal Investigator/Researcher: Ms. Minh Pham, Ph.D. Candidate

School of Information Science and Learning Technologies

College of Education

University of Missouri-Columbia

Phone: (573) 673-0672

Email: mtpr3d@umsystem.edu

Advisor: Dr. Rose Marra

You are being invited to participate in in a research study. You must be 18 years of age or older and are a student in the course IS_LT 2467 offered in the second half of Spring 2022 or Summer 2022. The purpose of the study is to explore effective instructional strategies used to support students' real-life problem-solving skills on asynchronous discussion forums. You are being asked to have your work of week 1, week 5, and week 6 of this class which includes your discussion post activities and your response to a survey used for my dissertation research on effective instructional strategies to support ill-structured problem-solving skills in asynchronous online discussion forums. Your participation in this research study is voluntary; you may decline without penalty. If

you decide not to have your data used, you may withdraw your data at any time without penalty.

The discussion board data being requested is your required coursework but sharing that data for my research is voluntary. Your participation in my research involves letting your data used and completing the survey. The survey aims to measure your argumentativeness and problem-solving skills and takes 5-7 minutes to complete. You will be awarded with 5 extra credit points for your participation in the study and your name will be entered into a raffle to win one of the three $50 Amazon gift card. Raffle winners will be notified privately via email by Week 4 of the course. If you do not wish to participate in the study, you can also make a self-introduction post posted on the general discussion as an alternative for extra 5 credit points.

Your data will be kept confidential and only the research team will have access. If you have questions about this study, you can contact the University of Missouri researcher at 573-673-0672 or email minhpham@mail.missouri.edu. If you have questions about your rights as a research participant, please contact the University of Missouri Institutional Review Board (IRB) at 573-882-3181 or muresearchirb@missouri.edu. The IRB is a group of people who review research studies to make sure the rights and welfare of participants are protected. If you want to talk privately about any concerns or issues related to your participation, you may contact the Research Participant Advocacy at 888-280-5002 (a free call) or email muresearchrpa@missouri.edu.

You can ask the researcher to provide you with a copy of this consent for your records, or you can save a copy of this consent if it has already been provided to you. We appreciate your consideration to participate in this study.

By providing your full name, e-mail address, and complete the survey and submitting the agreement below, you will provide consent to participate in this study.

Please provide your first and last name.

Please provide your Mizzou email address.

APPENDIX H. PERSONAL PROFILE SURVEY

Section 1. Argumentative Scale[8]

Instructions: This questionnaire contains statements about arguing controversial issues. Indicate how often each statement is true for you personally by placing the appropriate numbers in the blank to the left of the statement. Use the following scale:

1 = almost never true

2 = rarely true

3 = occasionally true

4 = often true

5 = almost always true

1. While in an argument, I worry that the person I am arguing with will form a negative impression of me.
2. Arguing over controversial issues improves my intelligence.
3. I enjoy avoiding arguments.
4. I am energetic and enthusiastic when I argue.
5. Once I finish an argument, I promise myself that I will not get into another.
6. Arguing with a person creates more problems for me than it solves.
7. I have a pleasant, good feeling when I win a point in an argument.
8. When I finish arguing with someone, I feel nervous and upset.
9. I enjoy a good argument over a controversial issue.
10. I get an unpleasant feeling when I realize I am about to get into an argument.
11. I enjoy defending my point of view on an issue.

[8] Adopted from Infante, D. A., & Rancer, A. S. (1982). A conceptualization and measure of argumentativeness. *Journal of Personality Assessment*, *46*(1), 72-80.

12. I am happy when I keep an argument from happening.
13. I do not like to miss the opportunity to argue a controversial issue.
14. I prefer being with people who rarely disagree with me.
15. I consider an argument an exciting intellectual challenge.
16. I find myself unable to think of effective points during an argument.
17. I feel refreshed and satisfied after an argument on a controversial issue.
18. I have the ability to do well in an argument.
19. I try to avoid getting into arguments.
20. I feel excitement when I expect that a conversation, I am in is leading to an argument.

Section 2. Students' Self-Report on Problem-solving Skills[9]

Instructions. The following questions inquire how you solve a problem. Please read the following statements and select the answer that best describes the way you are when you are trying to solve an ill-structured problem as part of your class activity or class assignment. Ill-structured problems are the ones which possess multiple solutions and solution paths and contain uncertainty about which concepts, rules, and principles are necessary for the solution. There are no right answers. Please describe yourself as you are, not how you want to be or think you ought to be. Use the following scale:

1 = almost never true

2 = rarely true

3 = occasionally true

[9] Adopted from Ge, X.(2001). *Scaffolding students' problem-solving processes in an ill-structured task using QPs and peer interactions*. [Doctoral Dissertation, Pennsylvania State University]. PennState Elecronic Theses and Dissertations for Graduate School. https://etda.libraries.psu.edu/files/final_submissions/6665

4 = often true

5 = almost always true

Before you begin to solve a hard problem, what do you do, …

21. I think to myself, do I understand what the problem is asking me?
22. I try to remember if I have worked a problem like this before.
23. I think about what information I need to solve the problem.
24. I ask myself, is there information in this problem that I don't need?
25. I try to think about the constraints of the problem.

What do you do as you work the problem?

26. I list all the information available and the constraints.
27. I try to identify the critical relationships from the information given.
28. I create a picture in my head or on a piece of paper to help me understand the problem.
29. I plan all the steps as I work on the problem.
30. I keep looking back at the problem after I do a step.

What do you do after you finish working on the problem?

31. I look back at my problem-solving process to see if it makes sense.
32. I try to find evidence to justify and support my solutions.
33. I think about the solutions and see if there are alternatives.
34. I try to look at the problem solutions from different perspectives.
35. I test my solution or hypothesis by asking myself "if…what…".

In what way do you work on problems?

36. I draw a picture to help me understand the problem.

37. I develop a hypothesis first and then test it.

38. I pick up the steps I needed to do for this problem.

39. I prioritize the problems or goals and focus on the most critical one.

40. I follow a problem-solving model.

Section 3. Demographic Questions

Instructions: This section consists of demographic questions about yourself.

41. Gender: F M

42. How old are you? …..years old.

43. What is your native language?....

44. What is your current academic status? a) undergraduate b) master student c) doctoral student

45. Why do you take this class? a) It is required for my major b) I am interested in it c) Other…(please specify)

APPENDIX I. PRE-TEST ASSIGNMENT

Module 1 Discussion: Problem Scenario on Digital (Use) Divide and Beyond

A problem scenario that has multiple points of view for you to discuss as you prepare to enter a "Leadership" position as a future teacher of the next generation of young students!!

Digital (Use) Divide and Beyond

Harvey is a 11-year-old fifth grader. He is the fourth child in a family of six K-12 school age children. His school has resumed face to face education since the beginning of this academic school year (2021-2022). Academically, Harvey is failing behind his peers. His homework assignments are sometimes not completed, poorly completed, or are late. He is more successful turning in paper- based assignments rather than assignments that require use of technology (e.g., online research). He also does not participate consistently in online discussion forum boards with his peers.

Harvey has access to an iPad provided by the school and can bring it home. His parents reported that since the outbreak of the pandemic, they have been provided the Internet access for free through the school district. However, they also reported it is hard for them, timewise, to help their children use technology and deal with internet problems such as the speed, reliability of quality of internet connection.

At school, his classmates complain that Harvey contributes little to nothing when they are assigned to work together on technology-based group projects such as creating a short video clip. When allowed to use iPad to play educational games or do research projects in class, he also tends to search for content and videos related to entertainment video games instead of working on assigned activities.

Tasks:

Introduce yourself and the grade and subject you hope to teach in the future!! Then complete the two tasks below, beginning with your first post covering Task 1.

Task 1. Please answer all the following questions in your first post in the discussion. **In your post, list the question first, and then your answer immediately following the question.**

This first post (Task 1) is due THURSDAY of this week's module (module 1/week 1). The second response posting (Task 2) is due by SUNDAY night at the end of the module week (Week 1).

1. From reading the case, what are the issues that Harvey seems to be having?
2. What might be contributing to, or causing the issues Harvey is facing? Please list the most likely cause(s) and support each with justifications and evidence.
3. Imagine you were Harvey's teacher, what could you do to help Harvey? As you think about this, specify what your goal would be in any help or intervention you might provide. Please justify your solution(s) with evidence.
4. What are other potential solutions?
5. Of all the potential interventions you have identified, which do you think is best and why?

Task 2. In the following posts, please make meaningful comments on others' posts and replies to others' messages to further understand the problem and possible solutions. When possible, provide support for your posts from class readings or other sources.

Click the REPLY button below to make your post (first post by Thursday night at midnight, please). Then post replies to at least two peers' posts by Sunday night at midnight.

APPENDIX J. INTERVENTION MATERIALS

Control condition

Module 5 Discussion: Problem scenario on teacher social media presence

A problem scenario with multiple points of view for you to discuss regarding whether/how teachers should be on social media.

Teacher Social Media Presence

Jane Doe is a science teacher in a large middle school in the Midwest, USA. She loves to share every moment of her life on social media: date nights, holiday pics, etc., She also tends to like, share, or re-post controversial content on social media (e.g., climate change, gun control). Jane, however, does not post actual comments on these controversial social media posts, although she tends to 'like' contentious comments on anti-vaccination, global warming denial, LGBTQ+ hostility, etc. All her social media accounts are public.

Your tasks (please read through all the tasks before you make your first post).

Task 1. In the first post, introduce yourselves, try to get to know your partner, and post your first idea about your views on the appropriateness or inappropriateness of Jane's social media behavior and provide a justification for your position. Make your first post no later than THURSDAY of this week's module (Module 5/Week5).

Task 2. In the following posts, discuss with your partners to address the following questions:

- What are the possible causes of the behavior with the use of social media by Jane Doe. Please list the most possible cause(s) and support your hypothesis with argument and evidence.

- What do you think teachers should do to create a positive online presence on social media so that they can establish their personal brand and at the same time be viewed as a professional leader in their career? Please justify your positions with evidence and/or example.
- What else do you think teachers could do relative to creating a positive online presence? Provide a justification for your position with evidence and/or examples.
- Of all the solutions you have identified, which do you think is the best and why? Provide a justification for your position evidence and/or examples.

Task 3. Log into the course **daily** to check your partners' messages and make meaningful replies. When possible, provide support for your posts from class readings or other sources.

Task 4. For all of the posts required in this forum, label each of your posts, using one of the eight pre-defined categories of argumentation behaviors you may make during the discussion with your partners (claims, agreeing, challenging, counter-challenging, integration, elaboration, making a concession, supporting reasons). **Please restrict the content of your post to address one and only one argumentation behavior at a time.** For the detailed description of the argumentation behaviors you should use to label each of your post, click HERE.

The first post (Task 1) is due THURSDAY of this week's module (module 5/week 5).

<u>Treatment one – Question Prompts only</u>.

Module 5 Discussion: Problem scenario on teacher social media presence

A problem scenario with multiple points of view for you to discuss regarding whether/how teachers should be on social media.

Teacher Social Media Presence

Jane Doe is a science teacher in a large middle school in the Mid-West, USA. She loves to share every moment of her life on social media: date nights, holiday pics, etc., She also tends to like, share, or re-post controversial content on social media (e.g., climate change, gun control). Jane, however, does not post actual comments on these controversial social media post, although she tends to 'like' contentious comments on anti-vaccination, global warming denial, LGBTQ+ hostility etc. All her social media accounts are public.

Your tasks (please read through all the tasks before you make your first post).

Task 1. In the first post, introduce yourselves, try to get to know your partner, and post your first idea about your views on the appropriateness or inappropriateness of Jane's social media behavior and provide a justification for your position. Make your first post no later than THURSDAY of this week's module (Module 5/Week5).

Task 2. In the following posts, discuss with your partners to address the following questions:

- What are the possible causes of the behavior with the use of social media by Jane Doe. Please list the most possible cause(s) and support your hypothesis with argument and evidence.
- What do you think teachers should do to create a positive online presence on social media so that they can establish their personal brand and at the same time

be viewed as a professional leader in their career? Please justify your positions with evidence and/or example.

- What else do you think teachers could do relative to creating a positive online presence? Provide a justification for your position with evidence and/or examples.
- Of all the solutions you have identified, which do you think is the best and why? Provide a justification for your position evidence and/or examples.

Task 3. Log into the course **daily** to check your partners' messages and make meaningful replies. When possible, provide support for your posts from class readings or other sources.

Task 4. For all of the posts required in this forum, label each of your posts, using one of the eight pre-defined categories of argumentation behaviors you may make during the discussion with your partners (claims, agreeing, challenging, counter-challenging, integration, elaboration, making a concession, supporting reasons). **Please restrict the content of your post to address one and only one argumentation behavior at a time.** For the detailed description of the argumentation behaviors you should use to label each of your post, click HERE.

As you work through the problem with your partner(s), **please use the following questions to guide your posts**.

Argumentation Behavior Types and Question Prompts[10]

Claims - in your post tell your partner... 1. What is your first idea about….?(e.g. what the problem is?/ what causes the problem?/ the	**Agreeing** - if you are agreeing with your discussion partner then explain …. 4. . … In what ways do you agree with the

[10] Question prompts adapted from Oh, S., & Jonassen, D.H. (2007). Scaffolding online argumentation during problem-solving. *Journal of Computer Assisted Learning 23*(2), 95-110.

solution to the problem? 2. What do you think is …? (e.g. the problem/ problem constraints/ problem context/causes of the problem/ possible solution) 3. What are the assumptions of the problem?	argument from your partner? (e.g. assumptions of the problem/ assumptions of the causes of the problem/ proposed solution)
Challenging - if you don't agree with your partner or if you are challenging them then explain your challenge or disagreement by answering one of these questions in your post… 5. In what ways do you not agree with your partner's argument? (e.g. assumptions of the problem/ assumptions of the causes of the problem/ proposed solution) 6. What is missing information in your partner's explanation? 7. What is unclear in your partner's explanation?	**Counter-challenging -** if you don't agree with your partner's challenge, then explain your disagreement by answering this question in your post… 8. In your post tell us how you do not agree with your partner's challenge? (e.g. your assumptions of the problem/ assumptions of the causes of the problem/ proposed solution)
Integration - in your post tell your partner... 9. How have you taken into account your partner's lines of reasoning to adjust the problem diagnosis/solution? 10. What do you think is a compromise solution after considering different lines of reasoning from you and your partner?	**Elaboration** - In your post tell your partner... 11. Why do you think this is ….? (e.g. the problem/ cause of the problem/ solution) 12. What is your chain of reasoning for selecting that solution? 13. What consequences are likely to occur if that proposed solution is not adopted?
Making a concession - In your post, tell your partner... 14. In what ways/How is the different point made from your partner true?	**Supporting reasons -** Support your claim by answering one of these questions, 15. How can you support your argument (e.g. hypothesized cause, solution, value of your position)?

	16. How reliable is your evidence? 17. How relevant are your experiences? 18. What are your personal beliefs? 19. What are the research findings?

The first post (Task 1) is due THURSDAY of this week's module (module 5/week 5).

Treatment two – Question Prompts and Social Presence Enhancement Strategies.

Module 5 Discussion: Problem scenario on teacher social media presence

A problem scenario with multiple points of view for you to discuss regarding whether/how teachers should be on social media.

Teacher Social Media Presence

Jane Doe is a science teacher in a large middle school in the Mid-West, USA. She loves to share every moment of her life on social media: date nights, holiday pics, etc., She also tends to like, share, or re-post controversial content on social media (e.g., climate change, gun control). Jane, however, does not post actual comments on these controversial social media post, although she tends to 'like' contentious comments on anti-vaccination, global warming denial, LGBTQ+ hostility etc. All her social media accounts are public.

Your tasks (please read through all the tasks before you make your first post).

Task 1. In the first post, introduce yourselves, try to get to know your partner, and post your first idea about your views on the appropriateness or inappropriateness of Jane's social media behavior and provide a justification for your position. Make your first post no later than THURSDAY of this week's module (Module 5/Week5).

Task 2. In the following posts, discuss with your partners to address the following questions:

- What are the possible causes of the behavior with the use of social media by Jane Doe. Please list the most possible cause(s) and support your hypothesis with argument and evidence.
- What do you think teachers should do to create a positive online presence on social media so that they can establish their personal brand and at the same time be viewed as a professional leader in their career? Please justify your positions with evidence and/or example.
- What else do you think teachers could do relative to creating a positive online presence? Provide a justification for your position with evidence and/or examples.
- Of all the solutions you have identified, which do you think is the best and why? Provide a justification for your position evidence and/or examples.

Task 3. Log into the course **daily** to check your partners' messages and make meaningful replies. When possible, provide support for your posts from class readings or other sources.

Task 4. For all of the posts required in this forum, label each of your posts, using one of the eight pre-defined categories of argumentation behaviors you may make during the discussion with your partners (claims, agreeing, challenging, counter-challenging, integration, elaboration, making a concession, supporting reasons). **Please restrict the content of your post to address one and only one argumentation behavior at a time.** For the detailed description of the argumentation behaviors you should use to label each of your post, click HERE (Links to an external site.).

As you work through the problem with your partner(s), **please use the following questions and social presence enhancement strategies to guide your posts**.

Argumentation Behavior Types and Question Prompts[11]

Claims - in your post tell your partner... 1. What is your first idea about….?(e.g. what the problem is?/ what causes the problem?/ the solution to the problem? 2. What do you think is …? (e.g. the problem/ problem constraints/ problem context/causes of the problem/ possible solution) 3. What are the assumptions of the problem?	**Agreeing** - if you are agreeing with your discussion partner then explain …. 4. . … In what ways do you agree with the argument from your partner? (e.g. assumptions of the problem/ assumptions of the causes of the problem/ proposed solution)
Challenging - if you don't agree with your partner or if you are challenging them then explain your challenge or disagreement by answering one of these questions in your post… 5. In what ways do you not agree with your partner's argument? (e.g. assumptions of the problem/ assumptions of the causes of the problem/ proposed solution) 6. What is missing information in your partner's explanation? 7. What is unclear in your partner's explanation?	**Counter-challenging** - if you don't agree with your partner's challenge, then explain your disagreement by answering this question in your post… 8. In your post tell us how you do not agree with your partner's challenge? (e.g. your assumptions of the problem/ assumptions of the causes of the problem/ proposed solution)
Integration - in your post tell your partner... 9. How have you taken into account your partner's lines of reasoning to adjust the problem diagnosis/solution? 10. What do you think is a compromise solution	**Elaboration** - In your post tell your partner... 11. Why do you think this is ….? (e.g. the problem/ cause of the problem/ solution) 12. What is your chain of reasoning for selecting that solution?

[11] Question prompts adapted from Oh, S., & Jonassen, D.H. (2007). Scaffolding online argumentation during problem-solving. *Journal of Computer Assisted Learning 23*(2), 95-110.

after considering different lines of reasoning from you and your partner?	13. What consequences are likely to occur if that proposed solution is not adopted?
Making a concession - In your post, tell your partner... 14. In what ways/How is the different point made from your partner true?	**Supporting reasons -** Support your claim by answering one of these questions, 15. How can you support your argument (e.g. hypothesized cause, solution, value of your position)? 16. How reliable is your evidence? 17. How relevant are your experiences? 18. What are your personal beliefs? 19. What are the research findings?

Social Presence Enhancement Strategies[12]

1. Use paralanguage such as emoticons and emojis, exaggerated punctuation or spelling to express your emotions (*To insert emoticons and emojis, on a Mac, press down Ctrl + Command + spacebar; On Windows, hold down Windows key + period*).
2. Present information about yourself outside of class.
3. Express apologies and self-criticism.
4. Express the understanding of your partner's feelings.
5. Quote or reference from your partner's post.
6. Phrase any questions challenges or responses to your partner in a polite way.
7. Express compliments, appreciation or acknowledging your partner's contribution.
8. Invite agreement, sympathy or comments from your partner.

[12] Adapted from Rourke, L., Anderson, T., Garrison, D.R., & Archer, W. (1999). Assessing social presence in asynchronous text-based computer conferencing. *The Journal of Distance Education/Revue de l'ducation Distance*, *14*(2), 50-71.

9. Address your partner by name.
10. Address your group work using inclusive pronouns such as *we, us, our, group*
11. Use phatic expressions or communications that serve merely a social function such as ‘Hi there’, ‘Have a nice day’ etc.

The first post (Task 1) is due THURSDAY of this week’s module (module 5/week 5).

APPENDIX K. POST-TEST ASSIGNMENT

Module 6 Discussion: Problem scenario on cyberbullying

Cyberbullying

Alex is a 17-year-old, attending a large high school in the Midwest, USA. Alex is an outstanding student in all aspects: academics, music, and sports. At the beginning of this year, Alex came out to his family and a few of his close friends at school as gay, and slowly he has become more comfortable embracing his identity. Recently, one of his close friends outed Alex to other at school without Alex's consent and knowledge in an Instagram private chat room. Since then, these persons have started to post all kinds of untrue information about Alex relative to his identity as a gay man. One such posting that was circulated to many at the school, contained a photoshopped image of Alex that portrayed him in a degrading way. Comments made on this image were both hurtful and demeaning.

Imagine you are the Extended Educational Experiences (EEE) teacher to both Alex and your daughter and have been teaching them for three years. A few days ago, your daughter blurted out Alex's sexual orientation information, showed you all circulating social media comments and pictures about Alex, and said she was concerned about Alex and those who have been bullying him on social media, but she did not know what best to do.

Task 1. Please answer all the following questions in your first post in the discussion. The first post is due on Thursday of this week's module (Module 6/Week 6).

1. How would you describe the behavior of those that were posting this content about Alex? Acceptable? Not acceptable? Describe the behaviors as being acceptable or not and provide a justification for your position.
2. What are the possible causes of the behavior with the use of social media by Alex's schoolmates? Please list the most possible cause(s) and support your hypothesis with argument and evidence.
3. Imagine you were the teacher in this case, what do you think you could do that can address this type of use of social media? Explain what the goal would be of your actions, and justify your positions.
4. What else do you think you could do relative to this situation? What do you think is the most viable thing you could do, and why?

Task 2. In the following posts, please make meaningful comments on others' posts and replies to others' messages to further understand the problem and possible solutions. ***Click the REPLY button below to make your post (first post by Thursday night at midnight, please). Then post replies to at least two peers' posts by Sunday night at midnight.***

APPENDIX I. CODING SCHEME FOR ARGUMENTATION BEHAVIORS[13]

Argument behavior types	Description
Claims	Making conclusions or statements about the problem/ cause of the problem/problem constraints /solution(s) to the problem etc. that the author wishes the audience to believe
Agreeing	Expressing agreement with the preceding argument made by their discussion partner
Challenging	Providing a counterargument that attempt to challenge, falsify or undermine an argument made by their discussion partner
Counter-challenging	Providing a rebuttal that rebuts their partner's challenge
Integration	Integrating primary and opposing lines of reasoning, suggesting a creative solution, or illustrating exceptions or conditions based on the examination of both primary and opposing lines of reasoning made by students and their partners
Elaboration	Elaborating one's preceding argument with reasons or evidence (e.g., personal beliefs, experience, expert opinions, research findings, etc.) or asking a question seeking additional information on a preceding statement
Making a concession	Acknowledging a point from the opposition
Supporting reasons	Providing scholars' work, personal experience, individual beliefs, research findings, or data to support the claim

[13] Agreeing, challenging, counter-challenging, integration, and elaboration are argumentation behaviors adapted from Kim,B. (2009). *The effects of prompts-based argumentation scaffolds on peer-led interactive argumentation*. [Doctoral Dissertation, University of Missouri-Columbia]. MOspace. https://mospace.umsystem.edu/xmlui/bitstream/handle/10355/6858/research.pdf?sequence=3

APPENDIX M. QUESTION PROMPTS[14]

Question prompts "Something to Think About…"

As you work through the problem with your partner, please read and think about the following questions.

Claims - in your post tell your partner...

1. What is your first idea about….?(e.g., what the problem is?/ what causes the problem?/ the solution to the problem?)
2. What do you think is …? (e.g., the problem/ problem constraints/ problem context/causes of the problem/ possible solution)
3. What are the assumptions of the problem?

Agreeing - if you are agreeing with your discussion partner then explain ….

4. … In what ways do you agree with the argument from your partner? (e.g., assumptions of the problem/ assumptions of the causes of the problem/ proposed solution)

Challenging - if you don't agree with your partner or if you are challenging them then explain your challenge or disagreement by answering one of these questions in your post…

5. In what ways do you not agree with your partner's argument? (e.g., assumptions of the problem/ assumptions of the causes of the problem/ proposed solution)
6. What is missing information in your partner's explanation?
7. What is unclear in your partner's explanation?

Counter-challenging

[14] Question prompts adapted from Oh, S., & Jonassen, D.H. (2007). Scaffolding online argumentation during problem-solving. *Journal of Computer Assisted Learning* 23(2), 95-110.

8. In your post tell us why you do not agree with your partner's challenge? (e.g., your assumptions of the problem/ assumptions of the causes of the problem/ proposed solution)

Integration - in your post tell your partner...

9. How have you taken into account your partner's lines of reasoning to adjust the problem diagnosis/solution?
10. What do you think is a compromise solution after considering different lines of reasoning from you and your partner?

Elaboration - In your post tell your partner...

11. Why do you think this is ….? (e.g., the problem/ cause of the problem/ solution)
12. What is your chain of reasoning for selecting that solution?
13. What consequences are likely to occur if that proposed solution is not adopted?

Making a concession

14. How is the challenging/different point made from your partner true?

Supporting reasons

15. How can you support your argument (e.g., hypothesized cause, solution, value of your position)?
16. How reliable is your evidence?
17. How relevant are your experiences?
18. What are your personal beliefs?
19. What are the research findings?

APPENDIX N. SOCIAL PRESENCE ENHANCEMENT STRATEGIES[15]

Affective

1. Use paralanguage such as emoticons and emojis, exaggerated punctuation or spelling to express your emotions (*Note. To insert emoticons and emojis, on a Mac, press down Ctrl + Command + spacebar; On Windows, hold down Windows key + period*).
2. Present information about yourself outside of class.
3. Express apologies and self-criticism.
4. Express the understanding of your partner's feelings.

Supportive

5. Quote or reference from your partner's post.
6. Phrase any questions challenges or responses to your partner in a polite way.
7. Express compliments, appreciation or acknowledging your partner's contribution.
8. Invite agreement, sympathy or comments from your partner.

Cohesive

9. Address your partner by name
10. Address your group work using inclusive pronouns such as *we, us, our, group*
11. Use phatic expressions or communications that serve merely a social function such as 'Hi there', 'Have a nice day' etc.

[15] Adapted from Rourke, L., Anderson, T., Garrison, D.R., & Archer, W. (1999). Assessing social presence in asynchronous text-based computer conferencing. *The Journal of Distance Education/Revue de l'ducation Distance*, *14*(2), 50-71.

APPENDIX O. CODING SCHEME FOR PROBLEM-SOLVING PROCESSES[16]

Processes	Indicators
Problem representation	- Statements that define the problem. - Statements that determine the context and the nature of the problem.
Solution generation	- Statements that select or suggest solutions and elaboration on how it is/they are linked to and/or will address the cause(s) of the problem.
Justification	- Arguments to support why the solution(s) is/are selected. - Evidence to support the arguments
Solution evaluation	- Statements that describe the consequences/effectiveness/benefits/pros and cons/side effects of the proposed solution relative to all of the important causes, issues, and/or constraints. - Statements that assess the viability of alternative solutions relative to key issues and constraints associated with (the causes of) the problem.

[16] Adopted from Ge, X. (2001). *Scaffolding students' problem-solving processes in an ill-structured task using QPs and peer interactions*. [Doctoral Dissertation, Pennsylvania State University]. PennState Elecronic Theses and Dissertations for Graduate School. https://etda.libraries.psu.edu/files/final_submissions/6665

APPENDIX P. RUBRIC FOR PROBLEM-SOLVING PERFORMANCE[17]

Criteria	Ratings		
<u>Problem representation</u> The problem is clearly and completely stated, and the context and nature of the problem are identified.	Very satisfied (5 pts) The problem is clearly and completely stated and at least 3 known factors and/or constraints of the problem are identified.	Satisfied (3 pts) The problem is clearly and completely stated and 2-3 known factors and/or constraints of the problem are identified.	Not satisfied (1 pt) The problem is vaguely or incompletely stated and/or 0 – 1 known factor and/or constraints of the problem are identified.
<u>Solution generation</u> The solution is clearly and completely stated with elaboration on how it is linked to and/or will address the cause(s) of the problem.	Very satisfied (5pts) The solution is clearly and completely stated with elaboration on how it is linked to and/or will address the cause(s) of the problem.	Satisfied (3 pts) The solution is clearly and completely stated without elaboration on how it is linked to and/or will address the cause(s) of the problem.	Not satisfied (1 pt) The solution is vaguely or incompletely stated.
<u>Justification</u> Explanations are provided to support why the solution(s) is/are selected with detailed examples/evidence.	Very satisfied (5 pts) Coherent and persuasive premises are provided to explain why the solution is	Satisfied (3pts) Clear premises are provided to explain why the solution is selected without	Not satisfied (1pt) The explanations to support why the solution(s) is/are selected are missing

[17] Adopted from Ge, X. (2001). *Scaffolding students' problem-solving processes in an ill-structured task using question prompts and peer interactions*. [Doctoral Dissertation, Pennsylvania State University]. PennState Elecronic Theses and Dissertations for Graduate School. https://etda.libraries.psu.edu/files/final_submissions/6665

	selected with detailed and/or strong examples/evidence.	detailed and/or strong examples/evidence	and/or irrelevant and/or the examples/evidence are not plausible or relevant.
Solution evaluation Statements are made about the consequences/ effectiveness/ b pros or cons/ side effects of pr solution and to assess the viability of alternative solutions	Very satisfied (5pts) Coherent and persuasive statements are made about the consequences/ effectiveness/ benefits/ pros or cons/ side effects of proposed solution and to assess the viability of alternative solutions and supported with strong evidence and/or examples.	Satisfied (3pts) Clear statements are made about the consequences/ effectiveness/ benefits/ pros or cons/ side effects of proposed solution and to assess the viability of alternative solutions but are not supported with strong/relevant evidence and/or examples.	Not satisfied (1pt) Statements are made about the consequences/ effectiveness/ benefits/ pros or cons/ side effects of proposed solution and to assess the viability of alternative solutions without any supporting evidence and/or examples.

APPENDIX Q. PRE-TEST PROBLEM-SOLVING PERFORMANCE INTERRATER RELIABILITIES

	Percent Agreement	Scott's Pi	Cohen's Kappa	Krippendorff's Alpha	N Agreements	N Disagreements	N Cases	N Decisions
Problem representation	88.64	0.78	0.78	0.78	39	5	44	88
Solution generation	93.18	0.86	0.86	0.86	41	3	44	88
Justification	86.36	0.72	0.72	0.72	38	6	44	88
Solution evaluation	84.09	0.70	0.70	0.70	37	7	44	88

APPENDIX R. ARGUMENTATION BEHAVIOR INTERRATER RELIABILITIES

	Percent Agreement	Scott's Pi	Cohen's Kappa	Krippendorff's Alpha	N Agreements	N Disagreements	N Cases	N Decisions
Agree	81.82	0.76	0.76	0.76	36	8	44	88
Challenging	97.73	0.92	0.92	0.92	43	1	44	88
Claim	68.18	0.63	0.64	0.64	30	14	44	88
Concession	95.45	0.64	0.65	0.65	42	2	44	88
Counter-challenging	97.73	0.74	0.74	0.74	43	1	44	88
Elaboration	68.18	0.63	0.64	0.64	30	14	44	88
Integration	97.73	0.65	0.66	0.66	43	1	44	88
Supporting reason	90.91	0.83	0.83	0.83	40	4	44	88

APPENDIX S. PROBLEM-SOLITING PROCESS INTERRATER RELIABILITIES

	Percent Agreement	Scott's Pi	Cohen's Kappa	Krippendorff's Alpha	N Agreements	N Disagreements	N Cases	N Decisions
Problem representation	68.18	0.64	0.65	0.65	30	14	44	88
Solution generation	75.00	0.72	0.72	0.72	33	11	44	88
Justification	70.45	0.66	0.66	0.67	31	13	44	88
Solution evaluation	77.27	0.71	0.71	0.71	34	10	44	88

APPENDIX T. POST-TEST PROBLEM-SOLVING PERFORMANCE INTERRATER RELIABILITIES

	Percent Agreement	Scott's Pi	Cohen's Kappa	Krippendorff's Alpha	N Agreements	N Disagreements	N Cases	N Decisions
Problem representation	88.64	0.77	0.77	0.77	39	5	44	88
Solution generation	88.64	0.71	0.71	0.71	39	5	44	88
Justification	86.36	0.73	0.73	0.73	38	6	44	88
Solution evaluation	81.82	0.67	0.68	0.68	36	8	44	88

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VITA

Ngoc-Minh Pham was born and raised in Thai Nguyen Province, a mountainous Northeast region of Vietnam. Since childhood, she dreamt of following in her mother's footsteps and becoming a teacher. She earned her bachelor's degree in English Linguistics and an MA in the same field from Vietnam National University, Hanoi. For more than 10 years, she worked as a high school teacher for gifted students in her home country before embarking on her academic adventure in the USA.

In the spring of 2014, she attended Bowling Green State University, OH, as a TEA (Teaching Excellence and Achievement) scholar under the sponsorship of the Fulbright program. She continued her studies and pursued her M.Ed. in Comparative and Global Education at Lehigh University, PA, as a Fulbrighter under another sponsorship of the Fulbright program from fall 2014 to Spring 2016. Finally, in the spring of 2023, she completed her Ph.D. in Information Science and Learning Technologies from the University of Missouri-Columbia.

Ngoc-Minh is interested in developing methods, principles, and theories to optimize student learning, especially through the use of cutting-edge technologies in both classroom and online environments. Her research focuses on enhancing online learning experiences using methods such as learning analytics, scaffolding, problem-based learning, social presence enhancement, and advanced technologies like augmented and virtual reality.