HOW LEARNERS INTERACT AND REFLECT TOGETHER IN VR-MEDIATED GROUP LEARNING: INTERPLAY OF IMMERSED AND OBSERVED EXPERIENCES

by

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(Under the Direction of Ikseon Choi)

ABSTRACT

The use of Virtual Reality (VR) as an educational tool is gaining attention due to its potential to provide immersive and authentic learning experiences. However, most schools cannot afford to provide individual access to VR, making VR-mediated group learning a promising solution for those with limited access to educational resources. Despite its potential benefits, there is a lack of research on the characteristics and group dynamics of this type of learning environment.

To address this research gap, this qualitative case study investigated how learners with different roles (Performer in VR vs. Observer without direct access to VR) experience, reflect, and learn together in immersive VR-mediated group learning. The study involved forty-five students divided into nine groups who learned with an immersive VR-based pedestrian safety education program. An inductive data analysis approach was used to analyze the experiences, group reflection, and learning results of both the Performer and Observer roles.

The study identified unique behaviors of the two roles and found that both were mentally immersed and cognitively engaged in solving problems in the VR program, albeit with different approaches to enact their thoughts. Additionally, the immersive VR-mediated group learning

space that combined the virtual and physical environments emerged from the data analysis to explain how the two roles construct their individual and collective experiences in the group setting. Furthermore, this study revealed a four-stage guided group reflection model to explain how the Performer and Observer reflect on their unique and shared experiences with the guidance of the Facilitator. The study also provided critical findings that could inform future research and practice in VR-mediated group learning and reflection.

The study found that both the Performer and Observer roles achieved similar learning results regarding their knowledge and behavior acquisition after the group learning. Both roles reported general satisfaction with their group learning experience, particularly with their shared recognition of the group reflection. In summary, this study sheds light on the interplay between immersed and observed experiences in immersive VR-mediated group learning and provides insights into the future research and practice of this learning environment.

INDEX WORDS: Immersive Virtual Reality, VR-mediated group learning, Group reflection, Group learning, Immersed experience, Observed experience, Case study

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DEDICATION

I dedicate this dissertation to my beloved family: Xian-Cui Wang, Kai-Yong Yang, Jun-Hui Yang, Xiao-Lei Huang, and Ivy Yang Huang. Your unwavering love, encouragement, and faith in me have been the driving force behind my success throughout this journey, and I could not have accomplished this without you. Thank you for being my pillars of strength.

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CHAPTER 1

INTRODUCTION

Background

Learning through concrete experiences is essential for students' meaning-making and construction of knowledge (Dewey, 1938; Kolb, 1984), especially for children when their abstract thinking and reasoning are not well-developed (Piaget & Inhelder, 1972). Therefore, Virtual Reality (VR) is gaining attention as a promising educational technology for providing authentic and immersive learning experiences that would not be possible due to distance, cost, safety, and disabilities (Makransky & Petersen, 2021; Matovu et al., 2023; Radianti et al., 2020). Specifically, immersive VR uses high-fidelity displays and interactive equipment to generate a three-dimensional (3D) virtual world in which students can freely navigate, manipulate virtual objects, and socially interact with other users (Shi et al., 2022; Suh & Prophet, 2018). Accordingly, students experience a high degree of immersion in a designed digital world, which leads to a sense of "being" in VR (Slater, 2017). Meanwhile, interacting with the virtual environment gives students the agency to construct meanings through concrete experiences (Makransky & Petersen, 2021). These affordances provide psychological learning experiences that cannot be obtained in formal education (Winn, 1993), such as presence, motivation, cognitive benefits, control and active learning, and reflective thinking (Ai-Lim Lee et al., 2010; Dalgarno & Lee, 2010; Makransky et al., 2019).

Despite the growing popularity of VR-based learning in research studies (Cao et al., 2023; Hamilton et al., 2021; Luo et al., 2021a), most schools cannot afford universal access to

immersive VR due to the cost of the technology (Maas & Hughes, 2020). Therefore, designing a learning environment where students can learn with limited resources becomes a practical solution. Meanwhile, social cognitive theory justifies the group learning setting in which one student simulates in VR and others observe their behaviors and consequences in VR (Bandura, 1986). In addition, experimental studies revealed the possibility of designing a group learning environment in which observational learning achieves a similar effect as immersive learning. For example, Luo et al. (2021b) compared children's learning with immersive and observed VR experiences and found that observed experiences had equal effects as first-person VR simulation when guided reflection was provided. Accordingly, VR-mediated group learning in which students observe and reflect on one member's simulation has the potential to benefit the group with limited access to educational resources.

Problem Statement

VR-mediated group learning creates a unique learning environment in which some students experience first-person immersion in VR while others observe in real-time. These students can interact and collaborate in a shared physical space, allowing those without access to VR equipment to participate by requesting specific actions from those who are immersed in VR. As a result, students could both obtain authentic learning experiences with limited access to technology in the group setting. However, the co-existence of VR and observed experiences fosters a unique learning space for social interaction and group collaboration. Despite the potential benefits of VR-mediated group learning, there is a lack of research on its characteristics and mechanisms.

While previous studies have explored the effectiveness of VR in individual learning contexts (Luo et al., 2020; Makransky et al., 2019), fewer have examined its application in group

settings (Monahan et al., 2008), especially for group learning in which students have different access to VR. Given the affordances and limitations of VR within group learning, it is important to investigate the social dynamics and interactions empirically. Additionally, the co-existence of virtual and physical spaces adds another layer of complexity to understanding group interactions and collaboration in this context. Therefore, the findings of VR-mediated education in individual learning contexts may not apply to group settings. There is a need to empirically investigate VR-mediated group learning to examine the characteristics, mechanisms, and potential challenges of such a learning environment.

Purpose of the Study

This study aims to investigate students' group learning with limited access to a VR-based pedestrian safety education program (SAVE Group, 2019). The group experiences the VR program with one student simulating pedestrian behaviors in a virtual city, and others observe in real-time with a projected display. Accordingly, the group is divided into two roles: the Performer in VR and the Observer without direct access to VR. Given the different divisions of labor and access to VR, the study aims to explore how learners with different roles (Performer vs. Observer) experience, reflect and learn together to construct meanings and knowledge. Specifically, this study examines (a) how different roles (Performer vs. Observer) influence students' learning experiences, (b) the interplay of immersed and observed experience in group reflection and learning, and (c) the research implications and practical challenges of such a group learning environment. The findings of this study are expected to contribute to both the theoretical understanding of VR-mediated group learning and the practical application of related group learning activities.

Research Questions

Based on the purposes of the study, this study addresses the following research questions:

1. How do learners with different roles (Performer vs. Observer) experience during the simulation of VR-mediated group learning? What are the similarities and differences in their experiences?
2. How do learners with different roles (Performer vs. Observer) reflect together on their experiences of the VR simulation?
3. How do learners with different roles (Performer vs. Observer) differ in their learning outcomes?

Significance of the Study

This research has the potential to contribute to the theoretical understanding and practical application of VR-based learning in group settings. Specifically, the study focuses on VR-mediated group learning in which students construct meaning based on one member's simulation in VR. The findings of this study could provide insights into the understanding of social interactions and group dynamics in VR-mediated group learning in which immersed and observed experiences co-exist. Moreover, this study offers an example of addressing limited educational resources in technology-supported group learning (e.g., access to immersive VR). Exploring the implications and challenges within such a group learning environment is crucial for designing practical activities that can optimize learning resources and benefit a wide range of students. Therefore, the results of this study have the potential to inform instructional design and practice in the context of group learning with limited resources, such as access to VR.

Definitions of Key Concepts and Terms

Virtual Reality (VR) is defined as a computer-generated environment that can simulate

users' experiences in the real world (Freina & Ott, 2015). By using special electronic equipment such as the computer and head-mounted displays (HMDs), the users are immersed in a virtual environment where they can manipulate and interact with the virtual objects to obtain a real-time action-based perception. In general, immersive and non-immersive VR are differentiated regarding the levels of immersion and interactivity they provide.

Immersive VR refers to the type of VR that disconnects users from the physical world and offers high levels of immersion and interactivity within the virtual environment (Hamilton et al., 2021; Luo et al., 2021a). Immersive VR provides 360-degree visuals through devices such as head-mounted displays (HMDs) (e.g., Oculus Rift, HTC Vive); it has auditory stimulation through earphones and offers user interactivity by controlling and tracking systems (Freina & Ott, 2015). Through the use of images, sounds, and other stimuli, immersive VR simulates a perceptually convincing environment in which users feel "being present."

VR-mediated group learning refers to a group learning setting where VR is used for simulation and promoting group experiential learning. In this study, the term indicates the group setting where one learner simulates in VR, and others observe their behaviors and related consequences in the virtual world. Accordingly, the group has two different roles: the learner simulating in VR acts as the Performer who obtains first-person experiences in VR. Others are Observers who obtain real-time observational learning experiences.

Immersed experience indicates the experiences one gets from directly interacting with the virtual environment. In this study, the learner obtains immersed experiences through a VR-based pedestrian safety education program supported by Oculus Rift. The learner immersed in the program needs to wear a headset with a head-mounted display, a set of on-ear headphones, and both-hand touch controllers to interact with the virtual world. Therefore, the learner can obtain

highly immersive and interactive experiences in VR and may feel disconnected from the physical world.

Observed experience indicates the experiences one gets from observing others' behaviors and related consequences in the environment. In this study, observed experience happens especially for learners who do not simulate in VR, and they need to observe the Performer's behaviors and what happens in the virtual environment.

CHAPTER 2

LITERATURE REVIEW

The literature review is divided into three main sections. The initial section reviews the literature on immersive VR-mediated learning, analyzing the affordances, concerns, and effectiveness of immersive VR in education. Meanwhile, the application of VR in group settings is discussed regarding its empirical findings and theoretical perspectives. In the second section, the literature review focuses on group reflection. A ten-year (2010-2020) systematic review of group reflective practices in educational settings is conducted to explore the theoretical foundation and current practices of group reflection. A three-dimensional conceptual framework for group reflection research is proposed to inform related research and practice.[1] The final section of the literature review examines the application of reflection in simulation-based learning, with a particular emphasis on group learning environments. Accordingly, it reviews the application of reflection in VR-mediated group learning.

Immersive VR-Mediated Learning

Two foundational features distinguish immersive VR from other media in education: it provides learners with high levels of immersion and interactivity regarding their relations toward the learning content (Cummings & Bailenson, 2016; Makransky & Petersen, 2021; Slater, 2017). Specifically, immersive VR provides a high level of immersion through high-fidelity displays and body tracking systems (Hamilton et al., 2020; Matovu et al., 2023). Meanwhile, different

[1] The second section of the literature review is an independent manuscript, which has been revised and published by the Journal of Educational Technology Research and Development. Yang, T. & Choi, I. (2022). Reflection as a social phenomenon: A conceptual framework toward group reflection research. *Educational Technology Research and Development*. https://doi.org/10.1007/s11423-022-10164-2

controlling devices allow users to interact with the virtual environment, which offers a high degree of agency and autonomy (Cao et al., 2023; Southgate et al., 2019). Thus, the combination of immersive perception and learner interactivity creates a particular psychological experience with a sense of presence and agency in the virtual environment (Fowler, 2015; Shi et al., 2022). Accordingly, immersive VR presents an opportunity to explore new educational possibilities (Häfner et al., 2018). For example, this technology enables students to learn by directly experiencing environments or situations that are typically inaccessible in traditional education (Hamilton et al., 2021; Luo et al., 2020).

The Affordances of Immersive VR

Based on the unique characteristics of immersive VR, the existing literature has identified several benefits of applying VR in education. First, immersive VR changes the potential relationships between learning and experience. For example, immersive VR allows repeated practice in safe environments to prepare students for real-time situations (Kamińska et al., 2019; Slater, 2017). Second, immersive VR supports a constructivist learning approach, allowing learners to construct their knowledge actively and meaning-making through experimentation and reflection (Chen, 2009; Luo et al., 2021b). Third, immersive VR provides a safe environment to examine learners' knowledge and skills that would be too difficult or dangerous to perform in real life (Luo et al., 2020). Last, immersive VR has the potential to increase students' motivation and engagement (Hu-Au & Lee, 2017; Martín-Gutiérrez et al., 2017).

Despite the benefits, there are some concerns regarding the application of immersive VR in education. For example, Parong and Mayer (2021) suggested that features of VR may cause cognitive or attractive distractions, thereby disrupting learning processes. They conducted a media comparison study and found that students in immersive VR had poorer learning outcomes

than those in desktop environments due to extraneous cognitive load and emotional arousal. In addition, Hamilton et al. (2021) found that the novelty of immersive VR may impede the user's learning experience, especially when learners are unfamiliar with the new technology. Meanwhile, some researchers have summarized the challenges of applying VR in education. For example, Kavanagh et al. (2017) identified ten potential issues hindering the widespread use of VR in education, including a lack of training, high costs, insufficient realism, and perceived ineffectiveness. Luo et al. (2021a) further indicated that the common technological problems (e.g., system glitches, safety hazards, and physical discomfort) and the high costs hindered sustainable and large-scale VR adoption in education.

The Effectiveness of Immersive VR

As immersive VR becomes popular in education, it is essential to understand how it affects learning outcomes and the underlying cognitive and affective processes. Several systematic literature reviews have examined the effectiveness of immersive VR with existing experimental studies. For example, Jensen and Konradsen (2018) reviewed 21 experimental studies investigating HMDs in education and training. The finding suggested that immersive VR was only useful for specific skill acquisition, such as cognitive skills related to spatial and visual knowledge, psychomotor skills related to head movement, and affective skills related to controlling emotional responses to difficult situations. After that, immersive VR showed no added value in some studies and was distracted from the learning task in some cases. Similarly, Hamilton et al. (2021) examined 29 experimental studies that compared immersive VR with other pedagogical methods, such as desktop computers. The review found that most studies revealed a significant advantage of using immersive VR, while most experimental studies used short interventions and did not examine information retention.

Luo et al. (2021a) reviewed 20 years of empirical research on VR applications in K-12 and higher education. They found that highly immersive VR did not induce superior learning outcomes compared to less immersive VR. The authors suggested that immersive VR provides unique affordances while the instructional design makes the technology beneficial to learning. Overall, experimental studies revealed that immersive VR could enhance learning in certain learning domains, such as abstract concepts and authentic problem-solving (e.g., Sattar et al., 2020; Schwebel et al., 2018). However, the features of immersive VR can also create a cognitive or affective distraction from learning if not used appropriately (Parong & Mayer, 2021). Notably, educational interventions such as guided reflection were identified as critical for the effectiveness of VR-based learning activities (e.g., Luo et al., 2021b).

VR-Mediated Group Learning

In a group learning environment, immersive VR is typically used in two distinct settings. The first setting involves a multi-user immersive VR system that allows collective experiences in a large virtual environment (Lorenzo et al., 2012; Podkosova et al., 2016; Kuchera-Morin et al., 2014). The advantage of such a group setting is that the system enables multiple users to simulate and collaborate in one virtual world, which enhances the shared presence, enjoyment, and social interaction experienced by the group (Park et al., 2019). However, such a group learning system requires costly equipment and program development, which is currently not feasible for universal education.

Another group setting involves a few members in immersive VR while others observe the process from a third-person view. This creates a hybrid space where the group can enjoy the VR simulation together while being located on the same world physical site (Lee et al., 2020). However, such a group setting raises concerns about equity and equal access to the learning

content, such as the VR-based educational program. As the group members have varying degrees of immersion and interactivity with the learning content, there is a risk that they may not obtain the same educational benefits. For example, Jang et al. (2017) compared medical students who directly manipulated a virtual anatomical structure to those who only viewed the interaction in a three-dimensional environment. The study found that students who directly manipulated virtual structures performed better on the posttest than students who only viewed these structures passively. The authors suggested that direct manipulation of the virtual environment facilitated embodied cognition and helped maintain a clear frame of reference.

Social cognitive theory supports group learning in which some students observe peers' behaviors and related consequences (Bandura, 1986). Accordingly, observers could obtain equal learning outcomes compared to those who have first-person experiences in VR. To examine the role of experiences in VR-based education, Luo et al. (2021b) compared children's learning with an immersive VR program. The study found no significant difference between children who had direct experiences in individual VR-based learning and those who observed VR learning experiences in groups. Instead, the study suggested that students can benefit from observed VR learning experiences if an instructional component of debriefing is provided.

Overall, there is a dearth of research on VR-mediated group learning, particularly in light of the practical issue of limited access to immersive VR in most schools (Maas & Hughes, 2020). Thus, it is crucial to investigate the characteristics and mechanisms of such a learning environment to inform instructional design and practices and maximize the potential benefits of immersive VR in education.

Theoretical Perspectives of VR-Mediated Group Learning

Learning theories serve as the underlying framework and basis for designing and

implementing educational interventions (Pritchard 2017; Schunk 2012). Consequently, it is crucial to ground the use of immersive VR in well-established learning theories to understand its affordances and characteristics, particularly in group settings. However, systematic reviews revealed that few experimental studies explicitly mentioned learning theory to support VR activities (Hamilton et al., 2021; Luo et al., 2021a; Radianti et al., 2020), resulting in a limited understanding of VR-mediated learning. Therefore, this session will explore the theoretical perspectives concerning the application of immersive VR in group learning.

Constructivism. Constructivism provides a valid and reliable foundation for VR-based learning (Winn, 1993). Constructivism is an epistemology or a philosophical perspective about the nature of learning. The basic argument is that individuals actively construct knowledge and understanding on experiences (Spector, 2015). Hernandez-Serrano, Choi, and Jonassen (2000) claim that constructivism combines several theories, including socially shared cognition, situated learning, distributed cognition, everyday reasoning, ecological psychology, case-based reasoning, and Deweyan pragmatism. Three assumptions of constructivism can be identified (Hernandez-Serrano et al., 2000; Spector, 2015), including (a) learning is essentially a process of meaning-making, (b) learning is inherently a social and a dialogical process, it is most natural and effectively done with peers and others, and (c) knowledge and cognition are distributed among the culture and history of their existence and is also mediated by the tools they use.

According to constructivism, knowledge is constructed through experiences and active meaning-making. Immersion in a virtual world allows learners to construct knowledge from direct experience instead of abstract descriptions. Meanwhile, constructivism emphasizes the critical role of social interactions. A shared experience by observing others' experiences is also a unique learning experience for learners in the group. Furthermore, constructivists believe that

meaning-making includes reciprocal intention-action-reflection cycles. Reflection on the experience is as essential as experience to meaningful learning. Accordingly, these claims from constructivist theory justify VR-mediated group learning where the interplay between immersed and observed experiences has the potential to enhance meaningful learning in group settings.

Experiential Learning Theory. The most used learning theory to justify VR-mediated learning is experiential learning theory (Luo et al., 2021b; Radianti et al., 2020). Experiential learning theory defines learning as "the process whereby knowledge is created through the transformation of experience" (Kolb, 1984, p. 41), which places experiences at the center of the learning process. According to experiential learning theory (Kolb, 1984; Kolb & Kolb, 2012), there are two modes of experience: concrete experience and abstract conceptualization. Accordingly, there are two related modes of transforming experiences: reflective observation and active experimentation. Furthermore, it suggests that learning happens by cycling through the four steps of concrete experience, reflective observation, abstract conceptualization, and active experimentation (Kolb, 1984; Kolb et al., 2001). In addition, the experiential learning theory is founded on the constructivist views of learning. For example, it suggests that learning should be drawn from a learner's personal experience, and the teacher takes on the role of a facilitator to motivate learners to address the various stages of the learning cycle (Kolb, 1984).

Experiential learning theory can be used as a theoretical foundation for VR-mediated learning. Specifically, immersive VR generates a simulation-based environment where learners can interact with the virtual world to obtain first-person experiences and experimentation (Kwon, 2019). Meanwhile, reflection as a critical activity is often included in VR-based instruction (e.g., Luo et al., 2020). Several studies have applied experiential learning theory as the theoretical framework for VR-based education. For example, Jarmon et al. (2009) found that a significant

level of experiential learning occurred in the 3D virtual world environment. The authors suggested that educators use VR by creating experiential instructional designs to help students work on real-world projects.

In addition, Choi et al. (2019) and Luo et al. (2021b) synthesized four principles for designing VR-based instruction based on experiential learning theory, including (a) designing authentic learning tasks that reflect the richness and complexity of real-world problems; (b) creating situational challenges with critical moments that require learners to make decisions; (c) enabling learners with the ownership of the process to develop and test solutions; (d) providing opportunities for and support reflection on the instructional content and the learning process.

Social Cognitive Theory. The social cognitive theory posits that learning occurs in a social context with dynamic and reciprocal interactions of the person, environment, and behavior (Bandura, 1986). Therefore, the theory emphasizes the importance of social factors in human behaviors and learning. Meanwhile, social cognitive theory suggests that learning occurs through direct experience or observing others' behaviors and consequences (Bandura, 1986). It suggests that humans have the vicarious capability to learn from observing others' experiences. Unlike learning by doing, which requires altering individuals' behaviors through repeated trial-and-error experiences, a single model can transmit new behaviors to many people in observational learning. In addition, social cognitive theory suggests that self-reflection is a distinctive characteristic of humans, which enables people to analyze their experiences and gain understanding (Bandura, 1986; Bandura, 2004).

Social cognitive theory depicts the dynamic influence of environmental and social factors on individual behaviors, justifying VR-mediated group learning where students learn through observing one member's simulation. In such group settings, students simulate in VR get first-

person experiences by directly interacting with the virtual environment. Meanwhile, those who observe the simulations can learn through others' behaviors and related consequences in VR. Importantly, humans have the self-reflective capability to analyze their experiences and negotiate meanings in the group setting. Therefore, VR-mediated group learning has the potential to benefit the group with limited access to educational resources.

Comparison between Immersed and Observed Experiences. There are two distinct roles in VR-mediated group learning: the Performer who is immersed in VR and the Observer who is physically present in the real world. Consequently, these two roles may result in two different learning experiences, each with its own unique characteristics. Table 2.1 summarizes the features of these two experiences. The Performer in VR has a high level of immersion and agency to directly interact with the virtual world, allowing them to construct their experiences actively. However, the Performer's immersion in VR can disconnect them from physical reality, limiting their participation in the group experience. In contrast, the Observer gets information from observing the Performer's actions and related consequences in VR. Although they have no control over VR, they can still influence the virtual world by directing the Performer to manipulate virtual objects. Additionally, the Observer has the advantage of being physically present, allowing them to engage in communication and interaction with other observers and the Performer.

Table 2.1

Features of Two Different Roles in VR-mediated Observational Learning

Features	**Performer (Immersed experience)**	**Observer (Observed experience)**
Level of immersion	Fully immersed in VR	Partial immersed in VR

Level of interactivity	Direct interaction with the virtual world; Indirect social interaction with others.	Direct social interaction with others; Indirect interaction with the VR (through the Performer).
Characteristics	Direct control in VR; Disconnect with the physical world; Potential cognitive or affective distraction from others	No control in VR; Access to information from both the virtual and physical worlds; Interact with the Performer and other Observers.
Theoretical support	Experiential learning theory Embodied cognition	Social cognitive learning
Interplay	Constructivism (distributed cognition, situated cognition, reflection)	

Based on characteristics of immersed and observed experiences, different learning perspectives support their unique learning opportunities. The experiential learning theory emphasizes the importance of direct experiences (Kolb, 1984; Kolb et al., 2001). Meanwhile, embodied cognition holds that cognitive processes are deeply rooted in the body's interactions with the environment justifies the Performer's learning experience (Wilson, 2002). In contrast, social cognitive theory suggests that all learning resulting from direct experience can occur vicariously by observing others' behavior and its consequences for them (Bandura, 1986). As a result, observed experiences could lead to the same learning result as direct experiences. For the interplay between immersed and observed experiences, constructivism suggests that learning occurs through actively constructing meanings with others within the social context. Therefore, the group can make meanings from their experiences to construct knowledge and understanding together.

A Conceptual Framework Toward Group Reflection Research[2]

Introduction

Dewey (1933) defined reflection as "active, persistent, and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and the further conclusions to which it tends" (p. 9). Reflection has been recognized as a type of human thinking crucial for individual learning and development (Boud et al., 1985; Dewey, 1933; Schőn, 1983). However, it is not sufficient to understand reflection as an individual meaning-making process without considering its social characteristics (Høyrup, 2004; Jay & Johnson, 2002; Reynolds & Vince, 2017). As implied in Dewey's definition, reflection is grounded in one's experiences that are most likely situated in specific social and cultural contexts. Human existence as social beings determines the influence of sociocultural factors on individuals' thoughts, reactions to stimuli, and meaning-making (Vygotsky, 1978). Therefore, we cannot neglect the social influence on reflection to explore its nature as a critical type of human thinking and expand its practical application.

We believe there are at least three reasons to explain why reflection has been conventionally investigated as an individual practice. First, research on reflection is rooted in a long history of analyzing cognition as an individual activity. The theoretical orientation on individual constructivism created a bias that reflection was a self-based practice that happens in solitary, such as contemplation (Hart, 2004; Stewart, 2011), meditation (Austin, 2010; Yun et al., 2020), and reflective writing (Furman et al., 2008; Wear et al., 2012). Second, reflection could be considered an "inherently individual and ipsative process" (Boyd & Fales, 1983, p. 102) due to

[2] Yang, T. & Choi, I. (2022). Reflection as a social phenomenon: A conceptual framework toward group reflection research. *Educational Technology Research and Development*. https://doi.org/10.1007/s11423-022-10164-2

its fundamental feature: reflection is grounded in personal experiences (Dewey, 1933; Rogers, 2001). This feature implies the self as the source of meaning-making (Boyd & Fales, 1983) while easily neglecting others' influence on one's thoughts. Lastly, since reflection often needs affective and cognitive engagement (Boud et al., 1985), the involvement of critical examination of feelings and beliefs may cause reflection in privacy rather than in public (Raelin, 2002).

However, there has been a trend of examining learning and cognition as social phenomena with the theoretical development of sociocultural perspectives (Vygotsky, 1978), social cognitive theory (Bandura, 1986), and situated cognition (Brown et al., 1989). As the social dimension of learning reveals its importance in both research and practice (Dillenbourg, 1999; Laal & Ghodsi, 2012; Rosenthal & Zimmerman, 2014), it is evident that considering reflection as an individual practice limits its theoretical development and practical application. In addition, we can find that practice has expanded from individual to social activities by examining diverse reflective practices across disciplines (Fleck & Fitzpatrick, 2010; Moon, 2004; Reynolds, 2017). For example, studies revealed reflection at the interpersonal level, such as reflective dialogues (Alvarado Gutiérrez et al., 2019; Yang, 2009), shared journal writing (Elhussain & Khojah, 2020), and collective reflection in online settings (Chen et al., 2020).

Although the social dimension of reflection is acknowledged in practices, there is a lack of systematic investigations on reflective practices in social contexts. Therefore, this article attempts to propose a conceptual framework to promote consistent and coherent research on group reflection. We first revisit reflective practices and legitimatize group reflection as an important form of reflection that received less attention than individual practice. Then, we conduct a systematic review to examine the recent educational studies, proving the claim that the characteristics and mechanism of group reflection were under-researched (Veen & de la Croix,

2017). In addition, we extract critical features of group reflection from our literature review to examine how different individuals reflect together within the group. Accordingly, we propose a conceptual framework with the key features (group composition and guidance on the practice) to serve as a common ground for future research on group reflection. Next, we illustrate how to apply the conceptual framework in three research areas with specific examples of research questions. Lastly, we discuss the study's implications for further research beyond the conceptual framework.

Reflective Practices Revisited

Different Theoretical Frames of Reflection

Reflection is generally defined as a meaning-making process to settle disequilibrium with one's experiences (Dewey, 1933; Rodgers, 2002). As a natural and particular way of thinking, reflection has been practiced, yet differently, across disciplines (Boud et al., 1985; Moon, 2004; Schőn, 1983). For example, at least three theoretical frames had been identified from different practices. The first lens regards reflection as an epistemology of practice, emphasizing reflective practices for meaning-making from experiences (Moon, 2004; Rodgers, 2002). Research in learning and professional development generally uses this theoretical frame to practice reflection (Boyd & Fales, 1983; Schön, 1987; Thompson & Pascal, 2012). The second lens views reflection as critical social inquiry, and the practice aims at critically examining one's assumptions, presuppositions, or dominant beliefs in the broader historical, social, and political contexts (Mezirow, 1981, 1991, 1998; Reynolds, 1998). Studies on perspective transformation mainly use this theoretical frame to practice reflection (Høyrup, 2004; Kember et al., 2008). The third lens emphasizes reflection as unique thinking necessary for humanity, which defines reflection as spontaneous practices ensuring the continuity of learning and living (Confucius, 500 BC; Dewey,

1933). Studies with such a philosophical standing consider reflective practices one force for individual and social progress (Clarà, 2015; Zhu, 1992).

Accordingly, reflective practices can lead to different results with different theoretical frames, such as knowledge/meaning construction for practical application (from epistemology frame), (re)examination of personal positions and identities (from critical social inquiry frame), or analysis of personal thoughts and feelings (from humanity frame). Despite theoretical lenses, reflective practices aim to evolve ideas and construct personal experiences (Atkins & Murphy, 1993; Finlay, 2008; Rogers, 2001). However, the outcome of practices varies regarding the level of reflection (Hatton & Smith, 1995; Hong & Choi, 2015; Lee, 2005). Research suggests the level of reflection is a continuum from describing one's experiences to critically examining personal positions and assumptions in a specific society (Fleck & Fitzpatrick, 2010; Jay & Johnson, 2002; Valli, 1997). Notably, reflective practices can be guided to achieve better outcomes. Different strategies have been used to support reflection successfully, such as prompts and guidelines (Chen et al., 2009; Davis, 2003; Grossman, 2009).

Common Characteristics of Reflection

Although reflective practices are enacted differently to satisfy various needs from multiple theoretical frames (Fleck & Fitzpatrick, 2010; Reynolds, 2017; Rogers, 2001), we believe it is possible to recognize common characteristics of reflection across the different practices. Among many (e.g., process, timing, level), we identify the following three characteristics to portray reflections.

Object of Reflection (introspection vs. extrospection). Since reflection is grounded in experiences (Dewey, 1933), the thinking process is rooted in one's interactions with the world (Finlay, 2008), one's emotions and thoughts attached to experiences (Boud et al., 1985), and

their premises, beliefs, and values situated in contexts (Jay & Johnson, 2002; Mezirow, 1981). Accordingly, the object of reflection can be categorized as a continuum from introspective to extrospective considerations (Hong & Choi, 2011). While introspection examines oneself as the object of reflection (Arndt et al., 2020; Hixon & Swann, 1993), extrospection focuses on objects of reflection from factors outside of oneself, such as the environment, social contexts, and others' roles (Valsiner, 2017).

Form of Reflection (implicitly vs. explicitly). The flexibility of reflection as a type of thinking enables various forms of practice. Depending on the expression of the thinking process, reflection can be enacted in an implicit or explicit form of practice. The implicit form of reflection does not express thinking processes with activities such as contemplation (Hart, 2004; Stewart, 2011) and Zen meditation (Austin, 2010; Tremmel, 1993; Yun et al., 2020). In contrast, the explicit form of reflective practice reveals the reflection processes with evident actions such as journal writing (Furman et al., 2008; Spalding & Wilson, 2002) and discussion (Foong et al., 2018b; Layen & Hattingh, 2020).

Practice of Reflection (individually vs. collectively). Reflection happens in different social environments depending on whether one reflects by themselves or with others. Self-reflection has been practiced widely as essential for individual learning and professional development (Hong & Choi, 2011, 2019; Ng et al., 2015; Schőn, 1983). In distinction to self-reflection, reflection in interpersonal contexts requires social interactions to resolve disequilibrium, construct meanings, and attain understandings from experiences (AguirreGarzón, 2018; Cord & Clements, 2010; Hong et al., 2019). Accordingly, self-reflection can be practiced in either implicit or explicit activities by oneself (e.g., meditation and journaling), while group reflection requires explicit thinking processes because people need to exchange perspectives for

constructing meanings together.

Significance of Group Reflection

Among the diverse reflective practices recognized above, group reflection rooted in social learning theories has received less attention than individual reflective practices (Johnson & Fells, 2017; Veen & de la Croix, 2017). Compared to the implicit thinking process directed by an individual, group reflection implies explicit reflection processes in social contexts, which requires more research to investigate how two or more people reflect together to achieve certain results (Raelin, 2002; Reynolds & Vince, 2017). In educational settings, the notion of group reflection is based on group learning, which is characterized by collaborative problem solving, displaying multiple roles, confronting ineffective strategies and misconceptions, and providing collaborative work skills (Brown et al., 1989). The features of reflection added to the characteristics of group learning contribute to a unique group activity of group reflection. To obtain a general understanding of the current exploration of group reflection, we first examine the theoretical importance of group reflection and then conduct a systematic review from 2010 to 2020 to examine its current research and practice in education.

From four theoretical perspectives, we argue the significance of reflective practices in group settings. First, group environments offer more opportunities for reflection than individual settings. A group includes individuals with different experiences, knowledge, and perspectives, which broaden collective experiences and meaning-making (Johnson & Johnson, 1999). Group reflection enlarges individuals' chance to reflect on the experience that might be dismissed as unimportant to themselves alone (Rodgers, 2002). Meanwhile, comparing oneself and others increases the chance of encountering surprising moments that trigger reflection (Dewey, 1933; Schön, 1983). For example, one can only recognize their misconceptions when they are exposed

to multiple and contradictory perspectives (Brown & Palincsar, 1989). Additionally, group reflection is more likely to arouse self-awareness of one's egocentric thoughts compared to solitary reflection (Eshuis et al., 2019; Peel & Shortland, 2004).

Second, group reflection, especially when guided by teachers or facilitators, has great potential to assist individuals in achieving what they cannot achieve by themselves alone (Vygotsky, 1978). According to Vygotsky's sociocultural perspective, learning occurs when children are exposed to the zones of proximal development, where children try to solve problems beyond their development level with others' help. Group reflection is grounded in the collective experiences and joint efforts of a group of people, which provides a better basis for reflection (Eshuis et al., 2019). Social interaction with more capable others is likely to enable individuals to construct deep and comprehensive meanings that they cannot achieve by themself (Smit & Tremethick, 2017; Yukawa, 2006).

Third, social environments can promote engagement and motivation in reflective practice. According to social constructivism and sociocultural theory, social interaction is an inextricable part of learning (Bandura, 1986; Vygotsky, 1978). The presence of others motivates individuals to clarify confusion, identify questions, and reach significant insights (Foong et al., 2018b; Knights, 1985), ultimately impacting students' engagement in social discourse and interaction (AguirreGarzón, 2018; Lin et al., 2013; Webb, 1982). Accordingly, group reflection is grounded in social experiences where others' involvement might promote individuals' motivation and engagement in practice.

Finally, group reflection has long-term social effects compared to solitary reflection (Castle et al., 1995). Reflection in a community provides social support for individuals' development in a specific cultural context. Wadsworth (1996) indicated that "each child is asked

by its culture to adapt not only to the developmental demands of life, but also to the expectations of the culture." (p. 147). Reflection in groups deepens individuals' understanding of their social norms and cultural values. Meanwhile, sharing experiences and reflecting within a community highlights the importance of trust, which builds a solid emotional base to support ongoing and continuous social learning processes (Peel & Shortland, 2004).

A Systematic Review of Group Reflection Studies in Education from 2010 to 2020

Along with the significance of reflection in group settings, we conducted a systematic review to examine the recent research on group reflection in educational settings. The aims are to identify research gaps and implications in current studies. Besides essential evaluations of the current studies on group reflection, including its definition, supporting theories, and activities in studies, we asked two questions to search for insights from existing research: Compared to self-reflection, what unique features of group reflection were revealed in empirical studies? What implications could be drawn from the review findings?

We searched studies on group reflective practices from the SSCI, APA PsycInfo, Educational research complete, and ERIC databases. Two clusters of key phrases were used for the initial search in the selected databases, including the signifiers of reflection and group settings. Consequently, typical search strings included '(reflection OR reflective) AND (group OR team OR collaborat* OR collect*).' Meanwhile, the following criteria were used to select studies for final review: (a) A focus on group reflective practices in learning and educational contexts, (b) English language papers published between 2010 and 2020, (c) Peer-reviewed journal articles, which ensured the quality of the selected articles and excluded publications such as reports. According to the criteria, we identified 74 studies relevant to the review from the initial literature search of 244 records, which included 60 empirical studies (36 qualitative, 15

quantitative, and nine mixed-method studies), 12 theoretical papers, and two review articles. The studies and key findings from our analysis are listed in Appendix A.

Recent Studies of Group Reflection

Terms for group reflection. The review of the 74 studies suggested that multiple terms were used to indicate reflection in group settings, including collective reflection, collaborative reflection, group reflection, team reflection, shared reflection, joint reflection, co-reflection, and reflective discourse. The review found that only 21 studies defined the term used to refer to group reflection (see Appendix). Specifically, collective reflection is defined in six studies as two or more people participating in a reflective exercise together, aiming at attaining a more profound understanding that would not be attainable by one person alone (e.g., Chen et al., 2020). Similarly, the term collaborative reflection was used in five studies as the collaborative format of reflection, which happens in a group with social interactions to construct shared knowledge in a learning community (e.g., Jiang & Zheng, 2020). Meanwhile, group reflection/reflective practice was defined in three studies (e.g., Lees & Cooper, 2019). In seven studies, team reflection was used to indicate a team of different roles evaluating past team activities to achieve better team performance (e.g., Schmutz et al., 2018).

Theories employed to justify group reflection. Among the 74 review articles, 19 studies explicitly indicated theoretical frameworks that integrated reflection and group contexts. Eight studies used the sociocultural theory to justify the reflective practice in social contexts (e.g., Bertling, 2019; Jiang & Zheng, 2020), among them other ideas, such as situated cognition, were added to support the group reflective practice (Collin & Karsenti, 2011). Six studies applied social constructivism (e.g., Elhussain & Khojah, 2020; McGarr et al., 2019). Finally, five studies used the community of practice theory to support their research on group reflection (e.g., Kuh,

2016; Layen & Hattingh, 2020). In contrast, 55 studies did not mention the theoretical foundation of group reflective practice but indicated it as a social activity in which reflection happened automatically in the group setting.

Activities for group reflection. The review found that various activities were used to enact group reflection. The most applied activity is (guided) group discussions, with 18 studies using group reflection meetings, seminars, and workshops to facilitate the practice. Meanwhile, the review found nine studies practicing group reflection in online settings, such as posting and replying in online forums (Chen et al., 2020), conducting online discussions (Smit & Tremethick, 2017), and writing collective blogs (Kalk et al., 2019). Furthermore, specific activities were found in the review, such as group reflection on individuals' presentations (Lees & Cooper, 2019), shared journal writing (Elhussain & Khojah, 2020), (guided) group reflection on cases/ dilemmas (Daniëls et al., 2020), (guided) debriefing (Min et al., 2020), group reflection on field-trip (Smit & Tremethick, 2017), and group visual reflection (Bertling, 2019).

Unique Features of Group Reflection Compared to Self-Reflection

Three distinguishing features of group reflection were revealed from the 60 empirical studies in the review. First, group reflection requires certain social conditions to function (Graham & O'Brien, 2020). Since group reflection is grounded in dynamic interactions between individuals, certain attitudes were needed from the participants' sides to engage in meaningful interactions, such as respect for others' opinions, open-mindedness, and commitment to the group activity (e.g., Daniëls et al., 2020; Elhussain & Khojah, 2020). Meanwhile, social obstacles like authority and power-related issues were likely to hinder the process and outcome of group reflective practices (Jiang & Zheng, 2020). Accordingly, the emphasis on social conditions distinguishes group reflection from solitary reflection and adds another layer of

complicity to the disciplined process of reflection.

Second, group size and group composition were found as two influential settings that impact the processes and outcome of group reflection (Farrell & Jacobs, 2016; Schmutz et al., 2018). We found very different group sizes and compositions for group reflective practices across studies. For example, some groups included heterogeneous students regarding their performances or experiences (e.g., Eshuis et al., 2019), while others included one or two facilitators with five to fourteen students (e.g., Graham & O'Brien, 2020). There were studies randomly assigning students to reflect together in a course (e.g., Chinnery et al., 2019), and others practicing group reflection with participants in different job roles (e.g., Lees & Cooper, 2019). With varied group sizes and compositions, some studies found that the diversity of group members impacted the dynamic and outcome of group reflection (e.g., Yoon & Kim, 2010). For example, Farrell & Jacobs (2016) found that teacher reflection groups functioned better in heterogeneous grouping settings. Meanwhile, group size was another factor that affected the atmosphere and performance of group reflection (Daniels et al., 2020).

Last, studies revealed that guidance played a significant role in group reflection. For example, Kim et al. (2013) found that both individual and collaborative reflection needed facilitation to ensure the sustainability of reflective practices. Meanwhile, Foong et al. (2018a) found that the facilitation style impacted students' reflective thinking levels. Notably, a facilitator's guidance at the group level differs from that in one-on-one settings. The interactive and dynamic features of group reflection contribute to the complicity of the needed guidance. For example, Daniels et al. (2020) and Otte et al. (2018) indicated that a facilitator should keep the group focused on the task and support deep reflection. Meanwhile, guidance was needed regarding the group's communication and cooperation (Clara et al., 2019; Farrell, 2016).

Implications Drawn from the Review Findings

This review revealed several important findings that can lead to further research on group reflection. First, the results suggested a lack of theoretical examination of reflective practices in interpersonal contexts. The review found that only 21 out of the 74 studies defined the term used to indicate reflection in group contexts. Meanwhile, multiple terms were used without clarification of their differences. Furthermore, only 19 out of the 74 studies explicitly indicated a theoretical foundation for their practice of group reflection. Accordingly, further research is needed to expand our theoretical understanding of reflection in various group settings.

Second, the review revealed a lack of exploration of how group reflection functions with the features of reflection in group settings. Fifty-five articles out of the 74 review studies considered group reflection as an activity that functioned automatically with groups of people. For example, Min et al. (2020) applied collaborative oral reflection to support preservice teachers' professional growth. The study examined group reflection as a medium for specific outcomes while not investigating how the group activity functioned. In contrast, 11 studies examined group reflection's characteristics, stages, types, and elements (e.g., Rantatalo & Karp, 2016; Sharmahd et al., 2018), revealing that group reflection was a system functioning by specific mechanisms. For example, Johnson and Fells (2017) proposed a model of collective reflection to fit the interactive context of negotiation, and they suggested that more studies were needed to enhance collective reflection.

Last, the review found several unique features of group reflection in empirical studies, which can serve as the tipping point to exploring the black box of group reflective practices (Veen & de la Croix, 2017). The review identified social condition, group size and composition, and guidance on the practice as critical features of group reflective practices. Intending to

examine how individual reflection becomes integrated at the interpersonal level to construct shared understanding within the group, we recognized group composition and guidance as two essential factors for further research. The social condition concerning the larger sociocultural environments in which groups are situated is beyond our focus on examining group reflection based on interactions within groups. Meanwhile, although there were studies suggesting the importance of group size (e.g., Schmutz et al., 2018), we did not include it as a crucial factor for exploration because it was a secondary group-level factor compared to group composition. Accordingly, we propose a conceptual framework to promote focused, coherent, and cumulated research on group reflection from the lenses of group composition and guidance on the practice.

A Three-Dimensional Conceptual Framework for Group Reflection Study

Considering individuals' attributes as the source for various group compositions, we identify three dimensions to outline the group reflection system based on the two critical factors of group composition and guidance on the practice (see Figure 2.1). The first dimension (X) is an individual-level factor that indicates critical individual attributes that influence group reflection. The second dimension (Y) is a group-level factor used to indicate a group's diversity regarding the first dimension's factor. These two dimensions constitute the group composition, which is an unavoidable characteristic of any group activity. We use the range of diversity levels from low to high to indicate the group composition regarding certain individual factors. The third dimension (Z) is the guidance on group reflection, which is an environment-level factor for the group system. The guidance is differentiated from *less* to *more*-structured scaffoldings with four different types of support on group reflection. Thus, combining these three dimensions provides an outline for a group reflection system where specific group processes and dynamics can happen and influence group reflection outcomes.

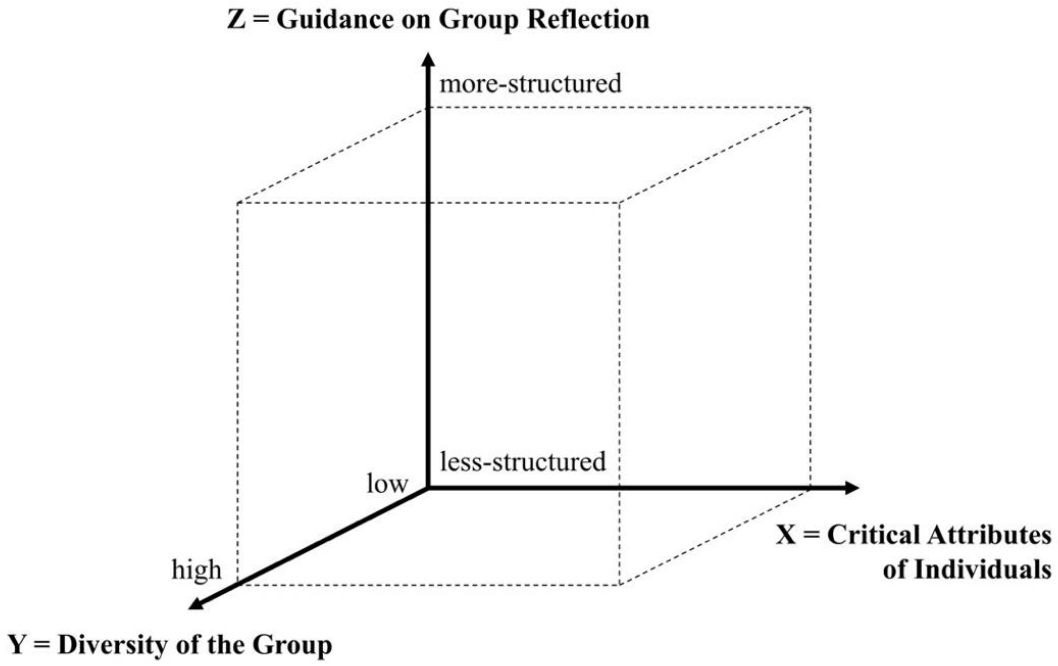


Figure 2.1

A Three-Dimensional Framework of Group Reflection

Group Composition of the Group Reflection System

The first and second dimensions (X, Y) delineate the group composition regarding certain composition factors. Reflection has been recognized as a demanding practice that requires certain altitudes (Dewey, 1933) and skills (Atkins & Murphy, 1993; Sandars, 2009). The social context of group reflection turns the influential attributes from the individual to group-level factors. As a result, the process and result of group reflection are influenced by individual attributes as well as the group composition on these attributes. The second dimension of the framework uses diversity level to delineate different groups from homogeneous (less-diverse) to heterogeneous (more-diverse) composition in terms of specific attributes.

We identified four possible categories of group composition attributes that may influence

group reflection (See Table 2.2). These personal attributes include demographic, social, reflective thinking capacity, and task-related characteristics. Since little attention has been given to examining the mechanism of group reflection with different group compositions, the selection of these potential factors is based on empirical studies on group learning activities and the theoretical understanding of reflective practices. We hope this list of potential factors provides a starting point for future research on various group reflective practices. Of course, a variety of group compositions must be studied before any conclusions are drawn about the relationship between group composition and group reflection.

Table 2.2

Potential Group Composition Attributes Which Influence Group Reflection

Category	Example of Attribute
Demographic characteristic	Gender (Bear & Woolley, 2011; Bradley et al., 2020; Díaz-García et al., 2013; Joshi & Roh, 2009; Kochan et al., 2003; Woolley et al., 2010)
	Ethnic (Cox et al., 1991; McLeod et al., 1996; Watson et al., 2002; Zheng & Wei, 2018)
Social characteristic	Personality traits (Barrick et al., 1998; Barry & Stewart, 1997; Halfhill et al., 2005; Juhász, 2010; LePine, 2003; Mohammed & Angell, 2003; Neuman et al., 1999; Tasa et al., 2011)
	Preference for group work (Bell et al., 2018; Jung & Sosik, 1999; Stark & Shaw, 2007)
	Social sensitivity (Bender et al., 2012; Woolley et al., 2010)
Reflective thinking capacity	Curiosity, Desire for growth, whole-heartedness, Directness, Open-mindedness, and Responsibility (Dewey, 1933)
	Self-awareness, Description, Critical analysis, Synthesis, and Evaluation (Atkins & Murphy, 1993)
Task-related characteristic	Knowledge (Eshuis et al., 2019)
	Experience (Foong et al., 2018b; Gutzan & Tuckermann, 2019; Yoon & Kim, 2010).

As shown in Table 2.2, the first category of the individual attribute includes demographic factors. The commonly investigated factors in group activities are gender and ethnic

composition. Gender composition has been examined to influence team collaboration (Bear & Woolley, 2011) and collective intelligence (Woolley et al., 2010). Gender diversity has been investigated as significantly impacting group processes and social interactions (Bradley et al., 2020; Kochan et al., 2003), ultimately affecting team performance (Díaz-García et al., 2013; Joshi & Roh, 2009). Similarly, group ethnic diversity has also been studied to influence the group's behaviors and performance on a task (Cox et al., 1991; Watson et al., 2002). Based on the empirical studies on the influence of gender and ethnic composition on group practices, we hypothesize that group composition regarding specific demographic characteristics can influence the processes and results of group reflection.

The second category includes the social characteristics that influence group reflection (Bell, 2007). For example, group personality composition has been studied to affect teamwork behavior and communication (Juhász, 2010; Mohammed & Angell, 2003; Tasa et al., 2011). For example, studies suggested that the diversity of personality was related to group effectiveness (Halfhill et al., 2005) and performance (Barrick et al., 1998; LePine, 2003; Neuman et al., 1999). Another social characteristic is the preference for group work, which was suggested to impact individuals' behaviors (Bell et al., 2018; Stark et al., 2007) and group performance (Jung & Sosik, 1999; Tasa et al., 2011). Social sensitivity is also an influential characteristic that might be correlated with team effectiveness and performance (Bender et al., 2012; Woolley et al., 2010).

The third category hypothesizes that group composition regarding individuals' reflective thinking capacity may influence group reflection. For example, people with different attitudes and beliefs might find it challenging to practice reflection together. Dewey (1933) suggested curiosity, desire for growth, whole-heartedness, directness, open-mindedness, and responsibility as the six attitudes needed for individuals' readiness to engage in reflection. Group composition

regarding each of these attitudes may impact the group dynamics and results of group reflection. Meanwhile, Atkins and Murphy (1993) found five skills necessary for reflection: self-awareness, description, critical analysis, synthesis, and evaluation. These individual capacities are also hypothetical attributes that may influence the result of group reflection.

The fourth category is related to individuals' task-related characteristics, such as domain knowledge and task-related experience. The research found that heterogeneous grouping provides multiple views, which provides a better basis for reflection (Eshuis et al., 2019). In addition, the diversity of group members in terms of experiences provides different perspectives and ways of thinking in group reflection (Foong et al., 2018a; Gutzan & Tuckermann, 2019; Yoon & Kim, 2010). Thus, group compositions on task-related knowledge and experience are hypothesized to influence how groups process and contribute to group reflection.

The Guidance on the Group Reflection

The framework's third dimension (Z) refers to the guidance on group reflection. The guidance is an environment-level factor that influences the function of group reflection. The conceptual framework suggests that group reflection can be supported in a range of less to more-structured guidance (see Figure 2.1). Meanwhile, four types of guidance are identified to support group reflections (see Table 2.3), including (a) guidance on the process of reflection, (b) coordination of group interactions, (c) support for the construction of collective knowledge, and (d) technology-enhanced guidance. This categorization of the guidance provides a framework for further research to examine more guiding strategies and tools to support group reflection.

Table 2.3

Four Types of Guidance on Group Reflection

Guidance Type	Explanation	Examples
Guidance on the process of reflection	Guidance on the process of reflection helps to direct and support the critical stages in the disciplined process of reflection. Some crucial phases are: reviewing experiences; returning to thoughts, feelings, and attitudes; identifying critical incidents; searching for new information from internal and external resources; evaluation and analysis; and making conclusions (Boud et al., 1985; Gibbs, 1988; Rodgers, 2002).	Use models or frameworks to direct the process (Golaghaie et al., 2019; Min et al., 2020; Tutticci et al., 2018). Use a reflection map (Eyler, 2002). Use the reflection rubric (Ward & McCotter, 2004) Use protocols to guide reflection (Brantley-Dias et al., 2020; Wetzel et al., 2015).
Coordination of group interaction	Coordination of group interaction provides guidance and necessary interventions regarding interpersonal interactions to maintain a collaborative learning environment for reflection.	Create a democratic and collaborative atmosphere (Jiang & Zheng, 2020; Sandars, 2009) Keep the group focused on tasks (Daniëls et al., 2020).
Support the construction of collective knowledge	Support on the construction of collective knowledge indicates guidance that helps the group construct knowledge and meanings in the reflection process, such as correcting misconceptions, providing alternative information and perspectives, offering help in solving problems, and providing feedback.	Help in finding useful experiences and choosing solutions (Griffin, 2003; Korthagen, 1985) Provide Feedback (Bain et al., 2002; Spalding & Wilson, 2002)
Technology-enhanced guidance	Technology-enhanced guidance refers to the indirect support of the group reflection through the design and development of tools, strategies, platforms, and artifacts used in group reflection (Fleck & Fitzpatrick, 2010; Kori et al., 2014).	Technical tools such as video (Lewis, 2017) and blogs (Kalk et al., 2019) Technology-enhanced environment (Kim & Lee, 2002) Pre-designed prompts and guiding questions (Chen et al., 2009; Davis, 2003)

The guidance on the process of reflection provides support on how the group unfolds the reflective practice. Since reflection is a disciplined thinking process with systematic stages (Boud et al., 1985; Rodgers, 2002), there are different levels of guidance in directing reflective processes. For example, more-structured guidance applies models of reflection to guide a determined reflective process (Brantley-Dias et al., 2020; Golaghaie et al., 2019), whereas less-structured guidance uses question prompts to suggest potential focuses for sense-making (Davis, 2003; Ward & McCotter, 2004). The second type of guidance is the support for group cooperation. Group reflection is based on the communal interaction between individuals to share experiences and construct meanings together (Foong et al., 2018a). Accordingly, different levels of coordination for social interactions are needed to ensure the group is focused on the reflection task (Daniëls et al., 2020) or on interacting in a democratic and equal collaborative atmosphere (Jiang & Zheng, 2020).

The third type of guidance is to support knowledge construction. Such guidance focuses on examining the accuracy and improving the richness of knowledge constructed in group reflection. Support for knowledge construction includes correcting misconceptions, offering help in closing knowledge gaps, and providing feedback (Spalding & Wilson, 2002). The fourth type of guidance is indirect intervention on group reflection by technology (Kori et al., 2014). Various guidance can be provided to the group reflective practice through the use of pre-designed tools (Chen et al., 2009; Davis, 2003), technology-supported activities (Kalk et al., 2019; Mansvelder-Longayroux et al., 2007; Paulus & Spence, 2010), and technology-enhanced environment (Kim & Lee, 2002; Lin et al., 1999).

Application of The Conceptual Framework to Group Reflection Research

The three-dimensional conceptual framework provides a stepping-stone for researching

group reflection with features of group composition and guidance on the practice. Accordingly, we suggested some hypothetical factors (see Table 2.2) as the starting point to examine whether and how group configurations impact group reflection. Meanwhile, four types of guidance (see Table 2.3) are proposed to inform further research and instructional design on group reflective practices. In addition, the multi-dimensional framework implies research on the interaction between group-level characteristics (e.g., diversity and power structure) and guidance on group reflection. Therefore, this section suggests applying the framework with three focus areas for group reflection study.

Research of Group Composition in Group Reflective Practices. The framework identifies group composition as a critical feature in exploring how different people reflect together. Although we suggested hypothetical attributes that may impact group reflection, empirical studies are needed before any conclusion can be drawn. Overall, there are three research directions in examining the impact of group composition on reflective practices. First, research suggested that team composition variables, such as gender, personality factors, and ability levels, influenced group performances and experiences (Bell et al., 2018; Kearney & Gebert, 2009). However, meta-analyses found that the significant effects can be attributed to the type and difficulty of the task under investigation (Bell, 2007; Bowers et al., 2000). Therefore, studies are needed to examine the impact of group composition on different types of reflective practices. Our revisit of reflective practices revealed various reflections from different dimensions, and researchers can consider the hypothetically influential factors (see Table 2.2) to explore the impact of group composition on different reflective practices. Some research questions can be: Does group composition regarding specific attributes (e.g., gender, task-related knowledge, and personality traits) impact the outcome of group reflection? What variables of

group composition are critical for certain types of group reflection (e.g., reflection with different objects)?

Second, it is essential to investigate how group diversity regarding specific attributes impacts group reflection to understand how different people reflect together. Although research indicated that group diversity regarding some variables (e.g., gender and personality) impact group processes and performance (Bradley et al., 2020; LePine, 2003), few studies examined the role of diversity in group reflective practices. We suggested hypothetical factors based on studies on other group learning activities (see Table 2.2), whereas empirical studies are needed to examine if and how these diversity factors play a role in group reflection. Some potential research questions are: Does group diversity in certain attributes (e.g., reflective thinking capacity, task-related experience) impact the outcome of group reflection? How does diversity in certain attributes (e.g., social characteristics) contribute to the process and outcome of group reflection? How do certain diversity levels influence individuals differently in the reflective practice?

Last, qualitative research is needed to explore group reflection's affordances and challenges from different group members' perspectives. Although the group engages in explicit reflection processes to exchange perspectives and construct meanings together, nuanced affective and cognitive processes may not be revealed in the group environment. Accordingly, it is important to study how different group members perceive their group reflection processes and what concerns or challenges they encounter during the process. The suggested hypothetical attributes (see Table 2.2) can be used to construct research questions to examine individual differences regarding their experiences in group reflections. For example, the research questions can be: How do people with different demographic /social/ reflective/ task-related characteristics

perceive the group reflection differently? What benefits and concerns are perceived by different individuals who participated in certain types of group reflection?

Research of The Guidance on Group Reflection. The guidance on group reflection is a critical environment-level factor influencing various group reflective practices (Clara et al., 2019; Mc Carthy et al., 2013). The proposed conceptual framework can be applied in future research to advance our knowledge regarding supporting group reflection. Specifically, we suggest four guidance categories (see Table 2.3) as a framework for future research to examine strategies and tools to support group reflective practices. The categorization is based on our systematic review of group reflection studies from 2010 to 2020, thus demanding continuous examination and modification to serve future research. Meanwhile, studies are needed to examine specific strategies and tools under each category to build up the toolkit that supports group reflection.

Another direction to research the guidance on group reflection is to examine the effectiveness of different supports in various reflective practices. Our review of reflective practices found that reflection can be distinguished from different dimensions. Thus, research is needed to examine what types of guidance support certain reflective practices in the group setting. Some examples of the research questions are: What kinds of guidance are needed for group reflection that happens in action (compared to reflection-on-action)? Do specific technological tools promote a higher level of reflection in the group reflective practice? If and why do certain types of guidance support some group reflective practice while having no/negative effect on others?

The third area is to examine guidance on group reflection in different learning environments. Research has considered the success of computer-supported and face-to-face

groups and found that they had different affordances and challenges to students' interactions and learning (Schneider et al., 2002; Shu & Gu, 2018). For example, Guiller et al. (2008) compared students' critical thinking activities in online and face-to-face settings. They found that the face-to-face sessions contributed to students' brainstorming, negotiation, and spontaneously constructing ideas. In contrast, the online condition was more beneficial for students to reflect on what they discussed and construct meanings with appropriate evidence. Accordingly, different settings and related communication formats (e.g., synchronous vs. asynchronous online vs. face-to-face) can provide different strengths and constraints to group reflection. More research is needed to examine how specific guidance on group reflections functions in different learning environments. Some research questions include: What instructional strategies can support group reflection in online environments (synchronous vs. asynchronous)? How does particular guidance on group reflection function differently in digital and place-based learning?

Research of Interaction between Group Composition and the needed Guidance. The three-dimensional framework suggests group reflection as a system constituted by specific group composition and guidance on the practice. Thus, factors under different dimensions are interwoven to forge the processes and outcomes of the group practice. It is insufficient to examine how group reflection functions in certain conditions without considering the interaction between group composition and guidance on the practice. For instance, the types of guidance needed for a group's reflection may depend on the level of diversity regarding a critical individual attribute for the reflection task (e.g., personality traits or task-related experiences). Thus, related research questions include: Is there an interaction effect between group composition and the needed guidance for certain types of reflective practice (e.g., reflection before, during, and after experience)? What outcomes are led by the interaction between group

composition and guidance on reflection? How does particular guidance function to connect different individuals and impact group reflection processes and outcomes?

In addition, longitudinal studies are needed to examine how group reflection changes over time with the intervention of group composition and guidance on the practice. For instance, social norms and structures (e.g., friendship, leadership, and power structure) usually emerge with the development of group activities across time (Rubin et al., 2015; Tuckman & Jensen, 1977). These group-level factors evolved from initial group compositions are likely to impact group processes and outcomes (Bendersky & Hays, 2012; Bunderson & Reagans, 2011). Longitudinal studies are needed to investigate how group reflection evolves with certain group compositions. Meanwhile, group reflection may require dynamic and adaptive guidance to meet continuous needs as the group develops (Azevedo et al., 2004, 2011). Thus, research on adaptive guidance is needed to examine group reflection in the evolving process across time. Some research questions are: What factors are influential in the longitudinal exploration of group reflective practices? When is adaptive guidance needed in the dynamic process of group reflection? How does the evolution of group development impact the group reflection processes and outcomes?

Furthermore, it is important to examine the interaction between group composition and guidance on group reflection in different learning environments (e.g., online vs. face-to-face). Since different environments and related communication formats provide distinguishing strengths and constraints to group reflective practices (Schneider et al., 2002; Shu & Gu, 2018), the interaction between group composition and guidance on the practice might vary depending on the settings. Accordingly, some research questions are: Does the interaction between group composition and guidance on the practice differ across various environments (e.g., synchronous

online vs. asynchronous online vs. face-to-face)? How does the interaction between group composition and guidance on the practice impact online group reflection? What types of guidance are found to have an interaction effect with certain group composition factors (e.g., task-related experiences, reflective thinking capacity) in online and face-to-face settings?

Overall, the conceptual framework offers a common ground for focused and coherent research on group reflection from the lenses of group composition and guidance on the practice. We illustrate how the framework can be applied in three related research areas to advance our understanding of group reflection. Additionally, we suggest that more research is needed to examine reflection as a social phenomenon with different approaches. Following are four research directions beyond the conceptual framework's focus.

Future Research beyond the Conceptual Framework

Theoretical Clarification of Group Reflection

The systematic review in this article revealed a lack of theoretical exploration of group reflection. Specifically, the review found that many studies did not define group reflective practices and used multiple terms to indicate the concept without distinguishing. A lack of clear definition and common ground disconnects researchers and practitioners (Rodgers, 2002), hindering group reflective practices' theoretical exploration and practical application. Therefore, there is a need to theoretically examine the nature of reflection in social contexts to define the notion further. Meanwhile, discussions are needed to distinguish various terms used to indicate group reflection (e.g., collaborative reflection, collective reflection, and team reflection). Such research will contribute to the clarification of the concepts and provide common languages for scholarly collaboration. In addition, the features of group reflection demand more attention to advance our understanding of reflection in specific social contexts. Accordingly, the literature

review of reflection in this article can be used as a stepping-stone for future theoretical exploration of the features of group reflection.

Empirical Exploration of the Theoretical Assumptions and Practical Challenges of Group Reflection

Another area for future research is exploring and validating the theoretical justifications and practical challenges of group reflection. Theoretically, group environments offer distinguishing affordances to reflection compared to individual settings (Brown et al., 1989; Johnson & Johnson, 1999; Webb, 1982). The article suggests four theoretical underpinnings of reflection in group contexts: (a) group settings offer more opportunities for reflection to happen, (b) group reflection can assist individuals in achieving what they cannot achieve alone, (c) social environments promote individuals' engagement and motivation in reflective practice, and (d) group reflection has long-term social effects compared to solitary reflection. However, these justifications are based on theoretical investigations on reflection and group learning (Bandura, 1986; Rodgers, 2002; Vygotsky, 1978), which require validation and further exploration through experimental studies. Meanwhile, in contrast to the research on the benefits and advantages of group reflection (Binyamin, 2018; Cord & Clements, 2010; Lin et al., 2013), there is a lack of studies investigating the problems and concerns of reflection in various social settings. Therefore, there is a need to examine group reflections' practical issues and challenges.

Group Factors beyond Group Composition

The third direction that demands further research is investigating other group-level factors that impact group reflection. For example, group cohesion has been widely studied as a crucial factor influencing teamwork's function and productivity (Dimas et al., 2021; Piper et al., 1983). Beal et al. (2003) conducted a meta-analytic examination of group cohesion and

performance. They found that cohesive groups performed better in certain situations while providing little help in other circumstances. Thus, future research can examine whether cohesion impacts group reflection and in what situation cohesive groups perform better. Another group-level factor that might impact group reflection is group efficacy, generally defined as the group's collective belief in its ability to perform a task (Gibson, 1999). Research revealed that group efficacy had beneficial effects on group dynamics and effectiveness (Pescosolido, 2003; Stajkovic et al., 2009), while there is a lack of studies focusing on the context of group reflection. Therefore, many group-level factors need to be examined to advance our understanding of group reflection from different angles. Notably, related methodologies are needed to investigate the relationship between group-level factors and various group reflections' processes and results (e.g., social network analysis and qualitative analysis).

Socio-Cultural Factors that Influence Group Reflection

The current paper focuses on framing group reflections based on the interaction between individuals within groups. The purpose is to conceptually explore how individual reflections become integrated at the interpersonal level to construct mutually shared understanding within the group. Such a focus implies the research paradigm that emphasizes examining how individuals interact in the group for better outcomes (Dillenbourg et al., 1996; Webb & Palincsar, 1996). Thus, the conceptual framework did not fully embrace the element of a larger sociocultural environment where the group activity is situated, which implies future studies on group reflections from another unique direction. As the research in organizational psychology suggests, sociocultural factors, such as the organization's learning culture and climate, play a salient role in group functioning (Bates & Khasawneh, 2005; Lingard et al., 2002). More studies are needed to explore how sociocultural environments affect the dynamics and outcome of group

reflection. Meanwhile, research combining the two complementary perspectives of group research approaches is required to understand how group reflection functions with certain members in a larger context of sociocultural environments (Van den Bossche et al., 2006).

Conclusion

This article attempted to revisit the notion of reflection and justify group reflection as an important practice while receiving limited attention in research (Miller & Maellaro, 2016; Reynolds, 2017; Sharmahd et al., 2018). Through a 10-year (2010–2020) systematic review, we identify the group composition and guidance on group reflection as critical factors for examining the characteristics and mechanism of group reflection. Accordingly, we proposed a three-dimensional conceptual framework (e.g., personal attributes, group diversity, and guidance) to promote consistent and coherent research on group reflection. Furthermore, we illustrate the application of the conceptual framework in three main research areas with specific examples of research questions. Lastly, implications for further research beyond the current conceptual framework were discussed.

Reflection in Simulation-Based Learning

Since the application of simulation in education and training, reflection has been considered the most important component in the learning process (Luo et al., 2021b). Studies revealed that reflection is essential for learners to re-evaluate an experience (Gaba et al., 2001; Lederman, 1992), release emotion (Dreifuerst, 2009), identify strengths and areas for improvement (Al Sabei & Lasater, 2016; Gardner, 2013), and generate meanings or resolutions from experiences (Decker et al., 2013; Gardner, 2013). Meanwhile, guided reflection allows learners to receive feedback from more knowledgeable others, which supports their meaning-making and knowledge construction (Grossman, 2009; Russell, 2005; Sandars, 2009).

One of the most used strategies of reflection in simulation-based learning is debriefing (Gaba et al., 2001; Lederman, 1992; Tannenbaum & Cerasoli, 2013). As a post-experience analytic activity, debriefing asks learners to recall, re-evaluate, and analyze their actions and decision-making in actual or simulated situations, thereby promoting purposeful reflection (Decker et al., 2013; Savoldelli et al., 2006). Accordingly, teachers can evaluate students' understanding and provide feedback (Gaba et al., 2001; Gardner, 2013). The effectiveness of debriefing as an approach to promoting reflection has been widely examined. For example, Tannenbaum and Cerasoli (2013) conducted a meta-analysis to examine the efficacy of debriefing across 31 studies. The results demonstrated a moderate effect of debriefing in improving participants' learning performance and suggested that debriefing worked equally well for groups and individuals.

Meanwhile, research has examined the application of debriefing in group learning. For example, Bilgin, Baek, and Park (2015) investigated how different debriefing strategies impact children's (11 to 12 years old) motivation and self-efficacy in game-based learning. They found that students in group debriefing showed higher motivation and self-efficacy scores than students in the self-debriefing setting. Moreover, students' interview data supported the conclusion that children benefited more from collaborative debriefing sessions. Verkuyl et al. (2019) further designed an experimental study to explore three different debriefing grouping methods: self-debrief with a set of debriefing questions, self-debrief plus a small-group (2 to 12 students) debriefing session with one instructor, and self-debrief plus large-group debriefing session with one instructor. Findings revealed that undergraduate students valued and benefited from a self-debrief before a group debriefing session. However, students who joined in group debriefing had a more satisfactory learning experience.

VR-medicated learning is a form of simulation-based learning that requires the essential component of reflection to promote meaningful learning. Empirical studies have examined the vital role of debriefing in VR-mediated learning. For example, Luo et al. (2021b) found that the debriefing session after the simulation is essential for children's learning with a VR-based pedestrian educational program. Children who received guided debriefing performed significantly better than those who did not reflect in individual simulation-based learning. Meanwhile, the study compared children who observed VR experiences in group settings with those who had first-person VR experiences in individual learning. The results revealed equal benefits of guided debriefing. However, although empirical studies examined the effectiveness of debriefing in VR-mediated group learning, there is a lack of qualitative studies exploring the characteristics and mechanisms of group reflection in such an experiential learning environment.

CHAPTER 3

METHODOLOGY

As a component of a broad research project that compares individual and group learning with an immersive VR-based pedestrian safety education program (refer to Luo et al., 2021b), this study was conducted in an elementary school in central China in December 2019. One week before the onsite research, informed consent forms were provided to both the students and their parents. Only the students who submitted both their written and parental consent were allowed to participate in the study. The Institutional Review Board (IRB) of the University of Georgia in Athens, Georgia, approved the research protocol.

Research Design

This study applies a case study research approach to investigate VR-mediated group learning in which two roles—the Performer in VR and the Observer with no direct access to VR—work together to construct experiences and meanings. Yin (2003) defined a case study as "an empirical inquiry that investigates a contemporary phenomenon within a real-life context, especially where the boundaries between phenomenon and context are not clearly evident." (p.13). In general, a qualitative case study is based on the in-depth analysis of one or a few instances of a phenomenon (Creswell & Creswell, 2018; Blatter, 2008). Accordingly, this study aims at exploring a few groups of children's learning with a VR-based pedestrian safety education program. The purpose is to obtain in-depth insight into the mechanisms and dynamics of VR-mediated group learning to answer the research questions.

Applying the case study approach in this study has several advantages. Firstly, case

studies are a crucial source of theoretical innovation, making them a valuable tool for exploring under-researched phenomena (Blatter, 2008). Since VR-mediated group learning is a new form of group experiential learning that has not been extensively researched, the case study approach offers the tool for investigating its characteristics and mechanisms. Additionally, case studies have the advantage of in-depth analysis of a phenomenon regarding empirical completeness, natural wholeness, conceptual richness, and theoretical consistency (Blatter, 2008). Compared to large-*N* studies that focus on the breadth of the propositions, the case study approach has the advantage of exploring a phenomenon with in-depth analysis. The case study approach can also lead to practical implications for solving real-world problems (Bennett, 2004). The insights gained from the analysis can help inform instructional decisions and design considerations on VR-mediated group activities, improving the practice of VR-mediated learning with limited resources.

Additionally, this study applied an embedded case study approach to investigate both groups and individuals within those groups. Embedded case studies involve analyzing multiple units and are not restricted to qualitative analysis alone (Scholz & Tiejie, 2002). The primary unit of analysis for the first two research questions, which focus on group dynamics and interactions, is the group itself. In contrast, Research Question Three requires separating different roles from groups to compare their learning differences, necessitating the unit of analysis to be individuals within groups. While a qualitative approach can address Research Questions One and Two, Research Question Three requires both qualitative and quantitative methods.

Research Participants

This study recruits forty-five students from grades two and three at an elementary school in central China. These students are between eight to ten years old, which is typical for China's

current elementary school system. The students are divided into nine groups, each consisting of five randomly assigned children from the same classroom, to participate in a school-organized safety education event that utilizes immersive VR technology to guide students in making safe decisions in real-life pedestrian situations. In China's elementary schools, a classroom is the primary unit within which most academic and social activities are grounded. As a result, students are familiar with their peers in the class, and even when randomly assigned to small groups for the learning activity, the group members are likely to know each other with previously built social relationships.

There are two main reasons for conducting the study in China with second-and third-grade children. Firstly, this study is part of a large research project with international collaboration that has already accumulated research experiences and resources in China. This includes well-trained researchers and established relationships with local schools, which facilitate the implementation of the study. Additionally, the target population for the VR-based safety education program is typically seven- to ten-year-olds, which aligns with the age range of second and third-grade students in China' school system. Secondly, qualitative research emphasizes researchers' crucial role in data analysis, interpretation, and meaning-making (Brodsky, 2008). As the primary researcher, the author, has a social and cultural background in China, and conducting the study in China facilitates in-depth reflection and meaning-making.

VR-based Learning Context

An immersive VR-based pedestrian safety education program is used in this study. Developed using the Unity 3D game engine and Oculus Rift software development kit, the VR program aims to promote safe behaviors in authentic and immersive traffic scenarios (SAVE Group, 2019). The learner wears a headset with a head-mounted display to immerse themself in a

3D virtual city with various traffic situations and uses hand controllers to simulate their daily pedestrian actions. For instance, they can decide when and how to cross streets based on traffic light signals. This VR-based education program enables the investigation of students' group learning mediated by immersive VR. In the group learning context, one student simulates in the VR program while others observe the child's actions and consequences within the virtual environment. Furthermore, there are no restrictions or rules regarding the group's interactions and how they experience the authentic traffic scenarios in the VR program.

The program includes three scenarios for children to make decisions and construct their pedestrian experiences. First, the participant needs to cross a street to join a virtual friend calling out to them. This scenario is a challenge for children easily attracted by others (e.g., the virtual friend) while neglecting the traffic situation on the road. Second, the participant needs to decide whether to cross a wide street when the green pedestrian light starts to flash, a sign suggesting insufficient time left to cross the street fully. This scenario tests children's understanding of the traffic rules and their safety awareness. Last, the participant needs to respond to a hazardous scenario where a school bus backs to the crosswalk while they attempt to cross a street with a green pedestrian crossing light. This scenario challenges children to decide between following the rule and crossing the street safely. Figure 3.1 shows the screenshots of the three scenarios.

Figure 3.1

The Screen Shots of Three Decision-Making Scenarios in the VR Program

Research Procedure

Immersive VR-mediated group learning involves two primary group activities. A group of five students participates in the VR-based pedestrian safety education program and assumes either the Performer or Observer role. The selection of roles is based on the voluntary or random assignment if no one wants to be the Performer. The student in the Performer role simulates in the VR program while others observe the Performer's actions and the virtual scenes on a projected display. A guider is present to ensure the safety of the students during the simulation and provides technical support without interfering with the group's decision-making in VR. After the VR experience, the group engages in a group reflection section led by a facilitator who guides the group through a set of debriefing questions (found in Appendix B) to reflect on their experiences. Figure 3.2 illustrates the arrangement of the two group activities.

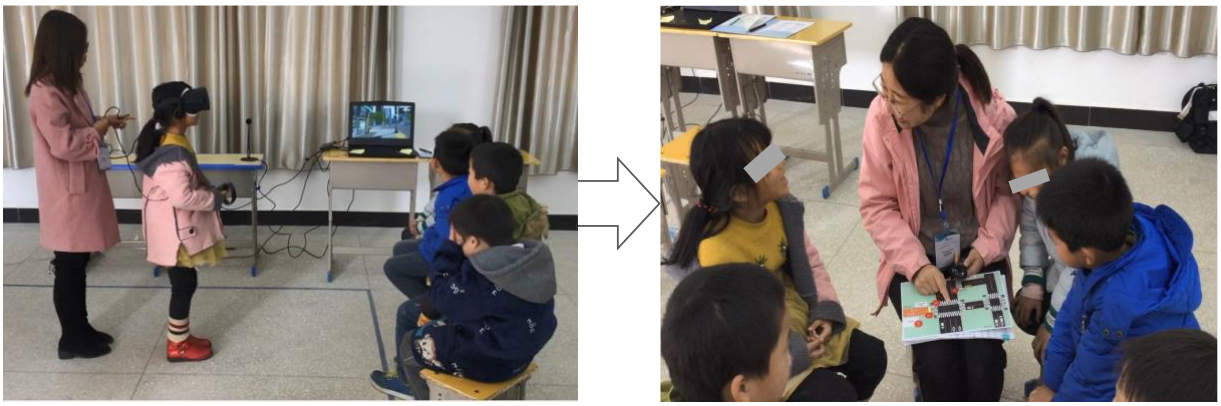


Figure 3.2

Two Group Activities: Group VR Simulation and Group Reflection

Following the two group learning activities, a set of individual activities are conducted to assess each student's learning outcomes. First, each student in the group simulates in the VR program and completes three challenges to evaluate their performance in decision-making. Then,

all the participants take a paper-and-pencil test to examine their knowledge of pedestrian safety in specific situations (found in Appendix C). Finally, each student participates in a semi-interview where they provide feedback and share their experience with the VR-mediated group learning process (found in Appendix D). Throughout the processes, the group VR experience, group reflection, performance test in VR, and interview are recorded on video for further data analysis.

Instruments and Data Collection

Several instruments are employed during the data collection process. Specifically, a debriefing protocol is created and used to facilitate group reflection. A pedestrian safety knowledge test is applied to evaluate students' learning outcomes following VR-mediated group learning. Lastly, an interview guideline is provided to assist researchers in obtaining feedback from the students regarding their experience with VR-mediated group learning.

Debriefing Protocol

A list of probe questions is designed to encourage students to recall their experiences with the VR program and provide a rationale for their reactions and decisions (see Appendix B). These questions are developed based on literature related to the debriefing and critical decision method (CDM) (Dreifuerst, 2009, 2012; Klein et al., 1989; Patterson et al., 2016). Typical probe questions include: (a) What did you see/hear/think in this situation? (b) What does it (a traffic sign or infrastructure) mean? (c) What were you trying to do? (d) Why were you trying to do it? (e) What did you think would happen? All probe questions are relevant to the three pedestrian challenges presented in the VR program.

One researcher, the author, is trained to facilitate group reflection using this debriefing protocol. The facilitator is responsible for guiding students' reflective discussion with the probe

questions and providing final guidance regarding safe and appropriate behaviors in traffic scenarios in the VR program.

Pedestrian Safety Knowledge Test

A pedestrian safety knowledge test comprising ten multiple-choice questions is used in this study (see Appendix C). The first four questions examine children's interpretation of traffic signs, and the remaining six questions test children's decision-making in specific traffic situations. All questions are created based on the official pedestrian safety education materials used in East Asian countries, including the Handbook of Child Traffic Safety Knowledge (Ministry of Education in China, 2012), cases of child pedestrian accidents published on the China Road Traffic Safety website, and an official safety test used in Korean elementary schools (Children's Safety School, 2019).

Interview Guide

A semi-interview guide is used to obtain students' feedback regarding their overall experience of the VR-mediated group learning activity. The interview aims to gain information regarding students' overall satisfaction with the learning activity, including their experience with the VR program and learning with peers in the group. A set of questions are prepared to assist the interview process (see Appendix D).

Data Collection

Multiple data resources are collected in the study. First, students' group learning processes are video-recorded as essential data sources for further analysis. Second, all the documents during the research process, such as students' knowledge tests and the facilitator's notes for group reflection, are part of the data for analysis. Last, researchers' filed notes and memos throughout the research process are important data to map research activities, extract

meaning from the raw data, maintain momentum, and open communication (Birks et al., 2008).

Data Analysis

A qualitative data analysis program, NVivo Version 12, is used to store, organize, and manage the data collected in this study. The use of qualitative data analysis software enables researchers to effectively analyze and manage different sources of data and is particularly helpful when an inductive approach is employed (Creswell & Creswell, 2018). This study collects various forms of data, including video files of the group learning process and screen recordings of the VR program, text files containing students' knowledge test results and researcher's memos, as well as audio files of the students' interviews. The primary data resource for analysis is the recorded videos of the group learning process, while other forms of data resources aid in the interpretation and analysis of the primary data.

Inductive Data Analysis Approach

This study applies an inductive data analysis approach to analyze the nine group cases of students' VR-mediated group learning. Thomas (2006) defined inductive analysis as "approaches that primarily use detailed readings of raw data to derive concepts, themes, or a model through interpretations made from the raw data by an evaluator or researcher" (p. 238). Thus, inductive analysis is a theory-building process that begins with specific observations to detect patterns, formulate tentative hypotheses, and develop general conclusions or theories (Bendassolli, 2013). An inductive analysis approach is a bottom-up approach where the analysis starts with the examination of the specific details and features of the data and gradually works towards creating a more general understanding of the phenomena under study.

This study explores the characteristics and dynamics of VR-mediated group learning through a bottom-up approach, allowing the data to speak for itself through the researcher's in-

depth analysis of the group cases. There are no preconceived hypotheses or theories used in the analysis process. A coding process included two major stages before further analysis and theme generation: (a) an initial stage of open coding, intending to identify and label codes, and (b) a second stage of pattern coding, developing more analytical categories from the initial codes (Bazeley, 2013). Accordingly, the coding process provides a means of purposefully locating, identifying, sorting, and managing the data set, becoming the foundation for further analysis and theme generation (Yin, 2018).

Intercoder Agreement Process

An intercoder agreement process is used to generate and validate codes by multiple coders, ensuring the credibility of the research findings (Creswell, 2007). This study uses three rounds of intercoder agreement process to examine and analyze the nine group cases. First, one group case is randomly selected and coded by the researcher and another experienced reviewer independently. The independent codes are reviewed and analyzed for the initial inter-coder reliability. Accordingly, the two coders discuss and negotiate any disagreed codes until the reliability reaches 90%. Second, another group case is randomly selected and coded independently by the researcher and another experienced reviewer. The acceptable reliability in this phase is 90%. Third, the researcher analyzes the remaining data independently, and the second reviewer will randomly select one or two cases to check the inter-coder reliability. The reliability is accepted if it reaches 80% or needs further negotiation on the disagreement between coders.

Validity and Reliability

The concepts of validity and reliability are used differently in qualitative studies than in quantitative research (Golafshani, 2003). In qualitative studies, validity is often described as the

quality, appropriateness, and trustworthiness of a study (Leung, 2015; Lincoln & Guba, 1985; Miller, 2008b), and reliability is broadly described as the dependability and consistency of the data collection, interpretation, or analysis (Lincoln & Guba, 1985; Miller, 2008a). Accordingly, validity and reliability are two crucial considerations for qualitative researchers to ensure the quality of the research findings.

To enhance the validity and reliability of this study, two main methods, triangulation and research audit trail, are employed. Specifically, Creswell and Miller (2000) defined triangulation as "a validity procedure where researchers search for convergence among multiple and different sources of information to form themes or categories in a study." (p. 126). In this study, qualitative data analysis depends on triangulating different sources of data, and multiple coders and researchers are involved in the study design and data analysis. This aligns with McMillan's (2012) suggestion that trustworthiness is established by triangulating the data using different data sources and the member-checking procedure.

Additionally, research audit trails with transparent descriptions of all procedures and issues relevant to the study could enhance the dependability of the qualitative research (Anfara et al., 2002; Carcary, 2009; Lincoln & Guba, 1985). Therefore, the study procedures, including the case study design, implementation, and data analysis, are documented in detail to ensure consistency and reliability (Creswell & Creswell, 2018).

Methodological Limitations

As Hodkinson and Hodkinson (2001) suggested, case studies are often time-consuming for data collection and analysis, and it is costly to apply on a large scale. Accordingly, this study examines limited cases to examine the phenomenon of VR-mediated group learning. There are several limitations. First, the selection of cases might not represent a large population.

Specifically, the study recruits student partitipants from an elementary school in China, which is situated in certain social, cultural, and economical environment. Thus, the students' learning experiences and results may not reflect others from different background. Second, findings in this study are grounded in the context of VR-based pedestrian education, which highlights behavior change as well as knowledge acquisition. Therefore, any implication from this study could be restricted to apply to other contexts with different learning objectives.

To address the above mentioned limitations and enhance the generalizability of the study, detailed descriptions of the research processes and background are needed (Gerring, 2007). The results of this current study are expected to provide broader implications with a well-informed research contexts and related findings. Accordingly, theoretical generalization from this study can be used to inform the research and practices of related studies (Tsang, 2014).

Ethical Considerations

Ethical considerations are especially important in qualitative studies because of the comprehensive and detailed nature of the research process (Arifin, 2018). Meanwhile, considering ethical issues throughout all stages of the qualitative study is crucial for keeping the balance between the potential risks and benefits of the research (Miller et al., 2012). Accordingly, this study follows ethical procedure guidelines to consider ethical issues in qualitative studies, such as informed consent, right to withdraw, intellectual property, confidentiality, and financial gain (Plummer, 2001).

In this study, all the student participants and their parents are informed to participate in the research activity. Individuals are free to stop at any time during the study. Meanwhile, since some children need to use VR equipment in group learning, anyone who feels dizzy or sick with VR will not be asked to simulate in the VR program. In addition, the selection of students who

simulate in VR is based on voluntary or random assignments if no one volunteers. Finally, to avoid misunderstanding or encouragement of risky behaviors, all students are guided with safe and appropriate pedestrian behaviors regarding the ten traffic scenarios used in the study.

Researcher Subjectivities

Subjectivity refers to an individual's personal opinions, feelings, or preferences (Siegesmund, 2008). Qualitative researchers argue that subjectivity is an inherent part of the research process, and it is a powerful means for shaping data (Peshkin, 1988). Therefore, it is essential to acknowledge researcher subjectivities in this study.

The researcher of this study has participated in the VR-based pedestrian safety education project for more than four years. The project's focus and achievements have influenced the Researcher's subjectivity. Initially, the project aimed to design an effective pedestrian safety education program using VR technology to create immersive and authentic learning scenarios. Reflection was deemed as the essential component to prompt learning. Thus, the researcher believes that VR technology can help students learn and reflect in authentic contexts, while the cost is the main concern of applying VR-mediated learning. Additionally, the designed VR program has been empirically proven effective for individual learners, whereas the cost of VR equipment has hindered its universal distribution from benefiting more learners. Therefore, the researcher shifted the focus to designing VR-mediated group learning in which students can work together with limited resources. The current study is based on such a research history.

This study aims to find the springboard for designing group activities that can increase the accessibility and effectiveness of VR-supported learning and education. The researcher believes that constructivism, social cognitive learning, and experiential learning provide the theoretical foundation for VR-mediated group learning, where students learn from observing one

member's simulation. Accordingly, exploring the mechanism and influential factors for such a new learning environment is essential for future instructional design and practice.

CHAPTER 4

RESULTS

This chapter presents the results of the current study with a detailed description of the studied cases and findings of the three research questions. Research Question One examines how learners with two roles (Performer vs. Observer) experience during the immersive VR-mediated group simulation. Research Question Two explores how the two roles reflect together on their VR simulation experiences. Finally, Research Question Three examines how the two roles differ in learning outcomes. An embedded case study approach is employed to address the three research questions. Nine group cases are investigated in this study, with five students in each group unit. The chapter reports the analysis process and findings of the current study. Specifically, we first present the profiles of the nine group cases and related participants to provide an overview of the studied cases. Then, the case analysis process is illustrated to show how the study conclusions are drawn from initial codes and generated themes. Finally, the results and findings of the study are reported according to the three research questions.

Overview of the Group Cases and Participants

An embedded case study approach was employed since this study aimed at examining groups as well as individuals within the groups. Distinctly, embedded case studies involve more than one unit of analysis and are usually not limited to exclusive qualitative analysis (Scholz & Tiejie, 2002). Research Questions One and Two focus on examining group dynamics and interactions with a qualitative approach, which can be addressed mainly with a qualitative approach. In contrast, Research Question Three compares individual differences with each

student as an analysis unit, requiring qualitative and quantitative methods. Therefore, the group case is the primary unit of analysis for Research Questions One and Two, and individual students within groups are the subunits of analysis to address Research Question Three. Accordingly, forty-five students from a Chinese elementary school participated in the study; they formed nine group cases, with five students in each group unit.

Table 4.1 shows detailed information on the nine group cases in the current research. Each group was formed with five students from the same natural classes, with four groups from the second grade and five from the third grade. The student participants in each group were randomly assigned together for the VR-supported pedestrian safety education activity while they knew each other as classmates. In each group, two different roles (Performer vs. Observer) were decided based on group members' preferences. Student participants could either volunteer to be the Performer or get a randomly assigned role if no one responded to the invitation.

Table 4.1

Overview of the Group Cases and Participants

#	Grade	Group Participants	Selection of Roles	A Glimpse of the Group
1	2nd	One girl and four boys	The girl was randomly assigned as Performer, as no one volunteered	VR simulation (8:29 mins): the Performer acted quietly in VR, and Observers were engaged by interacting with each other but not with the Performer Group reflection (8:37 mins): active discussions guided by the Facilitator. The Performer and Observers share experiences and opinions based on the prompt questions.
2	2nd	Two girls and three boys	One girl volunteered to be the Performer; The other girl had VR experience before	VR simulation (4:06 mins): active interactions between the two roles, with the Performer sharing and asking for helps and the Observers responding and directing the Performer Group reflection (16:56 mins): active

				discussions guided by the Facilitator. Observers interrupt the Performer to share their observations and opinions actively.
3	2nd	One girl and four boys	One boy volunteered to be the Performer	VR simulation (5:18 mins): the Performer attempted to interact with Observers while he acted to finish VR tasks, while Observers interacted with each other but not with the Performer Group reflection (9:31 mins): active discussion guided by the Facilitator. The Performer and Observers talk through their experiences and opinions based on the prompt questions.
4	2nd	Four girls and one boy	One girl volunteered to be the Performer; she had VR experience before	VR simulation (3:41 mins): the Performer acted quietly and confidently, and others engaged in observing with few interactions Group reflection (9:55 mins): discussion led by the Facilitator, with the Performer sharing actively and Observers listening most of the time
5	3rd	Four girls and one boy	One girl was randomly assigned as Performer, as no one volunteered	VR simulation (3:33 mins): few interactions in the group with the Performer quietly acting and others engaging in observing Group reflection (7:15 mins): discussion led by the Facilitator. The group responded to questions and prompts but not actively sharing opinions.
6	3rd	One girl and four boys	One boy volunteered to be the Performer; he had VR experience before	VR simulation (4:10 mins): the Performer talked throughout the VR simulation, and the Observers engaged in watching with few interactions with others. Group reflection (7:51 mins): active discussion guided by the Facilitator, with the Performer actively sharing and others passively responding.

7	3rd	Two girls and three boys	One boy was randomly assigned as Performer, as no one volunteered	VR simulation (3:33 mins): few interactions during the VR simulation, with the Performer acting quietly and others engaged in observing Group reflection (8:48 mins): active discussions guided by the Facilitator. The Performer and Observers share experiences and opinions together, with few interruptions to others' sharing
8	3rd	Two girls and three boys	One girl was randomly assigned as Performer, as no one volunteered	VR simulation (4:11 mins): few interactions during the VR simulation, with the Performer acting quietly and others engaged in observing Group reflection (15:34 mins): active discussions guided by the Facilitator. The Performer and Observers share experiences and opinions together, with few interruptions to others' sharing
9	3rd	Three girls and two boys	One boy was randomly assigned as Performer, as no one volunteered	VR simulation (3:51 mins): the Performer searched for help and acted according to others' directions. Observers actively interacted with others. Group reflection (10:34 mins): active discussions guided by the Facilitator. The Performer remains relatively quiet while the Observers answer questions and share their opinions on behalf of the Performer.

In Group Case #1, there were four boys and one girl from a second-grade class. The Performer role was randomly assigned to the girl, as no one in the group had initially intended to take on the role. The group spent approximately eight minutes on the VR simulation, during which the Performer acted quietly to complete the tasks in the virtual environment while the Observers engaged in observing. It is worth noting that the Observers interacted with each other while not directly involved in the simulation. The research team faced some technical difficulties as the VR program collapsed midway through the simulation, causing the group to spend more time than planned (around five minutes). For the group reflection, the Facilitator led an active

discussion where both the Performer and Observers actively shared their experiences and opinions in response to the Facilitator's prompts.

Group Case #2 consisted of three boys and two girls from a second-grade class. One of the girls had previous experience with the VR program, having participated in a previous research project a year before the current study. However, she declined the invitation to act in VR, and the other girl volunteered to be the Performer. The group spent approximately four minutes in the VR simulation, with active interaction between the Performer and Observers. The Performer shared her views and thoughts throughout the process, while the Observers provided feedback and directed her actions in the virtual environment. During the group reflection section, the group engaged in an interactive discussion with the Facilitator for around 17 minutes. While the Observers actively shared their observations and opinions, there were some noticeable interruptions to the Performer's sharing.

In Group Case #3, there were four boys and one girl from a second-grade class. One of the boys in the group volunteered to be the Performer. The VR simulation lasted approximately five minutes, during which the Performer successfully completed the VR tasks. However, the Performer attempted to interact with the Observers, but they did not respond. Instead, the Observers interacted with each other, discussing the Performer's actions and laughing together. One of the Observers attempted to disrupt the Performer, but another Observer intervened to prevent this. During the group reflection, the group spent around ten minutes discussing their experience with the guidance of the Facilitator. The Performer actively responded to the Facilitator's prompts, while the Observers had less participation in the discussion.

Group Case #4 comprised one boy and four girls from a second-grade class. One of the girls in the group had previous experience with the VR program from a year before the current

study and volunteered to be the Performer. The Performer completed the VR tasks quietly and confidently, using less than four minutes to finish. The Observers were engaged in observing without much interaction with each other. During the group reflection, the Facilitator led the discussion, with the Performer actively sharing her experience while the Observers primarily listened. The discussion lasted for around ten minutes.

Group Case #5 consisted of one boy and four girls from a third-grade class. One girl was randomly assigned as the Performer as no one volunteered for the role. The Performer acted quietly during the simulation, completing the VR tasks in less than four minutes. The Observers were primarily engaged in observing with limited interaction with each other. The group reflection was led by the Facilitator and lasted for approximately seven minutes after the VR simulation. Both the Performer and Observers responded to the Facilitator's questions and prompts, but they did not actively share their opinions.

Group Case #6 involved one girl and four boys from a third-grade class. One boy volunteered to be the Performer, and he had prior experience with the VR program from a year before the study. The VR simulation lasted approximately four minutes, with the Performer talking throughout the process while the Observers focused on watching with minimal interaction with others. During the group reflection, which lasted around eight minutes, the Facilitator guided an active discussion. The Performer actively shared their views and opinions, while the Observers only responded to the Facilitator's questions when prompted.

Group Case #7 comprised two girls and three boys from a third-grade class. One boy was randomly assigned as the Performer as no one volunteered to be in the role. The Performer acted quietly during the simulation, finishing tasks in the VR program in less than four minutes. Observers engaged in observing with minimal interaction with others. The group engaged in an

active discussion guided by the Facilitator during the reflection section, with little interruption to others sharing their opinions. The discussion lasted approximately nine minutes.

In Group Case #8, there were three boys and two girls from a third-grade class. The role of the Performer was randomly assigned to one of the girls since no one volunteered for the task. The Performer completed the virtual assignment quietly within four minutes, while the Observers primarily observed without interacting much. During the group reflection session, which was led by a Facilitator, the group engaged in an active discussion that lasted about 16 minutes. Both the Performer and Observers listened while others were talking, seldom interrupting each other during the conversation.

In Group Case #9, there were two boys and three girls from a third-grade class. The Performer's role was assigned to one of the boys, as no one volunteered for the position. The VR simulation lasted for about four minutes, during which the Performer actively sought help and followed the Observers' directions. The Observers were highly engaged, actively interacting with each other and the Performer throughout the simulation. During the group reflection session, which was guided by the Facilitator, there were several instances where Observers answered questions and shared their opinions on behalf of the Performer. The reflection session lasted approximately ten minutes.

Overview of Case Analysis

The case analysis process follows the procedure of thematic analysis, which is a practical data analysis approach for qualitative inquiry (Kiger & Varpio, 2020). Thematical analysis entails searching across a data set to identify, analyze, and report repeated patterns (Braun & Clarke, 2006). Therefore, it is a powerful analytical method to summarize, highlight key features of, and interpret a wide range of data sets. This study employed an inductive approach to theme

identification, with a data-driven approach to derive themes from the data set (Varpio et al., 2017). Compared to a deductive approach using a pre-existing theory or framework to identify themes, an inductive approach provides a broader, more comprehensive analysis of the entire body of data (Kiger & Varpio, 2020).

The current study applied Braun and Clarke's (2006) six-step thematic analysis procedure, which has become the most widely employed method to analyze data and identify themes within the qualitative literature (Clarke & Braun, 2017). Specifically, the first step is familiarizing with the data, which was practiced throughout the process of collecting and reviewing the data set. The data set, including the on-site data collection and off-site researcher reflection, was organized according to group cases in this step. The second step is generating initial codes, which is discussed in details in the following section. Since this study aimed at exploring and comparing different roles' experiences in the group learning process, initial codes were generated based on roles (e.g., Performer, Observer, and Facilitator).

Based on the initial codes created in the second step, the third step is searching for themes. The theme identification process was based on continuous collaboration and negotiation between the two independent researchers. The fourth step is reviewing themes, which was conducted to revisit the generated themes to ensure their accountability across the time of the process. The fifth step is defining and naming themes, which mainly focuses on finalizing the themes and associated definitions. This step resulted in the findings of the study based on collaborative discussion and negotiation between the two researchers. The final step is producing the report, leading to the results of this study to address the research questions.

The Results of Coding

Based on the thematic analysis procedure, qualitative codes were manually created,

categorized, assembled, and organized into hierarchical landscapes and formats for content analysis and pattern detection. Qualitative data analysis software NVivo 12 was used to create and organize codes for further theme identification. Saldaña (2013) noted that the research questions can impact the coding decisions that researchers make. Therefore, given that the goal of the research was to examine and compare the experiences of different roles in VR-mediated group learning, distinct codes were developed for each role in the group cases.The coding process included two major stages before further analysis and theme generation (Saldaña, 2013): (a) an initial stage of open coding, intending to identify and label codes, and (b) a second stage of pattern coding, developing more analytical categories from the initial codes (Bazeley, 2013). Accordingly, the coding process provides a means of purposefully locating, identifying, sorting, and managing the data set, becoming the foundation for further analysis and theme generation (Bazeley, 2013; Yin, 2018).

To address the potential issues of inconsistency and lack of coherence that can arise when developing themes from research data through thematic analysis (Holloway & Todres, 2003), this study established trustworthiness through researcher triangulation (Lincoln & Guba, 1985). In particular, to ensure the reliability of the coding process, an intercoder agreement procedure was employed to verify the consistency of the coding process and the generation of themes. This involved a second researcher, who is an expert in the field, independently coding two group cases during the data analysis process and checking another. The intercoder reliability rates for these cases are shown in Table 4.2. Specifically, Group Case #3 was the first case selected and was coded independently by both coders. The initial intercoder reliability rate was 85%, but this improved to 97% after the coders discussed and negotiated any disagreements. Once a shared understanding of the codes was established in the first round of intercoder agreement, the two

coders randomly selected and coded another case (Group Case #7), and the reliability rate increased to 98% using the same process as before.

The author then coded the remaining group cases based on the established code scheme to address the research questions. Lastly, Group Case #6 was randomly selected to check the intercoder agreement rate, and the reliability rate for this case was also 97%, indicating that the intercoder reliability procedure was successful. Therefore, the two coders showed a shared understanding of the coding in this study.

Table 4.2

Intercoder Reliability Rates for Three Randomly Selected Group Cases

Session #	Case #	Code (N)	Agreement (n_0)	Initial Agreement Rate (n_0/N)	Agreement after adjustment (n_1)	Agreement Rate (n_1/N)
1	3	195	165	85%	190	97%
2	7	188	159	85%	185	98%
3	6	220	200	91%	214	97%

Note. In the data analysis process, three rounds of intercoder agreement checks were conducted. For Session #1 and #2, intercoder reliabilities were calculated based on the independent codes of two coders and their subsequent negotiation. In Session #3, the intercoder reliability was calculated based on the second coder's review and agreement on the author's independent codes.

To aggregate the initial codes into categories, the two coders engaged in discussions and negotiations in the second stage of coding. The data resource for this study mainly consisted of videos, and the units of code were behaviors that occurred in a short time. To assist with the coding process, sound and word messages from the videos were transcribed. In addition, the VR-mediated group learning in this study consisted of two parts: VR simulation and group reflection,

each addressing different research questions. As a result, the analysis process examined the two parts separately. Tables 4.3 and 4.4 summarize the results of the two stages of coding from the nine group cases.

For the VR simulation activity, 105 codes emerged from the data coding units, including 28 codes indicating Performer's behaviors and 77 codes for Observer's. Furthermore, the 28 codes of Performer's behaviors were reduced to six categories, merging similar codes to indicate different types. Observers' behavior codes were reduced to seven categories with a similar process. Table 4.3 shows the initial codes generated from the nine group cases, with the frequencies of group cases including the code and references in which the content was reported. With the initial codes and categories, themes are generated to address Research Question One. The details of Table 4.3 and generated themes will be addressed in the following sessions.

Table 4.3

Results of Open Codes and Category for the VR Simulation Part

Category | Open Code	**Frequency**	
	Case	**Code**
Role: Performer (6 categories, 28 codes)		
Spontaneous action/reaction in VR	**9**	**214**
Chuckle while performing in VR	1	2
Think out loud with their thoughts in VR	2	23
Have control in VR to act as they want	6	15
Have control in VR to obtain balance on their own	3	5
Have control in moving freely in VR	9	157
Lose balance with a certain action in VR	1	3
Unaware of the physical environment	4	9
Independent (conscious) action to accomplish the assignment	**9**	**199**
Actively interact with virtual objects	2	4

Freely explore the VR environment (not related to accomplishing the assignment)	1	4
Navigate in the virtual environment	9	97
Interact with the virtual environment to accomplish the assignment	9	69
Make safe decisions to complete the assignment	9	19
Not follow the Observers' direction (make their own decisions)	2	4
Not follow the VR guidance (make his own decision)	1	1
The Performer's previous experience hinders his action in VR	1	1
Responsive actions in VR	**9**	**27**
Respond to the Guider's facilitation (reply to the Guider's question)	6	19
Look around to check objects mentioned by Observers	2	3
Reply to the Observers' comments	3	5
Influenced actions in VR	**9**	**39**
Act according to the Observers' request	3	3
Act with the information provided by Observers	2	2
Follow the Guider's direction	9	25
Follow the Observers' direction	4	9
Active interaction with others	**6**	**18**
Ask for confirmation of her desired action	2	2
Seek out help	4	4
Share her interactions with the virtual environment	2	5
Share out loud what they see in VR	3	7
Others	**2**	**7**
Ask questions about the VR program	2	4
Comment on the VR program	1	3
Role: Observer (7 categories, 77 codes)		
Engaged (conscious) observation	**9**	**336**
Look at the Performer	9	79
Look at the screen	9	174
Look at the Performer and screen	9	65

Observers have different focuses for their observation	5	18
Spontaneous Action/Reaction during Observation	**9**	**80**
Imagine performing (mimic walking) in VR	7	18
Point to the Performer	3	11
Point to the screen	6	24
Think aloud, imagining he has control in VR	1	1
Think aloud, interpreting the virtual object	1	1
Think aloud, preparing for his own VR experience	1	1
Think aloud regarding the virtual scene	2	2
Think aloud as they are in VR	3	13
Use body language (gesture) to indicate the direction in VR	5	7
Use gestures to illustrate something to another Observer	2	2
Responsive Action/Reaction during Observation	**5**	**43**
Laugh out loud with the Performer's response to their direction	2	4
Laugh after the Performer seeks help (with no action)	2	2
Look at the Observer who directs the Performer	2	2
Look at the Performer after the Performer makes certain actions in VR	3	13
Look at the Performer after the Performer seeks help	1	1
Reply to the Performer's question	3	7
Respond to other Observers' suggestions on the virtual scene	2	4
Respond to the Guider's facilitation (on behalf of the Performer)	3	6
Respond to the Performer's share with the virtual scene	1	1
Respond to the virtual scene with physical actions	2	3
Proactive Actions	**5**	**37**
Comment on the Performer's action in VR	4	7
Comment on the task in VR (think like a Performer)	1	4
Describe the virtual scene	5	20
Predict/guess what happens next in VR	1	4
Predict/guess the Performer’s following action in VR	1	2

Active Interactions with the Performer	**6**	**65**
Ask the Performer about their virtual experience	1	1
Direct the Performer not to act	3	5
Direct the Performer to act	6	39
Encourage the Performer	2	2
Provide information to the Performer	5	10
Share strategies with the Performer	1	1
Suggest the Performer how to act	2	3
Talk with the Performer regarding the virtual scene		
Warn the Performer of dangerous situations or behavior	3	4
Active Interactions with other Observers	**6**	**45**
Challenge other Observers' direction on the Performer's action	2	3
Discuss the Performer's action in VR with other Observers	1	2
Discuss the virtual scene with other Observers	2	4
Illustrate something to another Observer with a gesture	1	1
Look at another Observer after observing something	2	9
Look at another Observer after the Performer makes a decision in VR	1	3
Prevent others from disturbing the Performer	1	2
Whisper to another Observer	7	21
Simultaneous and Interrelated Actions	**7**	**90**
Chuckle while interacting with other Observers	1	1
Chuckle while observing the Performer	5	14
Chuckle while observing the screen	3	3
Look at the Performer and laugh out loud	2	2
Look at the Performer and predict the following VR scene	1	1
Look at the Performer and smile	1	2
Look at the screen and comment on the Performer's action	1	1
Look at the screen and describe the virtual scene	3	9
Look at the screen and direct the Performer to act	4	13

Look at the screen and discuss with other Observers	4	7
Look at the screen and imagine performing in VR	3	5
Look at the screen and predict the Performer's action in VR	1	2
Look at the screen and provide information to the Performer	2	3
Look at the screen and reply to the Performer's question	1	1
Look at the screen and suggest to the Performer how to act	1	1
Look at the screen and talk with the Performer regarding the virtual scene	1	1
Look at the screen and think aloud about the virtual scene	2	2
Look at the screen and warn the Performer of a dangerous situation	3	3
Look at the screen and whisper to another Observer	2	4
Talk to another Observer while mimicking performing in VR	1	1
Point to the Performer and whisper to another Observer	1	1
Point to the screen and describe the virtual event	5	6
Point to the screen and direct the Performer to act	1	1
Point to the screen and discuss with other Observers	2	2
Point to the screen and indicate the virtual object	1	2
Point to the screen and use gestures to indicate a direction	2	2
Others	**3**	**6**
Off-task attention	2	2
Off-task conversation between Observers	1	3
Off-task interaction between Observers	1	1

For the group reflection part, 137 codes emerged from the data coding units, including 33 codes addressing the Performer's actions, 54 codes for the Observers, and 50 for the Facilitator. The second coding stage reduced the three roles' initial codes to four categories, merging codes indicating different stages of group reflection. Table 4.4 shows the open codes and categories generated from the nine group cases, with the frequencies of group cases including the code and references in which the content was reported. With the initial codes and categories, themes are

generated to address Research Question Two. The details of Table 4.4 and generated themes will be discussed in the following sessions.

Table 4.4

Results of Open Codes and Category for the Group Reflection Part

Category ⎮ Open code, frequency	Frequency	
	Case	Code
Role: Facilitator (50 behavior codes)		
Guidance on Retrospection	**9**	**305**
Ask the Performer to recall what they saw	9	35
Ask the Performer to recall what they heard	8	14
Ask the Performer to recall what they did in specific situations	9	36
Ask the Performer's thoughts during the experience	9	30
Ask the Observer to recall what they see	6	10
Ask the Observers' observation of the Performer's action	3	7
Ask Observers' actions during the Performer's VR simulation	2	2
Ask the Observer's thoughts on the experience	5	11
Ask the group to recall detailed information	6	7
Ask the Observer to recall detailed information	6	14
Ask the Performer to recall detailed information	9	56
Lead further retrospection with critical cues	7	12
Guide on retrospection by describing the VR scenario	9	31
Guide on retrospection by describing the Performer's action	6	19
Guide on retrospection by describing the group's action	2	3
Repeat the Observer's description of their observation	3	6
Repeat the Performer's description of the VR experience	8	12
Ask for Interpretation	**9**	**46**
Ask the group to interpret a critical sign or signal	9	29
Ask the Performer to interpret a critical sign or signal	5	8

Ask the Observer to interpret a critical sign or signal	6	9
Ask for Decision Making	**9**	**82**
Ask the group's opinion on hypothetical questions	9	24
Ask the Performer to answer hypothetical questions	8	10
Ask the Observer to answer hypothetical questions	4	6
Ask for decisions in a specific situation	9	42
Ask for Explanation	**9**	**25**
Ask the Performer to explain certain behavior in VR	7	13
Ask the Performer to further elaborate on certain decision-making	3	5
Ask the Observer to further elaborate on certain decision-making	4	7
Support on Knowledge construction and Transfer	**9**	**104**
Ask about the resource of mentioned knowledge	1	2
Ask about daily behaviors beyond the VR experience	3	4
Clarify unclear/incomplete descriptions mentioned in the group	2	2
Confirm the group's prediction in specific situations	2	3
Guide on safe pedestrian behaviors	9	51
Guide on pedestrian knowledge	9	32
Explain the reason for certain safe pedestrian behaviors	2	2
Summarize the safe pedestrian behavior or solution	6	8
Facilitation on Teamwork	**9**	**131**
Diagnose reasons for possible issues	5	8
Direct attention to a certain topic	9	25
Direct attention to those who are interrupted by others	3	4
Induce discussion by asking for agreement on certain opinions	2	3
Induce discussion by asking others' thoughts	9	46
Solicit all opinions in the group	2	3
Invite Observers to participate in the discussion	8	23
Invite Performer to participate in the discussion	3	8
Induce discussion by contrasting different opinions in the group	4	5

Induce discussion by interpreting the Performer's action in VR	2	2
Induce discussion by suggesting ideas not mentioned by the group	1	1
Explain possible reasons for issues in a given situation	2	3
Role: Performer (33 behavior codes)		
Retrospection and Description of the Experience	**9**	**211**
Describe what they heard (by answering questions)	6	11
Describe what they saw	9	39
Simply indicate what they saw by answering questions	1	6
Describe what happens in the VR scenario	5	15
Describe what happens to them in VR	2	2
Describe what they did in VR	8	30
Indicate what they did by simply answering questions	3	8
Exhibit what they did with body language/gestures	2	4
Describe their thoughts in specific situations	9	22
Can't illustrate their thought during VR (respond with silence or not know)	2	3
Indicate that they thought about nothing during VR	1	4
Point to a location on the map to indicate detailed information about their VR experience	6	19
Indicate heir confusion in a specific situation in VR	2	3
Forget detailed information in VR (cognitive load)	2	6
Miss critical cues in VR	3	6
Notice critical cues in VR	9	33
Analysis and Thinking about the Experience	**8**	**25**
Explain their actions in VR	4	10
Interpret a critical sign (by answering questions)	5	9
Interpret a critical sign with further explanation	4	4
Share heir daily pedestrian practice in a specific situation	1	2
Knowledge Construction and Decision Making	**9**	**41**
Make their decision in a given situation	9	21
Elaborate their decision-making by answering questions	1	1

Explain their decision-making in a given situation	2	2
Predict results from hypothetical behaviors	9	17
Interactive and Collaborative Meaning-making	**5**	**16**
Agree with others' decision-making in a given situation	2	2
Suggest alternative decision-making in a given situation	1	1
Complement others' opinions	1	1
Complement safe decision-making in a given situation	1	3
Complement the knowledge discussed in the group	1	2
Agree with others' prediction from hypothetical behaviors	3	3
Try to answer about their VR experience but is interrupted	2	3
Being upset when Observers' comment on their actions	1	1
Role: Observer (54 behavior codes)		
Retrospection and Description of the Experience	**9**	**194**
Describe what they saw on the screen	9	33
Simply indicates what they saw by answering questions	5	7
Indicate what they saw beside the Performer's description	3	6
Describe what they heard from VR	2	2
Describe the Performer's actions in VR	7	22
Describe situational information related to the Performer's action	6	13
Describe details that the Performer didn't remember	2	2
Mimic the Performer's actions in VR to indicate what they see	1	3
Describe their actions during the Performer's VR simulation	4	5
Describe their thoughts during the Performer's VR simulation	4	4
Answer they thought nothing during the Performer's VR simulation	5	6
Describe their related experiences (for those who had VR experience)	1	3
Point to a location on the map to indicate their observation in VR	6	27
Comment on another Observer's thoughts on the Performer's actions	1	2
Comment on the Performer's actions in VR	3	7
Have limited VR experience with audio modality	4	7

Answer questions regarding the VR events on behalf of the Performer	3	10
Miss critical cues in VR	3	6
Notice critical cues in VR	9	19
Notice the Performer's actions in VR	6	10
Analysis and Thinking about the Experience	**9**	**80**
Interpret a critical sign (by answering questions)	9	28
Interpret the Performer's actions in VR	3	5
Analyze safe pedestrian decisions in a specific situation	2	3
Can't explain their decision-making (respond with silence or do not know)	2	2
Try to explain their decision-making but is interrupted	1	1
Can't interpret a critical sign (by answering questions)	2	2
Explain their decision-making in a given situation	5	10
Predict results from hypothetical actions	9	29
Knowledge Construction and Decision Making	**9**	**64**
Ask questions related to their decision-making in a given situation	1	1
Complement others' interpretation of a critical sign or signal	2	5
Complement the knowledge discussed in the instruction stage	2	5
Complement the safe behavior discussed in the instruction stage	3	4
Make one's decision in a given situation	9	39
Plan for one's own VR experience later	1	3
Share one's daily pedestrian practice regarding a specific situation	3	3
Suggest alternative actions in a given situation	2	3
Summarize safe pedestrian behaviors in the discussion	1	1
Interactive and Collaborative Meaning-making	**9**	**67**
Agree with others' decision-making in a given situation	8	15
Agree with others' interpretation of a critical sign or signal	5	7
Agree with others' prediction from hypothetical behaviors	5	6
Agree with the Performer's description of the VR scenario	3	5
Challenge others' opinion by showing disagreement	2	3

Challenge others' opinion by predicting potential results	2	2
Challenge others' interpretation by showing disagreement	2	3
Challenge others' decision-making by suggesting alternative situations	2	3
Challenge the instruction by suggesting a hypothetical situation	1	2
Challenge the Performer's retrospection	1	1
Comment on others' decision-making in a specific situation	1	1
Complement on others' analysis	4	7
Deny their previous suggestion after getting challenged	1	1
Interrupt the Performer to explain the Performer's actions in VR	1	2
Interrupt the Performer to describe their own experience instead	3	3
Interrupt the Performer's retrospection and describes what they saw	2	3
Interrupt others to explain a certain decision making	2	2
The Group as An Unit (15 behavior codes)		
The group complements the safe behaviors suggested in specific situations	2	2
The group interprets a critical sign by answering questions	6	8
The group interprets a critical sign by linking to a safety formula	1	1
The group predicts the same results from hypothetical behaviors	9	13
The group predicts different results from hypothetical behaviors	2	3
The group shares their daily pedestrian practice by answering questions	2	7
The group suggests the same decisions regarding a specific situation	5	11
The group suggests different decisions regarding a specific situation	3	6
The group agrees with the safe pedestrian behaviors suggested by the Facilitator	9	17
Observers' different focuses in observation	2	3
Observers' inconsistent experiences in catching cues in VR	1	1
Performer and Observers' inconsistent experiences in catching cues in VR	2	2
The group discusses the VR program (not related to the reflecting activity)	2	5
The group's off-task attention	3	10
The group's off-task interactions	2	4

In the following section, we report the study's results by the three research questions. Specifically, Research Question One and Two explore the group dynamics with different roles (e.g., Performer, Observer, and Facilitator), which can be answered by the qualitative data analysis. Research Question Three examines and compares the two roles' (Performer and Observer) learning outcomes from the VR-mediated group learning, which is answered by the qualitative and quantitative data collected in this study. Accordingly, the three research questions will be addressed in the following sections.

Research Question One: Two Roles' Experiences during VR-mediated Group Simulation

This section presents the findings from the data analysis that aim to answer Research Question One: How do learners with different roles (Performer vs. Observer) experience during the simulation of VR-mediated group learning? What are the similarities and differences in their experiences?. Initially, I investigated the two roles' actions during the VR-mediated group simulation to distinguish their distinctive behaviors (see Table 4.3). Then, using the first and second stages of coding analysis, I identified emergent themes to summarize the two roles' experiences in the VR simulation. Lastly, I compared the experiences of the two roles and generated themes that highlight their similarities and differences.

Different Types of Behaviors Identified from Initial Coding

Table 4.3 lists the initial codes and categories of the Performer' and Observer's behaviors during the VR-mediated group simulation. Specifically, the Performer's 28 behavior codes are categorized into six different types of actions: (a) Spontaneous Action, indicating the Performer's natural behaviors in the virtual environment. For example, Performer looks and moves spontaneously in VR to navigate in a certain direction. The role also responds naturally to the virtual objects to accomplish tasks in VR; (b) Independent (Conscious) Action, which suggests

the Performer's active and self-decided actions in VR to complete the assignment. For example, the Performer makes their own decisions according to the signals in VR. The role also consciously explores the virtual world with a purpose unrelated to the VR tasks; (c) Responsive Action, indicating the Performer's response to others' intervention; (d) Influenced Action, suggesting the behaviors enacted due to others' presence or involvement. For example, Performer follows the Observer's direction or request. The Performer also responds to others' comments or directions to indicate others' influence; (e) Active Interaction with Others, such as sharing what they see with others, seeking help, or asking others' opinions regarding one's decisions, and (f) Other Behaviors that not related to the group learning activity, such as curiosity on the VR program.

The Observer's 77 behavior codes are categorized into seven different types of actions: (a) Engaged Observation, including the Observer's conscious observation of the VR scenes and Performer's actions; (b) Spontaneous Action, indicating the Observer's unconscious and immediate behaviors during observation. For example, the Observer uses body language to imagine performing in VR; (c) Responsive Action, including Observater's reactions to the VR program and others' behaviors; (d) Proactive Action, suggesting the Observer's behaviors that go beyond the explicit requirement of the role. For example, the Observer predicts what would happen next in VR or suggest what the Performer should do; (e) Active Interaction with the Performer, specifically indicating the Observer's interactive attempts and actions with the Performer, such as directing the Performer to act; (f) Active Interaction with other Observers, specifically indicating the interactive behaviors happen between the Observers, such as discussion between Observers regarding observed objects; and (g) Other Behaviors not related to the learning activity, such as off-task interactions between Observers. Notably, some behaviors

can happen simultaneously, especially for actions occurring with Engaged Observation.

Table 4.5 compares the two roles' behaviors with generated categories. Interestingly, the two roles shared similar types of behaviors during the VR-mediated simulation, though they had different resources and approaches to the VR simulation. The off-task behavior is not included in the comparison since we only focus on the types of behaviors related to the research questions. Accordingly, five types of behaviors are listed in Table 4.5 to present and compare the two roles' behaviors in the group. The role of Performer was given the immersive VR resources to finish the pedestrian task in the virtual environment, and the Observer was presented to observe the real-time simulation process with the freedom to interact with both the Performer and other Observers. With the tacit missions in the group setting, five types of behaviors are categorized from the initial codes to illustrate the Performer' and Observer's experiences.

Table 4.5

Comparison of the Performer' and Observer's Behaviors in Immersive VR-mediated Group Simulation

Behavior	**Performer** Finish the pedestrian tasks in VR	**Observer** Present and observe the peer actor and VR program
Spontaneous	React to the VR environment React to the Observers' intervention Navigate in the virtual environment Lost balance in the physical environment	React to the VR environment React to the Performer's actions Imagine walking in VR
Responsive	Respond to the Guider's direction Respond to the Observers' comments /requests	Respond to the Guider's direction Respond to the Performer's needs/requests Respond to other Observers' actions
Independent /proactive	Have control to act as one wishes Conscious decision-making in specific situations	Influence the Performer to act Conscious decision-making in specific situations

	Actively interact with the virtual objects	Engaged observation Comment / think aloud regarding one's observation
Influenced	Act to get others' attention Act according to others' direction /suggestion	Act to get others' attention Enact or stop certain actions due to others' encouragement or prevention
Interactive	Actively interact with Observers	Actively interact with the Performer Actively interact with Observers

Firstly, the Performer was fully immersed in VR with spontaneous behaviors to navigate and interact with the virtual environment. The Observer also displayed unconscious reactions to the VR program alone with their close observation of the Performer and the screen. For example, the Observers stepped on their feet and waved their hands to imagine moving in VR with the Performer. Meanwhile, with others present in the group, both roles reacted to each other spontaneously. For example, when the Observers talked about things in the VR program, the Performer turned to the mentioned virtual object unconsciously. Similarly, the Observer reacted to the Performer's actions naturally without premeditation. For example, when the Performer hit a wall in VR, the Observer would lean back to show their spontaneous reactions. Noticeably, the role of Performer lost their balance in the physical environment with their full immersion in the virtual world. As a result, the Performer spontaneously stepped out of the working zone or adjusted their balance in the physical world during the simulation.

Secondly, both roles showed responsive behaviors with others in the group setting. Interestingly, both roles responded to the Guider's direction, although only the Performer had control in the virtual environment to act as the Guider suggested. The Performer responded to the Guider by replying to questions or acting in the direction the Guider suggested. Meanwhile, the Observer responded to the Guider by repeating the suggestion or answering questions on behalf

of the Performer. For example, when the Guider directed the Performer with virtual objects, “do you see the road in front of you? You could go to cross it.” Both the Performer and Observer would respond to the question, “I see it.” (Group Case #1, #5). However, only the Performer can respond to the directive information with actions in VR. Meanwhile, the two roles responded to each other’s requests and comments. For example, the Performer acted according to the Observers’ requests/directions/suggestions, and the Observer replied to the Performer’s questions /inquiries/ needs. In addition, the Observer also responded to other observers’ behaviors and attempts at interaction. For example, the Observers reacted to each other’s comments on the virtual scenes (e.g., Group Case 3).

Thirdly, the Performer’s independent behaviors and the Observer’s proactive behaviors are considered the same type of behaviors. The Performer had control to act as they wished to make an impact in VR, and the role made conscious and independent decisions to accomplish the tasks despite others’ intervention. On the contrary, the Observer also created an impact on the virtual environment by actively influencing the Performer. Through engaged observation of the virtual environment and the Performer’s actions, the Observer thought aloud their reactions to the VR tasks and asked the Performer to enact their plans. Accordingly, the role also made conscious decisions to accomplish the tasks through their proactive behaviors.

Fourthly, the two roles showed behaviors not only from one’s will but are influenced by others. Specifically, the role of the Performer could easily be influenced to act according to others’ directions or suggestions. For example, Observers hurried the Performer to “walk faster” (Group Case #2, #3) or “check the pedestrian traffic light” (Group Case #1, #5), and the Performer acted as others suggested spontaneously or responsively. Because of the Observers’ present and active involvement, the Performer acted in a certain way that they might not do the

same by themself. In contrast, the Observer was mainly influenced by peers with the same role in the group. Observers discussed with each other the Performer's actions and the virtual scenes. Additionally, the Observer's actions were encouraged or prevented by others in the group. For example, an Observer intended to touch the Performer and test if they could see things in the physical world, while another Observer prevented such action from protecting the Performer (Group Case #3).

Lastly, interactive behaviors are found in both roles as the Performer and Observers interacted with others in the group. The Performer actively interacted with Observers by sharing views and thoughts from their side and asking for opinions and help from others' side. For example, the Performer asked the Observers' views to get confirmation on his decision, "can I go now?" (Group Case #7). Compared to Performer's limited interaction with others, the Observer had various interactive behaviors with both the Performer and other Observers. For example, the Observer showed both prosocial and antisocial attempts to interact with the Performer. The Observer provided suggestions and emotional support to the Performer to help her finish the virtual tasks (Group Case #2, #9). Meanwhile, the Observer also hindered the Performer's actions by tricking or disrupting the role (Group Case #3). The interaction between Observers was mainly based on what happened in the group. The Observers tended to communicate with other observers, who shared the same roles as them in the group, regarding their observations on the simulation.

Findings from the Inductive Data Analysis

According to the categorical aggregation of the Performer' and Observer's behaviors, emergent themes are summarized from the inductive data analysis to illustrate the two roles' experience in the VR-mediated group simulation. Specifically, three emergent themes are found

to show the Performer's experience, and six themes are drawn for the Observer's experience. Meanwhile, the similarities and differences between the two roles' experiences are summarized from the comparison between their behaviors and experience. Finally, this section reports the findings of Research Question One with generated themes and visual displays to indicate our conclusions regarding the VR-mediated group simulation.

Emergent Themes regarding the Performer's Experience in Simulation

Three themes emerged from the inductive data analysis regarding the Performer's experience during the VR-mediated group simulation (see Table 4.6). First, the Performer's gains and losses with immersive VR technology are found in the data analysis. The Performer has full access to the VR program with multimodal experiences, and the role has the control to impact the virtual world. With access and power in the virtual environment, the Performer has the implicit mission and awareness to make their decisions to accomplish the tasks in VR. However, the privilege of being fully immersed in VR disconnects the Performer from the physical world. The role has decreased their sensibilities to stimuli in their surrounding area due to the multimodal immersion in VR. As a result, the Performer can easily lose track of their position and balance in the physical world.

Second, the role of Performer is bound to unclaimed duties requiring their efforts to fulfill. As a student volunteers or is assigned to the role, they need to wear the VR equipment and get immersed in the virtual world. The role of the Performer is linked to a tacit responsibility: accomplishing the tasks in the VR program in the presence of four peers. Accordingly, the role needs to orient and adjust themself in the virtual world, overcoming any difficulties caused by the setting (e.g., can't see one's physical environment and learning how to move in the virtual environment). Meanwhile, the role needs to finish the VR tasks, requiring one to make decisions

with certain pedestrian knowledge and understanding of complex situations. For example, the Performer needs to make their decision to cross the road when the traffic rule allows them to do so, while it can be dangerous/risky with uncontrollable factors. Additionally, the role needs to accept others' presence and related interventions. The Performer does not accomplish the VR task by themself but in the company of others, including the safety Guider who intends to help them, four peer Observers from the same class, and researchers who are present to collect data. The presence of various people can cause unpredictable interventions to the Performer's simulation experience.

Third, the hybrid learning environment with peer Observers' involvement affects the Performer's actions and decision-making. The learning group is formed with peers from a class, which may bring pre-established social relationships into the group learning process. Accordingly, the Performer is affected merely by knowing peer Observers' presence. Such awareness of others' presence can lead to an unconscious change in one's behaviors. The Performer also actively invites Observers' involvement in their decision-making. For example, the Performer asked the Observers' opinions on their attempted decision to get confirmation (Group Case #3). In addition to the invited involvement, the Observer actively influences the Performer's actions and decision-making through commenting and sharing information. For example, Observers direct the Performer to act in specific ways that reflect their decisions and wishes (Group Case #2). Meanwhile, more than one Observer causes intervention on the Performer due to their interactions. For example, the Performer is affected by conversations between Observers.

Table 4.6

A Summary of the Emergent Themes regarding the Performer's Experience in Simulation

Theme	Explanation
Gain and loss with the immersive VR technology	• The Performer has full access to the virtual world with multimodal experiences • The Performer has the control and awareness to make their own decisions in the simulated environment • An immersive VR environment disconnects the performer from the physical world with a decreased sense of their surrounding area
Unclaimed efforts and duties bound with the role	• The Performer needs to orient and adjust themself in the virtual environment • The Performer needs to accomplish the pre-determined goal of finishing the tasks in the VR • The Performer needs to accept others' presence and any intervention
Affected actions and decision-making in the group setting	• The Performer is affected by others unconsciously • The Performer is aware of others' presence and asks for their involvement in decision-making • The Performer responds to others' requests and directions

Emergent Themes regarding the Observer's Experience in Simulation

Six themes emerged from the inductive data analysis regarding the Observer's experience during the VR-mediated group simulation (see Table 4.7). First, the Observer can obtain a sense of mental immersion in VR through engaged observation. Although the role did not put on the VR equipment to immerse in VR, the Observer displayed spontaneous reactions to the virtual environment by watching the desktop screen. For example, the role used body language to indicate moving in the virtual world (Group Case #1, #6). More importantly, the Observer showed thinking as the actor in VR while observing the peer's performance. For example, the Observer had think-aloud comments on the Performer's movement to cross a rod, "only if I can walk faster (in VR)" (Group Case #2).

Secondly, the Observer can interact with the virtual world by influencing the Performer's action. The Observers impacted the virtual environment, though they had no direct control of the

VR program. Observers asked or directed the Performer to enact their deliberate actions to try out their decision-making. For example, the Observers urged the Performer to cross the road before the traffic signal changed, “run! Go faster, faster!” (Group Case #9).

Thirdly, the Observer has the advantage of shifting perspectives between the virtual and physical worlds. Compared to the Performer’s full immersion in VR, the Observer had access to the virtual world through the desktop screen and was fully aware of their surrounding environment. Accordingly, the role can shift sights and perspectives between the worlds to make sense of the hybrid learning setting. For example, Observers discussed the VR tasks with other Observers from the physical environment (Group Case #7). The Observer also planned for their experience in the virtual world based on their observations of others’ actions. For example, noticing the Performer did not look upward to check the traffic signals, one Observer shared his plan for further VR experience, “then I will look up to check the traffic signal.” (the students’ height requires them to look upward to see the traffic signal that attached to a high place)

Fourthly, the Observer develops a sense of ownership/collaboration by helping the Performer accomplish the assignment. Although there was no pre-determined rule regarding how the group worked together, most group cases showed collaboration in finishing the simulation tasks. Furthermore, the Observer supported the Performer in completing the assignment by providing suggestions/directions (e.g., Group Case #9), encouragement (e.g., Group Case #2), and efforts to prevent disruption and promote the process (e.g., Group Case #3). Accordingly, finishing the VR simulation became not merely the Performer’s mission but a shared and collaborative experience for the Observers.

Fifthly, Observers play multiple roles in the VR-mediated group simulation. Throughout the data analysis with the 45 Observers from the nine group cases, five profiles are identified to

illustrate the different roles Observers play during the simulation. There were Observers simply present in the group as a *bystander* without much involvement except engaged observation (e.g., Group Case #4). Some Observers imagined simulating in VR with the Performer as a *co-player*, mimicking taking actions in VR (e.g., Group Case #2). There were Observers acting as the *director* (e.g., Group Case #7), asking the Performers to act in the way they wanted. Additionally, some Observers behaved as a *disturber* of the Performer's acting process (e.g., Group Case # 3), while others were more like a *helper* to support the Performer in finishing the assignment (e.g., Group Case # 9).

Lastly, Observers can influence each other's observational experience during the VR-mediated group simulation. Since there was more than one Observer in a group, Observers interacted with each other as well as with the Performer. Different interactive behaviors were found between Observers from the data analysis process, which suggests the Observer's experience was also influenced by others who shared the same role in the group. For example, Observers were found to share their observed information and opinions with each other. Furthermore, when an Observer directs others' attention to their focus, he influences other Observers' information-taking from their perspective. Meanwhile, Observers were also found to interact with each other during the simulation, including discussing the Performer's actions and exchanging opinions on the VR tasks. Additionally, Observers were found to encourage or prevent other Observers' actions in the group, leading to unique experiences created by the interactions.

Table 4.7

A Summary of the Emergent Themes regarding the Observer's Experience in Simulation

Theme	Explanation
The sense of mental immersion obtained through engaged observation	• The Observer reacts spontaneously to the virtual environment while observing the desktop screen • The Observer mimics moving in VR to react to the virtual environment • The Observer thinks like the performer while observing the peer's performance in VR
Interacting with the virtual environment through the Performer	• The Observer influences the Performer to act from their perspective on the virtual environment • The Observer asked the Performer to act according to their decisions
The flexibility of shifting perspectives between the virtual and real worlds	• The Observer thinks like acting in the virtual world • The Observer discusses the VR scenes and tasks with others in the real world • The Observer plans for their VR experience based on observation of the Performer's actions
A sense of ownership in the simulation experience through helping the Performer finish the task	• The Observer thinks actively about solving problems in VR • The Observer encourages and supports the Performer to complete the assignment • The Observer prevents others from disturbing the Performer
Multiple roles the Observer can play	• Observers play multiple roles during the performer's task accomplishment, such as co-player, helper, disturber, director, and bystander
Influenced observational experience due to other observers	• The Observer discusses and shares their perspectives and opinions with other observers • The Observer interacts with others to direct their attention • The Observer encourages or prevents other observers' actions in the group

Comparing the two Roles' Behaviors in Immersive VR-mediated Group Simulation

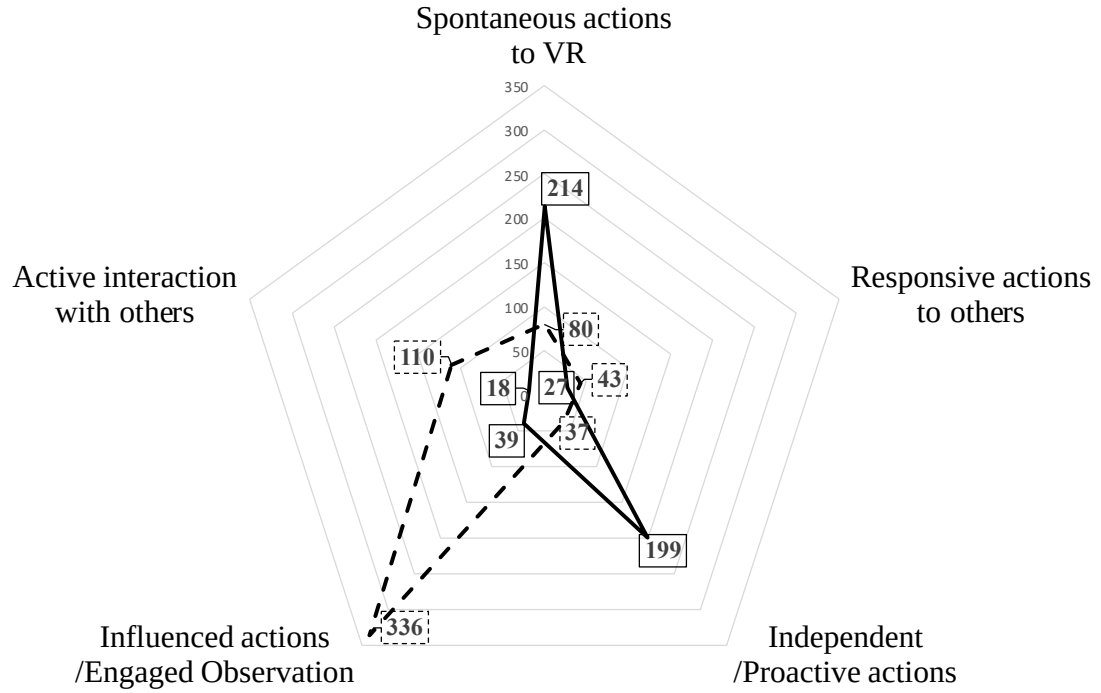
The Performer' and Observer's behaviors in VR-mediated group simulation were compared according to the identified behavior categories (see Table 4.3) and emergent themes on their experience (see Table 4.6 and Table 4.7). Noticeably, The two roles had similar behaviors during the VR simulation (see Table 4.5 for detailed comparations). Although the Performer and Observer had different access to the VR program—one was fully immersed in VR with control,

and the other saw the virtual world from projection—they both had active and responsive actions to the virtual world. The Performer actively acted and responded to accomplish the tasks in the VR program, while the Observer responded to the virtual world unconsciously and proactively during their observing process. Accordingly, both roles displayed *spontaneous*, *responsive*, *active decision-making* actions in the VR program. Meanwhile, *interactive* behaviors between the two roles also happened in VR mediated group learning, where they were connected through the real-time projection of the VR program and free communication between each other.

The difference between the two roles' behaviors is also apparent. Since the Performer was the only person simulated in VR, the role was exposed more to the virtual world, triggering various *spontaneous actions* during the simulation process. Meanwhile, since the Performer had the control and implicit duty to accomplish tasks in VR, the role enacted more *conscious* and *independent actions* than the Observer. Furthermore, the Performer was the only person in the group who could actually make an impact on the virtual world, therefore, endured others' presence and active involvement to enact *influenced behaviors*. In contrast, the Observer's behaviors in the group were based upon their notice of the Performer's action and the virtual world projected on the screen.

The behavior pattern identified from the initial coding (see Table 4.3) provide a means to compare the actions of the Performers and Observers in immersive VR-mediated group simulation. By analyzing the frequency of each behavior categories, a radar image is generated to show and compare the two roles' behaviors during the simulation process. Figure 4.1 illustrated five types of behaviors that were compared, including Spontaneous actions to VR, Responsive actions to others in the group, Independent/ proactive actions, Influenced action/ Engaged observation, and Active interactions with others. The solid line represents the Performer, the

dashed line indicates the Observer, with the frequencies of each behavior category are marked in the figure. For example, the nine Performers exhibited 214 instances of Spontaneous actions in VR, whereas the thirty-six Observers displayed 80 instances of Spontaneous actions toward the virtual environment. As the radar image shows, the Performers had more actions regarding their reactions and decision-making in the virtual environment. In comparison, the Observers had more actions influenced by others, such as observing and interacting with others.



Note. The numbers indicate the frequencies of observed behaviors of the Performers and Observers across the nine group cases. Table 4.3 shows the detailed information with specific actions under each behavior category.

Figure 4.1

A Radar Image Comparing the Performer' and Observer's Actions

Research Question Two: Group Reflection on the VR-mediated Group Experience

This section presents the results of the data analysis that aim to answer Research Question Two: How do learners with different roles (performer vs. observer) reflect together on their experiences of the VR simulation? Firstly, I examined the behaviors of three different roles (Performer, Observer, and Facilitator) during group reflection to identify any pattern codes (see Table 4.3). Then, using the first and second stages of coding analysis, I identified emergent themes to summarize how the Performer and Observer reflect together with the guidance of a Facilitator. Lastly, I reported the findings from the data analysis to illustrate the characteristics of group reflection in VR-mediated group learning.

Code Scheme of Different Roles' Actions in Group Reflection

Based on the initial coding, the Performer exhibited 33 different actions in group reflection, the Observer had 54, and the Facilitator had 50 actions. Table 4.8 presents the coding scheme used to identify the behaviors of three roles from the data set. The first character of the indicator is used as to suggest the role, and a following character is applied to differentiate different behaviors of the role. For example, "F-" denotes one action of the Facilitator, and "F-R" signifies the Facilitator's behavior of providing guidance on retrspection. The table includes four different actions for each role, resulting in 12 codes that represent the primary behaviors during group reflection. Additionally, each code is explained with specific examples.

Table 4.8

Code Scheme of Different Roles' Actions in Group Reflection

Ind.	Code	Explanation

F-R	Guidance on retrospection	The Facilitator helps the group to return to and discuss their VR experience. Students are guided to recall what they saw, heard, thought, and did in critical events that need further analysis. The Facilitator identifies critical information and leads for detailed description, e.g., “what did you notice when you crossed the street?” “I saw you stopped here, right? What happened?” or “I heard you say, ‘run, there is a flashing light’ what did you think at that moment?”
F-A	Support on experience analysis and reconsideration	The Facilitator asks individuals and the group to interpret critical signals/events, explain their opinions and actions, and make decisions in specific situations. The questions can trigger students’ analysis and reconsideration of their experience and observation. Questions include: “what does it mean when the traffic light flashes?”, “Why did you act like that?” and “what if you rushed into the road at that moment?”
F-C	Facilitation on group collaboration	The Facilitator guides the group to participate in the on-topic discussion to share opinions and exchange ideas. This kind of support focuses on leading the group to focus on the topic, creating a collaborative group atmosphere, and inducing discussion with the involvement of group members. For example, the Facilitator directs the group’s attention to the topic, “do you agree with that? (turn to two Observers who are not paying attention)” and “let's look at this first, okay?” The Facilitator invites everyone to participate in the discussion, “how about you? what do you think? (facilitator turns to those who did not answer the question)”, “what would you do if you were there?”
F-KC	Support on knowledge construction and transfer	The Facilitator supports the group in understanding and coming up with safe pedestrian knowledge and behaviors in specific situations. This kind of support helps the group construct meanings and decision-making regarding what they experienced in the VR program. For example, the Facilitator suggests and summarizes safe solutions in a specific condition, “so, we need to check both sides on the road to ensure the vehicle stops when we cross the street.”
P-R	Retrospection and description of the experience	The Performer indicates and describes what they noticed, thought, and did during the VR simulation. The Performer also uses body language or gestures to represent what happened in the experience. For example, “I saw the pedestrian traffic light is red at that time.”, “I was thinking I can’t go (crossing the road).”

P-A	Analysis and reconsideration of the experience	The Performer analyzes and thinks about the experience to review their knowledge and actions. The thinking process includes interpreting critical signals/events, explaining their opinions and actions, and making decisions in specific situations. For example, “the flashing light means no time to cross the road” and “I would wait for another green light.”
P-C	Interactive and collaborative meaning-making	The Performer constructs meanings collaboratively from the analytical discussion with others. The Performer shares their opinions as well as responds to others’ others’ thoughts. The interactive meaning-making process includes expressing agreement/disagreement, complimenting/challenging others’ perspectives, and responding to others’ ideas with actions/illustrations. For example, “I would do the same.”
P-KC	Knowledge construction and generalization	The Performer concludes with safe pedestrian knowledge or decision-making in specific situations. The Performer acquires understanding and potential behaviors from experience, such as predicting consequences from hypothetical situations and making decisions in a given situation. The Performer links the VR experience to their real-life situations and generates their conclusions to other contexts, and illustrates a better individual understanding.
O-R	Retrospection and description of the experience	The Observers indicate and describe their observations and actions during the Performer’s VR experience, recalling what they noticed, thought, and did during the VR simulation. Observers also use body language or gestures to represent what happened during the experience. The retrospection also includes the Observers’ comments on the Performer’s action. For example, “I clearly saw you (the Performer) dashed into the street.”, “the traffic light was red for a while, but no car was on the road.”
O-A	Analysis and reconsideration of the experience	The Observers analyze and think about their observations and experience to review their knowledge and construct meanings. The thinking process includes interpreting critical signals/events, explaining their opinions and actions, and making decisions in specific situations. For example, “the flashing green light means it will turn to red light soon,” and “he was so close to the school bus. If the driver didn't see him, he would be hit to death.”

O-C	Interactive and collaborative meaning-making	The Observers construct meanings collaboratively from the analytical discussion with others. Observers share their opinions as well as respond to others' others' thoughts. The interactive meaning-making process includes expressing agreement/disagreement, complimenting/challenging others' perspectives, and responding to others' ideas with actions/illustrations. For example, "(the crosswalk is used by pedestrians) but you have to wait for the traffic signal when the traffic light is green." or "I would not be like that (hurry up to cross the street). I would wait for another green light to cross the street."
O-KC	Knowledge construction and generalization	The Observers conclude with safe pedestrian knowledge or decision-making in specific situations. Observers acquire understanding and potential behaviors from experience, such as predicting consequences from hypothetical situations and making decisions in situations. Observers link the VR experience to their real-life situations and generate their conclusions to other contexts and illustrate a better individual understanding. For example, "(an Observer compliments what the facilitator mentioned) you still need to check on both sides of the road (beyond traffic light), if you don't check, and there could be cars." and "(an Observer concluded) so you have to continue crossing the street in that situation (where the traffic light starting flashing when you in the middle of the road)."

Note. F indicates Facilitator; P indicates Performer; O indicates Observer; characters following the role (e.g., -R, -A, -C, and -KC) denotes four different actions in group reflection.

The Facilitator showed four types of actions during their guidance on the learner's reflection. Specifically, F-R (Guidance on retrospection) indicates the Facilitator's guiding actions in helping the group return to their VR simulation experiences. For example, the Facilitator asked the group to recall what they saw/heard in a critical moment to trigger their further thinking on key information. F-A (Support on experience analysis and consideration) indicates the Facilitator's guiding behaviors for the group to analyze and reconsider their decision-making and thoughts during specific moments. F-C (Facilitation on group collaboration) suggests the Facilitator's supporting actions help the group work together on

reflecting activities. F-KC (Support on knowledge construction and transfer) indicates the Facilitator's actions in helping the group build new understandings and decision-making in specific situations.

The Performer and Observer showed four similar actions during their group reflection guided by the Facilitator. P-R (Retrospection and description of the experience) and O-R (Retrospection and description of the experience), matching with the Facilitator's action F-R (Guidance on retrospection), indicate the group's actions to recall the details of the VR simulation experience. P-A (Analysis and reconsideration of the experience) and O-A (Analysis and reconsideration of the experience) suggest the group's efforts in evaluating and analyzing their decision-making and thoughts during specific moments. P-C (Interactive and collaborative meaning-making) and O-C (Interactive and collaborative meaning-making) reveal the group's actions on teamwork. P-KC (Knowledge construction and generalization) and O-KC (Knowledge construction and generalization) indicate the group's efforts to make meanings from the VR simulation experience.

In addition to coding the three roles' actions in group reflection individually, I analyze the group as a unit to explore any inseparable actions among roles. Accordingly, 15 group actions were found from the nine group cases (see Table 4.4). For example, a group of five students suggested different decisions toward a specific situation asked by the Facilitator (e.g., Group Case #5), which indicates a dynamic group interaction with different opinions. Meanwhile, some interesting findings are revealed when I analyze the group as a unit. For instance, the Performer and Observers suggested different contents when they were asked to recall the experience, which revealed the fact that the two roles had different focuses during the experience. More interesting findings will be discussed in the following section.

Four Stages of Group Reflection Emerged from the Inductive Data Analysis

Four stages of group reflection emerged from the inductive data analysis. Table 4.9 shows the four stages with each of the three roles' actions. The first stage is Guided Retrospection and Description of Experience, suggesting the group's efforts to return to their VR simulation experience. The Performer and Observers share their individual and collective experience for further analysis, and the Facilitator provides guidance for the group to recall critical details and their thoughts during the experience. The second stage is Guided Analysis and Evaluation of Experience, indicating the group's deliberation on their VR experience. The Performer and Observer evaluate and analyze their individual and shared VR experiences with the support of the Facilitator. The third stage is Guided Group Exploration and Discussion, indicating the group's guided teamwork in examining and analyzing the VR simulation experience. The final stage is Learning and Conclusion, which indicates the group's meaning-making and future decisions from the group reflection.

Table 4.9

Four Stages of Group Reflection based on the Code Scheme

Stage	Description	Facilitator	Performer	Observer
1	**Guided Retrospection and Description of Experience**, including the return to individual and collective experiences	F-R: Guidance on retrospection	P-R: Recall and describe one's experience	O-R: Recall and describe one's experience
2	**Guided Analysis and Evaluation of Experience**, including careful examination and consideration of experiences and potential solutions	F-A: Support on experience analysis and reconsideration	P-A: Analysis and (re)think about one's experience	O-A: Analysis and (re)think about one's experience

3	**Guided Group Exploration and Discussion,** including group collaboration and interaction, which contribute to the shared goal of learning	F-C: Facilitation on teamwork/group discussion	P-C: Make meanings with others	O-C: Make meanings with others
4	**Learning and Conclusion,** indicating new understanding and change from the group reflection	F-KC: Support on knowledge construction and learning transfer	P-KC: Construct understanding and personal decisions	O-KC: Construct understanding and personal decisions

Note. F indicates Facilitator; P indicates Performer; O indicates Observer; characters following the role (e.g., -R, -A, -C, and -KC) denotes four different actions in group reflection.

Findings from the Inductive Data Analysis

The four stages of group reflection have emerged, indicating how the group with different roles reflect collaboratively, thus addressing Research Question Two. Moreover, several significant findings from the inductive data analysis offer valuable insights into group reflection. This section reports findings from various perspectives. Firstly, I present key findings from examining the individual positions of the three roles in the group reflection. Then, I report on the findings from analyzing the group as a whole.

Findings From the Facilitator's Position in Group Reflection

Three key findings are discovered from the Facilitator's unique position in the group reflection. Firstly, the importance and requirements for the Facilitator emerged from the study. The group reflection was guided by the Facilitator with prompt questions and feedback, indicating the importance of guidance for group reflection, especially for learners who lack skills and experience in teamwork and reflection. The Facilitator's (the author) memo indicated her perceived importance of the role, "I think I am playing an essential role in the group reflection as

the student groups rely on my guidance on their review and analysis of critical experiences." Meanwhile, three types of critical skills emerged to show the requirements of the Facilitator to lead a successful group reflection. One needs related knowledge and experiences on the reflecting objects to lead the group activity. It also requires the role of understanding the nature and process of reflection to lead a meaningful group discussion. Furthermore, creating and maintaining a group environment with supporting ground for teamwork and collaboration is essential for leading group reflection.

Meanwhile, some practical challenges in guiding a group reflection emerged from the Facilitator's after-event reflection. First, setting the role of the Facilitator could have some passive influence on the group reflection. For example, the group might totally rely on the Facilitator's selection and direction on actions/events to reflect, hindering individuals' active and autonomous efforts in reflection (e.g., Group Case #8). In addition, the Facilitator role could be considered the authority in the group, especially for individuals who have lower status than the Facilitator in any way (e.g., power, knowledge level, and social status). Such a group setting could impact group dynamics and the results of group reflection.

Furthermore, maintaining a group reflection, especially for large groups, is demanding and challenging for the Facilitator. A memo from the Facilitator indicates such challenges, "it is stressful when five children in the group talk to me at the same time, especially when they are focusing on different things. They all want my attention, but I can only lead one topic at a time. Looking back at the video (the recorded group reflection video), I found myself forgetting to follow up with other topics after letting one child share their opinion first, let alone handling conflicts or disagreements between different individuals."

Findings From the Performer's Position in Group Reflection

Two primary findings emerged when examining the Performer's actions in the group reflection. Fundamentally, The Performer has social pressure of being judged or commented on their actions. The reflection process is primarily based on the Performer's actions, putting the role in the spotlight. The Observer could be aggressive or judgmental when discussing the Performer's actions, which can cause social pressure for the Performer to react and reflect in the group. For example, in Group Case #2, the Observers expressed their disagreement with the Performer's risky behaviors in VR, causing the Performer to become upset and withdraw from the discussion. She looked down at the floor and stopped actively sharing her opinions, turning to passive listening instead. The Facilitator noticed the Performer's emotional shift and invited her to participate in the discussion.Meanwhile, since the Observers shared the Performer's experience in VR simulation, they tended to ignore the importance of the Performer's retrospection. For example, when the Facilitator asked the Performer to recall and share their actions in VR, the Observer answered the question on behalf of them or interrupted the role to share opinions.

Furthermore, the Performer has a high cognitive load due to full immersion in VR, which may influence their achievement in group reflection. The immersive VR environment provides the Performer with multimodal stimulation and various information for their process. Such advantage of immersive experience could lead to a disadvantage in reflection. For example, in the VR simulation, the Performer missed critical cues noticed by the Observers due to distractions from other information (e.g., Group Case #5). The Performer also showed difficulty in remembering details in the virtual world. For example, when asked about critical information in a specific situation, the Performer occasionally stated that they had forgotten. At one point,

when the Performer wanted to contribute to the discussion while others were speaking about what happened in VR, she was asked to recall a specific detail. She responded by saying, “I think I remember it, but I just can't recall it at the moment.” (e.g., Group Case #2).

Findings From the Observer’s Position in Group Reflection

Three key findings reveal the Observer’s unique position in the group reflection. Firstly, Observers share a sense of ownership in the VR simulation experience. For example, when the Facilitator asked the Performer to recall the details in the VR simulation, the Observer interrupted the Performer to answer the question on behalf of the Performer or share what they noticed instead. In Group Case #6, one Observer consistently used first-person perspective to describe the Performer’s actions in VR, suggesting that he took the ownership of the simulation experiences. For instance, when the Facilitator asked about a particular situation, the Observer replied with, “I didn’t see the traffic light so I thought it was okay to cross the road.” Meanwhile, the Observer provided additional details to the Performer's retrospection by noting things that the Performer had not observed or had forgotten. For example, when the Performer could not recall the details about the traffic signals, the Observer shared what they had seen, stating, “It was flashing before you arrived at the corner.” (Group Case #5). Furthermore, the Observer challenged the Performer’s description of the VR simulation, especially when they noticed critical cues missed by the Performer. When the Performer indicated his notice of the school bus on the first road, the Observer disagreed, “that happened on the third road, not at the beginning.” (Group Case #2).

Secondly, the Observer keeps aware that their role differs from the Performer in the group reflection. Even though there was no separation of roles in the group discussion (compared to the clear division of labor in group VR simulation), the Observer knows the difference between roles

and compares themself with the Performer. For example, the Observer commented on or judged the Performer's actions in the VR simulation to suggest their different decision-making in certain situations. When the Performer stated that he would cross the road when the vehicles had stopped, the Observer disagreed, stating, "I would not do that. It is still risky. I would verify the traffic light and vehicles." (Group Case #4). Moreover, while discussing the Performer's behavior, the Observer planned for their own VR experience. For instance, when the group debated whether the Performer's action was safe in VR, one Observer looked around and said aloud, "I will do something like this..." (Group Case #2).

Thirdly, there is a lack of social rules regarding Observers' interaction with others in the group. For example, Observers showed a lack of respect for others' opportunities to share opinions. The Observer interrupted the Performer and others to answer questions or share their perspectives. For example, in Group Case #1, when the Facilitator asked the Performer about her actions in a particular situation, the Observer interrupted and said, "She was waiting there because the traffic light showed red." The Observer had a tendency to interrupt others during discussions, often without realizing it. In Group Case #3, one Observer was actively engaging with the Facilitator's questions and frequently interjected their opinions into other participants' conversations (e.g., Group Case #7). Meanwhile, the Observer seemed not to know how to handle different opinions. For example, the Observer judged others' actions or thoughts, causing the Performer to be upset (e.g., Group Case #2). In some cases, the Observer would retract their earlier suggestions after facing challenges from peers (e.g., Group Case #3). For example, one Observer shared their decision-making process for a particular situation, saying, "I would cross the road when the flashing light comes on." However, another Observer disagreed and asked, "Who said that?" The first Observer then denied having made that suggestion, saying, "I didn't

say that."

Findings From Examining the Group as A Unit

When examining the group as a unit, some critical findings catch our attention. First, the current study provides some empirical support for the theoretical foundation of group reflection proposed in the conceptual framework. Specifically, individuals in the group had different angles of perspectives in the VR simulation, leading to a collective experience with different focuses and critical information for their discussion. Such a finding supports the first theoretical underpinning of group reflection: group settings offer more opportunities for reflection to happen. Meanwhile, the group collaborated together to clear misunderstandings regarding pedestrian knowledge and risky behaviors during the VR simulation, supporting the claim that group reflection can assist individuals in achieving what they cannot achieve alone.

Furthermore, some practical challenges of group reflection emerge from the study. The importance of facilitation on group reflection is apparent, while the study reveals high demands and requirements on the facilitator (discussed above in the finding from the Facilitator's position). Identifying and assigning an appropriate facilitator for group reflection with certain members can be challenging as it requires both skills, experience, and understanding of the group members. Another challenge is establishing the rules and shared understandings regarding group collaboration and reflection. A lack of preparation for teamwork can result in low achievement and unpleasant experiences for the group. The final practical challenge in the study may only apply to group settings similar to this study. For a group consists different roles and divisions of labor in an experience, specific support or guidance is needed to overcome any challenges granted by the role assignment.

Research Question Three: Learning Outcomes from the VR-mediated Group Learning

Research Question Three investigates and compares the learning outcomes of Performers and Observers in VR-mediated group learning. Accordingly, the nine performers and thirty-six observers from the nine group cases constituted two group samples for Research Question Three. This study examines three learning outcomes: knowledge acquisition, behavior performance in VR, and satisfaction with the group activity. To address this research question, both quantitative and qualitative data were collected and analyzed. This section first presents results of the quantitative data analysis, which reveals the Performers' and Observers' knowledge and behavior acquisition. Following this, this section reports on the qualitative data analysis of interviews, which provides insights into discloses the Performers' and Observers' perceived experience of the group learning activity.

The Performers' and Observers' Knowledge Test

After the VR-mediated group learning, each student took a pen-and-pencil test to evaluate their knowledge acquisition. The knowledge test included ten questions that assessed the students' comprehension of traffic signals and decision-making in specific situations. To determine a student's test score, the number of correct answers was divided by the total number of questions, resulting in a score between 0 (0% accuracy) and 1 (100% accuracy).

Figure 4.2 presents the average knowledge test scores of the Performers and Observers, suggesting that the Performer group did better on the knowledge test. Independent sample t-tests were employed to compare the test scores of the two group. Despite having unequal sample sizes, the Performer and Observer groups exhibited equivalent variances in their scores on the knowledge test, meeting the assumption of independent t-tests (Moore et al., 2014).

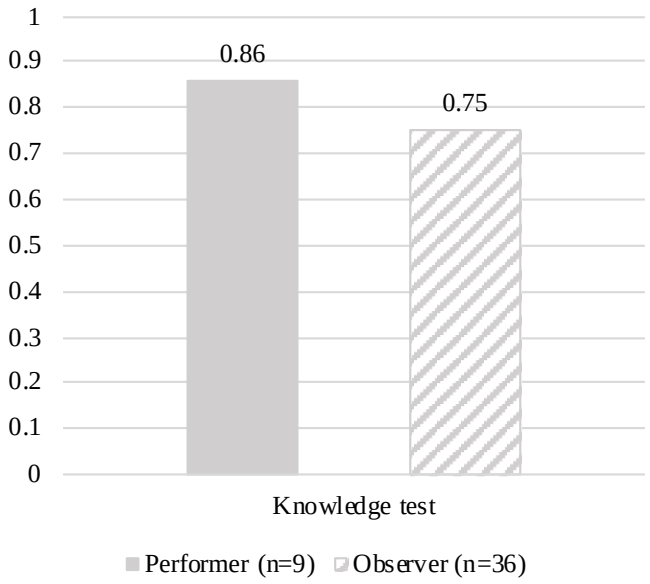


Figure 4.2

Bar Chart of the two Roles' Knowledge Test (Posttest)

Table 4.10 displays the results of the knowledge test for the Performers and Observers. The Performer group, consisting of nine students, had an average knowledge test score of 0.86 with a standard deviation of 0.13. In contrast, the Observer group, comprising thirty-six students, had a mean score of 0.75 with a higher standard deviation of 0.23. The results indicate that the Performer group had higher accuracy in answering the questions and had less variability in scores compared to the Observer group. Furthermore, a post-hoc independent sample t-test was conducted, and the result ($t_{(43)} = 1.34$, $p = .19$) suggested no signiticant differences between the two role groups' knowledge test scores. Therefore, the results suggested that the Performer and Observer groups had similar learning outcomes in terms of their knowledge acquisition.

Table 4.10

Descriptive Analysis of the Knowledge Test

Role	Performer (n=9)		Observer (n=36)		t value	Sig
	Mean	SD	Mean	SD		
Knowledge test (0-1)	.86	.13	.75	.23	1.34	.19

In addition, each participant in the study took a pre-knowledge test before starting the group learning activity. By comparing the results of the pre- and post-knowledge tests, the effectiveness of the group learning activity on students' knowledge acquisition can be determined. A paired-samples t-test was conducted to compare the mean score of the forty-five students' knowledge test before (M = .62, SD = .26) and after (M = .77, SD = .22) participating in VR-mediated group learning. The t-test showed a significant increase in scores from pre- to post-training, $t(44) = -5.23$, $p < .001$, indicating that the group activity was effective in enhancing students' knowledge acquisition.

The Performers' and Observers' Behavior Performance in VR

After completing the VR-mediated group learning, each student participated in the VR program to evaluate their behavior performance in the immersive environment. To assess students's actions at 11 decision-making points within the VR program, a safe pedestrian behavior rubric was employed. A student's score on the behavior test was calculated by dividing the number of safe actions by the total number of decision-making points, resulting in a score between 0 (0% safety) and 1 (100% safety).

Figure 4.3 depicts the average behavior performance scores of the Performers and Observers, showing that the Observer group had better behavior performance than the Performer group. An independent sample t-test was conducted to compare the test scores of the two group. Despite having unequal sample sizes, the Performer and Observer groups exhibited equivalent variances in their behavior performance scores, satisfying the assumption of independent t-tests

(Moore et al., 2014).

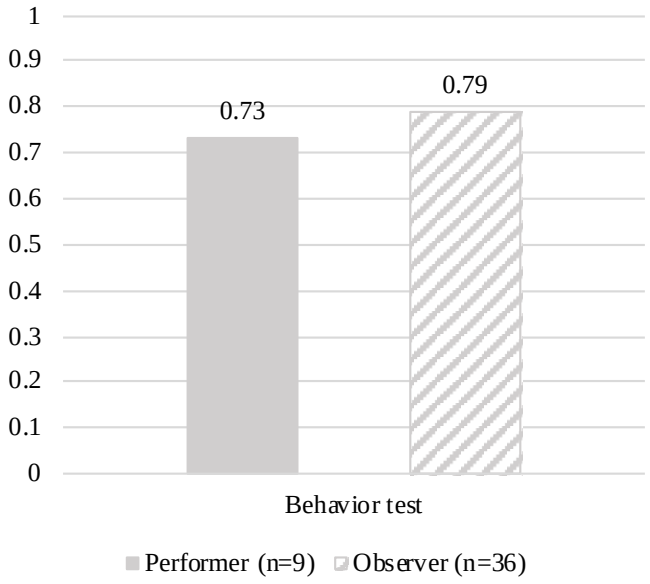


Figure 4.3

Bar Chart of the two Roles' Behavior Performance(Posttest)

Table 4.11 displays the results of the behavior performance of the two roles. The Performer group obtained a mean score of 0.73 with a standard deviation of 0.22, whereas the Observer group had a higher mean score of 0.79 and a lower standard deviation of 0.17. A post-hoc independent sample t-test was conducted to compare the two role groups' behavior scores, and the result ($t_{(43)} = -.80$, $p = .43$) suggested no significant difference between them. Thus, the Performer and Observer groups achieved similar learning outcomes in terms of their behavior performance in the VR program.

Table 4.11

Descriptive Analysis of the Behavior Performance

Role	Performer (n=9)		Observer (n=36)		t value	Sig
	Mean	SD	Mean	SD		
Behavior performance (0-1)	.73	.22	.79	.17	-.80	.43

The Performer' and Observer's Satisfaction and Perceived Learning Experience

A closing interview asked the forty-five students from the nine group cases to provide feedback on their satisfaction with the VR-mediated group learning activity. The nine Performers and thirty-six Observers were asked about their perceived experiences in two main parts: (a) their roles in the group simulation and (b) their work with others in the group reflection. Overall, participants expressed enjoyment in the VR experience and believed it helped them learn pedestrian knowledge. Most students reported that they learned from the activity and would be able to apply it real life. For example, a student shared, "I like this event because I learned something that I could use when I cross roads (in daily life) next time." As for the group learning setting, the majority of students reported positive experiences working with their peers. The following sections report the two roles' perceived learning experiences separately to provide insights into individuals' feedback on VR-mediated group learning.

For the experience in VR simulation, six Performers suggested they preferred simulating in the VR program with others' presence compared to by themselves alone. The main reasons mentioned are the company and support from peers. For example, the Performer explained, "I preferred group experience when others were around. They (the Observers) could give me suggestions like when I didn't notice the traffic light, they told me to go." (Group Case # 3). Another Performer mentioned, "I prefer experiencing the VR with peers than doing it by myself. I can hear others when I was playing. I like them talking to me." (Group Case # 7). In contrast, three Performers indicated preferring experiencing the VR program alone without being

observed by peers. Two main reasons were mentioned by the three Performers, including their concerns about others' interruption and personal preference for group activities. For example, a Performer suggested, "I prefer experiencing the VR by myself. They would laugh at me. I don't like that." (Group Case #4). Another Performer mentioned, "I prefer experiencing the VR by myself. It was noisy when they (peers) were around." (Group Case #2).

Notably, all Performers from the nine group cases suggested they liked discussing the VR experience with peers in the group reflection. One frequently mentioned reason is the enjoyment of peer company and interactions. For example, one Performer shared, "I prefer discussing the experience with the group compared to one-on-one with the facilitator; it's more fun with peers." (Group Case #8). Another important reason is the learning achievement one can accomplish with peers' presence. For example, a Performer indicated, "I like discussing with peers. They might come up with better suggestions." (Group Case #6). Another Performer suggested, "I like discussing the experience with others because they would help me correct my mistakes (risky behaviors). I like to reflect with others because they would also learn things" (Group Case #2).

The Observers suggested similar perceived experiences compared to the Performers. Twenty-four Observers indicated that they preferred experiencing the VR program alone than observing others, meaning it is more fun to have an immersive experience with free control. For example, an Observer said, "I prefer playing the program by myself than observing. It will be more fun. I like the scenes (in VR). I can do whatever I want." (Group Case #9). In contrast, five Observers suggested that they preferred observing others' simulations to experiencing the VR program. Personal preferences and concerns were the main reason mentioned. For example, an Observer indicated, "I felt dizzy in VR. I prefer observing other peers than playing the VR myself." (Group Case #9). Another Observer shared, "I dare not play the VR program. I am

afraid of being hit (by cars in the virtual world).” (Group Case #4).

CHAPTER 5

CONCLUSION AND DISCUSSION

This chapter summarizes the results of the current study and discusses some critical findings revealed from the case analysis. Specifically, the three research questions are revisited and addressed with key findings from the data analysis. Then, a discussion section further explores several findings emerged from the data analysis, such as the discovery of immersive VR-mediated learning space, a profile of different roles in the group setting, the stages of the group reflection, and the group's learning outcomes. Meanwhile, the implications of findings are summarized to provide insights into related practices and research. Finally, this study suggests possible directions for further research.

Summary of Research Findings

Research Question One explored the experiences of learners with two roles (Performer vs. Observer) in VR-mediated group simulation. Thematic analysis of the nine group cases revealed unique and shared experiences of the Performers and Observers. Specifically, Performers faced unclaimed duties of completing virtual tasks while under the presence of peers. This necessitated conscious decision-making based on their knowledge and judgment of specific situations, while also dealing with the interventions of others. Consequently, the Performer's actions and decision-making were consciously and unconsciously influenced by the Observers. However, the Performer also gained a multimodal experience and full control in the virtual environment, albeit at the cost of decreased senses in their physical surroundings. This disadvantage resulted in the Performer losing track of their balance and position in the real

world.

In contrast, the role of Observers did not provide students direct access to the VR program, but it did offer several unique advantages in the group. For instance, the Observer could shift perspectives between the virtual and physical worlds while observing the Performer's actions in VR. Moreover, the Observer could influence the Performer's decision-making and actions to impact the virtual environment. This allowed the Observer to experience mental immersion in VR and invest in cognitive engagement similar to the Performer, without having to overcome the physical challenges of full immersion in VR. Additionally, the Observer was found to engage in social interactions with both roles (Performer and Observer) in the group, indicating their influence in both virtual and real environments. Through active participation and engaged observation, the Observer developed a sense of ownership of the VR simulation.

Furthermore, Research Question One aimed to identify the similarities and differences between the experiences of the two roles. Several themes emerged from comparing the behaviors of Performers and Observers during the simulation. Both roles were aware of their role differences compared to others in the group, and they were motivated and cognitively engaged in problem-solving within the VR program. However, both roles' behaviors and actions were influenced by others, resulting in a co-constructed and shared experience in the group rather than an independent one. Nevertheless, some notable differences were found between the Performer's and Observer's experiences. For instance, they had different goals when they joined the group with assigned roles and resources, and they used various means to enact their thoughts and impact the virtual environment. Moreover, when analyzed quantitatively, the Performer performed more actions related to their decision-making and reactions in the virtual environment, whereas the Observer had more actions influenced by others, such as observing

peers and interacting with them.

Research Question Two aimed to investigate how the Performer and Observer reflected on their VR simulation experiences together. Through data analysis, four stages of guided group reflection emerged, indicating how the two roles reflected on their unique and shared experiences with the guidance of the Facilitator. Specifically, the first stage, *Guided Retrospection and Description of Experience*, focuses on reviewing critical experiences for further analysis. The Performer and Observer shared their individual and collective experience, and the Facilitator provided guidance for the group to recall critical details and their thoughts during the experience. The second stage, *Guided Analysis and Evaluation of Experience*, suggests the group's deliberation on their VR experience. The Performer and Observer evaluated and analyzed their individual and shared VR experiences with the support of the Facilitator. The third stage, *Guided Group Exploration and Discussion*, indicates the group's guided teamwork in examining and reconsidering their VR simulation experience. The final stage is *Learning and Conclusion*, which indicates the group's meaning-making and future decisions from the group reflection.

From the practice of guided group reflection, some critical findings emerged. For example, the Performer faced social pressures of being ignored or judged during group discussions, as the Observers tended to take ownership of the simulation experience, neglecting the Performers' unique perspectives and thoughts. Additionally, the Performer could be subject to critique and judgment when others have different decision-making in virtual situations. Observers were aware of their distinct role compared to the Performer during the VR simulation and tended to dominate the discussion during reflection. The study also identified a lack of social rules on open and collaborative group reflection. The groups were formed with seven- to ten-year-old students needing support in social interactions based on their developmental level,

which should be considered when interpreting the results. Furthermore, the critical role and high requirements for the Facilitator emerged from the study, suggesting the practical challenges of guiding group reflection, such as providing adaptive support and helping the group collaboratively think through their opinions. Those findings can inform further research and instructional design for group reflection activities, which will be discussed in the following sections.

Finally, Research Question Three aimed to investigate potential differences in learning outcomes between learners with the Performer and Observer roles in the nine group cases. The study used both quantitative and qualitative data to address this research question. A pedestrian knowledge test and behavior examination in the VR program were administered to the two roles, and the results showed that both Performers and Observers achieved similar learning outcomes regarding their knowledge and behavior acquisition after group learning. Although the Performers had a slightly higher score on the knowledge test, and the Observers had a higher score on the behavior examination, these differences were not statistically significant upon further analysis.

In addition, a closing interview was conducted with all students from the nine group cases to gather feedback on their satisfaction with the VR-mediated group learning activity. The results indicated that both Performers and Observers reported general satisfaction with their group learning experience, particularly with their shared acknowledgment of the group reflection. Overall, participants enjoyed the VR experience, found it fun, and believed that it helped them learn pedestrian knowledge. Most students also indicated that they learned from the activity and would apply it to real-life situations. Regarding the role assignment experience, the study found that some students preferred being the Performer, with direct access and control in

VR, while others preferred the Observer role.

Discussion and Implication

The Discovery of Immersive VR-mediated Group Learning Space

The experiences of Performers and Observers in VR-mediated group learning can be explained using a unique approach: an immersive VR-mediated learning space that combines virtual and physical environments. Immersive VR technology creates a virtual learning space where Performers interact with virtual objects, while the physical site provides a space for Observers to see the Performer's actions and real-time simulation in VR. The virtual and physical spaces overlap, creating a collaborative learning space where the two roles interact with each other. Observers can see the virtual scenes through a projected display and interact with the Performer to impact the virtual world. Therefore, Observers obtained similar senses of mental immersion and cognitive engagement as the Performer.

This creates different types of realities in the group learning setting, as illustrated in Figure 5.1. The exclusive Virtual Reality is a designed digital world where the Performers simulate pedestrian actions without reference from the real world. The blue area in Figure 5.1 indicates such a virtual world. In the nine group cases, Performers navigated in exclusive Virtual Reality when they receive no intervention from their physical surroundings. In contrast, the exclusive Physical Reality is where the Observer presents and acts without information from the virtual environment. The yellow area in Figure 5.1 indicates such a physical space. Our analysis on the Observers' actions indicated that students in the physical environment were aware of their distinct role compared to the Performer in VR, and they freely acted in the physical environment with no restrictions on their behaviors. For example, an Observer intended to touch the Performer and wave hands to test if they could see things in the physical world, and another

Observer prevented those actions and whispered to others (Group Case #3). Such actions occured in the Physical Reality, which included the VR simulation as part of the group setting. However, Observers were unaware of what happened in the Virtual Reality.

Additionally, the group setting creates a novel learning space where the boundaries between the virtual and physical worlds are blurred through the use of a projected display. In the nine group cases studied, Observers in the physical environment were able to see and understand what Performers in the VR program were experiencing in the virtual world. Furthermore, students from virtual and physical realities were able to collaborate and communicate with each other to solve problems. For example, in Group Case #3, an observer was able to guide the Performer who was unable to move forward by instructing them, "there is a wall in front of you, turn left." (Group Case #3). This overlap between the virtual and physical realities enabled the Performer and Observer to construct a shared group experience, which we define as Mixed Reality in this study. This is represented by the color green in Figure 5.1, which is the secondary color created by combining blue and yellow.

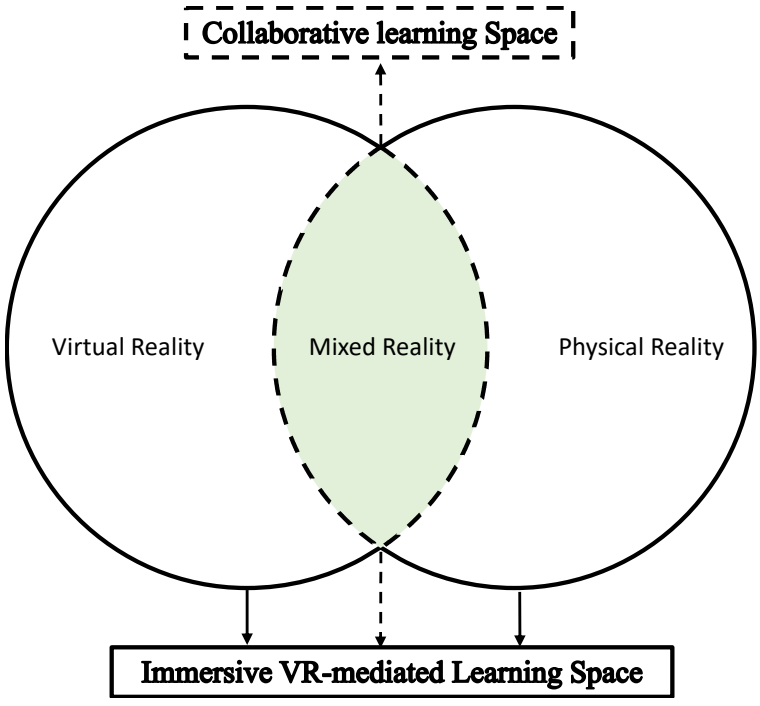


Figure 5.1

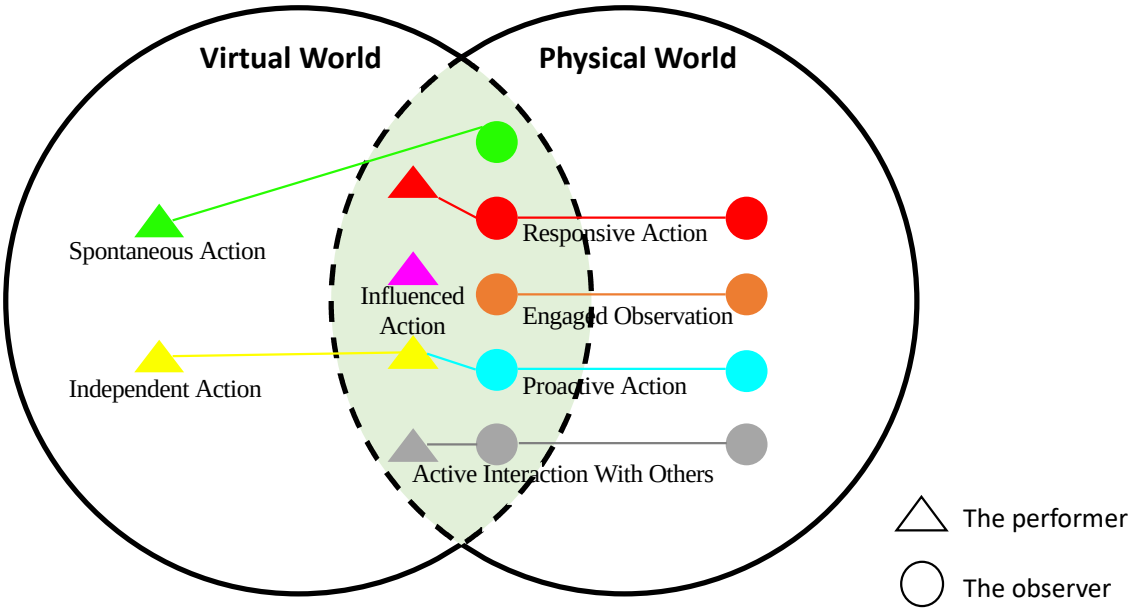
Immersive VR-mediated Group Learning Space Combining Different Spaces

The immersive VR-mediated group learning space framework can help us understand the behaviors of Performers and Observers in different realities (see Table 4.5). Specifically, both role showed *Spontaneous Actions* to the virtual environment through either reacting in the virtual reality or imagining responding in the physical reality. Both role exhibited *Responsive Actions* to others in the group. For instance, Performers responded to Observers' requests to act in a certain way within the VR program, while Observers responded to Performers' call for assistance. Furthermore, Performers' *Independent Actions* within the VR environment and observers' *Proactive Actions* within the group were deemed comparable as they were both conscious decision-making responses to specific situations. Furthermore, both roles domonstrated *Influenced* and *Interative Actions* based on the presence and involvement of others within the group. For example, Performers received direction from others on how to act within the virtual reality, while Observers attempted to draw attention from their peers by enacting certain behaviors within the group.

Accordingly, Figure 5.2 depicts the two roles' actions in the immersive VR-mediated group learning space framework. The triangle represents the Performer, and the rectangle indicates the Observer. Different colors are used to indicate different types of behaviors, and the connecting line between shapes indicates that they are the same type of behavior. In specific, Performers' *Spontaneous Actions* occur in virtual reality as they make they navigate in the VR program. Such actions also take place in mixed reality when the Performer spontaneously react to the virtual object due to the Observers' influence. For example, the Performer turned to the

virtual object immediately after he heard Observers mentioned it (Group Case #5), suggesting their unconscious responds in the overlapped area between virtual and physical realities. In contrast, *Independent Actions* happen when the Performer makes their own decisions in VR and in mixed reality when they are not influenced by others' interventions. Meanwhile, *Responsive, Influenced, and Interactive* Actions occur in mixed reality where Observers are present and actively involved in Performers' actions.

Observers' *Spontaneous Reactions* to the VR program only happen in the mixed reality where the virtual world overlaps with the physical world with the projection of the virtual scenes. However, most of the Observers' behaviors occur in both the physical and mixed realities. For example, *Engaged Observation* happens in the physical learning space as the Observer watches the Performer and others in their surroundings. Meanwhile, the Observer overlooks the projection of the virtual world from the screen, leading to engaged observation from mixed reality. Similarly, the Observers' *Proactive*, *Responsive*, and *Interactive* behaviors occur in physical reality with others from the physical world. At the same time, these behaviors happen in mixed reality, where Observers actively enact and respond to the Performer and the VR program.



Note. Different colors are used to indicate different behavior categories, and the connecting line between shapes indicates that they are the same type of behavior.

Figure 5.2

Two roles' Actions in the Immersive VR-mediated Group Learning Space

The visualization of Performers' and Observers' behaviors in the VR-mediated group learning space provides an approach to examine the similarities and differences between their experiences. Noticeably, most of behaviors of both roles occurred in Mixed Reality, where the virtual and physical environments overlapped for the two roles to share information and collaborate with each other. However, Performers' experiences in physical reality were compromised due to full immersion in VR, which caused decreased sensations in their surroundings. Similarly, Observers had access to virtual scenes through a projected display but lacked multisensory experiences and direct control in VR, compromising their experiences in virtual reality. As a result, the Performer's experience existed in three different but connected spaces, including *Exclusive Virtual Reality*, *Mixed Reality*, and *Compromised Physical Reality*. Meanwhile, the Observer's experience was rooted in *Compromised Virtual Reality*, *Mixed Reality*, and *Exclusive Physical Reality*. The discovery of the learning space provides a means to further explore the Performer' and Observer's experience in immersive VR-mediated group learning. The following discussion explores the experiences of Performers and Observers in the immersive VR-mediated learning space, using the inductive data analysis findings from the nine group cases presented in Chapter 4.

Performer's Experience in Immersive VR-mediated Learning Space

In Exclusive Virtual Reality, the Performer had full access to the digital world and could

experience it through multiple senses, such as 360-degree visual views, simulated sound, and interactive virtual objects. Meanwhile, they had direct control to impact the virtual space. However, the Performer needed to adjust themself from the real world to the virtual space and make conscious decisions for their actions in the virtual space. As the Performer, they accepted the pre-determined goal of finishing tasks in the VR program.

In Mixed Reality, the Performer was situated in the virtual world with the presence of their peers in the physical space. The Performer was aware of the group community, therefore, would react consciously and unconsciously to others from the physical space. Unavoidably, the Performer was influenced by others from the physical world to impact the virtual environment. The mixed reality provided a space connecting the two roles to interact and collaborate. The Performer actively invited peers from physical world to participate in their decision-making in virtual reality.

In Compromised Physical Reality, the Performer's sensory experiences were limited. For example, they did not have visual cues from their surrounding because of the head-mounted display on their eyes. Furthermore, the auditory sounds from the physical world were restricted due to sounds from the virtual world. Meanwhile, their movement in the physical world was limited within the VR working station. The role also had limited control over objects in the real world, making it difficult to make an impact in the physical world. Accordingly, the Performer needed to overcome the challenges of orienting themself in the physical world, which was a trade-off for full immersion in VR.

Observer's Experience in Immersive VR-mediated Learning Spaces

In Compromised Virtual Reality, the Observer had limited control and impact on the virtual environment compared to the Performer. The Observer did not have a multisensory

experience in VR and could only see the virtual world through the Performer's perspective, which was projected on a desktop screen. The Observer had limited sound input from the virtual environment through the Performer's headset. In addition, the Observer had no direct control over the virtual environment to make an impact.

In Mixed Reality, the Observer oversaw the Performer's actions and related consequences from both the physical and virtual environments. At the same time, they reacted consciously and unconsciously to the objects in virtual reality with actions in the real world. Although they had no direct control over the virtual objects, they interacted with the Performer to explore the virtual space, such as by asking the Performer to see or move in a certain direction. The Observer impacted the virtual space by actively influencing the Performer's action in VR. Thus, the mixed reality space provided a chance for those who were not immersed in VR to enact their thoughts in virtual reality.

In Exclusive Physical Reality, the Observer had full access to their surroundings with a multisensory experience. For example, the Observer saw and heard from their surroundings to sense what happened in the group setting. In addition, the Observer had direct control to make an impact in the physical world, including freely interacting with others in the group. As a result, the Observer also influenced other Observers' actions and experiences in group learning.

The Group's Experience in Immersive VR-mediated Learning Space

The immersive VR-mediated learning groups were formed by two roles with different resources and constraints. The Performer and Observer had different accesses to the VR program, one with a head-mounted display and controller and the other with a desktop screen. Meanwhile, the two roles had different challenges during the simulation process. The Performer needed to adjust themself to overcome the disconnection between virtual and physical realities.

The Performer needed to deal with the disruptions from the other role in mixed reality. In contrast, the Observer had no direct control to impact the virtual environment as they wanted. Meanwhile, the two roles used different approaches to enact their thoughts in the virtual environment. The Performer tested their thought with actions, while the Observer tried out their thoughts by thinking aloud and actively influencing the Performer to act. Furthermore, Observers could be considered a sub-group within the group community, sharing the same role, whereas the Performer toke the role by themself. Therefore, the Observer owned more social resources than the Performer.

In the immersive VR-mediated learning space, a shared goal of collaborating and accomplishing virtual tasks evolved during the simulation process. The two roles had different goals and divisions of labor when the group is initially formed: the Performer had the tacit duty of finishing tasks in Virtual Reality, and the Observer presented to observe the process in physical reality. With different resources and constraints in the immersive VR-mediated learning space, the Performer and Observer were conscious of their role difference compared to the others, and they behaved in the way the assigned roles imply. However, due to the co-existence and overlapping of the virtual and ohysical spaces, both roles obtained access to the simulated environment. They were influenced by each other to make joint decisions in virtual situations. As individuals engaged in solving problems and accomplishing the assignment despite their roles, a shared goal evolved in the immersive VR-mediated learning space.

Noticeably, the Mixed Reality space connected the two roles and triggered collaboration between them. Individuals in the group were aware of the roles differences and resources distributions regarding their access and control within the VR program, which could result in contrasting experiences for the two roles. Nonetheless, the mixed reality space enables

communication and collaboration between the two roles, empowering them to make decisions and impact the virtual world together, and offers opportunities for shared group experiences. As the group worked together to solve problems and accomplish tasks in the VR program, an awareness of collaboration and shared ownership of the simulation experience developed within the group. Accordingly, individuals' experience in mixed reality was co-constructed by both roles in the group community. The Performer and Observer contributed to each other's decision-making and experience in Mixed Reality.

Furthermore, the immersive VR-mediated learning space triggered mental immersion and cognitive engagement through authentic situations rather than direct access to technology. Despite different accesses to the immersive and multimodal virtual experience granted by technology, the Performer and Observers were mentally immersed in VR to make spontaneous and conscious decisions to accomplish virtual tasks. Both roles invested their cognitive efforts actively to solve problems in specific VR situations, indicating mental immersion and cognitive engagement were triggered in the group undifferentiated.

Implications of Immersive VR-mediated Group Learning Space for Research

The discovery of immersive VR-mediated learning space has some implications for future research. Firstly, the study identified Mixed Reality (MR) as an overlap and collaboration between the virtual and physical spaces. Such a definition aligns with Benford et al.'s (1998) suggestion of mixed reality, defining it as a shared space based on constructing and integrating transparent boundaries between real and virtual spaces. Dix et al. (2005) also indicated that "mixed reality relies on the cognitive process of mapping (drawing connections between) multiple spaces." However, as Speicher et al. (2019) found from their interview with experts and literature review, the definition of mixed reality is highly fragmented and diverse. Multiple terms

are found to be used interchangeably with MR (e.g., augmented reality, virtual reality), and the MR experience is not clearly described and defined in studies. Accordingly, the notion of a mixed reality experience requires further research for better understanding and characterization.

Furthermore, group learning in immersive VR-mediated learning space needs further research. The study reveals the potential of collaborative learning in immersive VR-mediated group environment. The group setting where one student simulated in VR and others closely observed provided students with interactive and effective learning experiences despite the limited cost of VR technology. However, further studies are needed to investigate the nature and characteristics of collaboration in such a learning space. Specifically, different layers of collaboration happen in the group community, including the group collaboration, where the two roles co-construct their experience, and the sub-group collaboration between observers who expand their observational experience with peers sharing the same role. More research is needed to reveal how students interact and learn together with limited resources in the group (e.g., VR technology, students' attention, and cognitive load).

Implications of Immersive VR-mediated Group Learning Space for Practice

The discovery of immersive VR-mediated learning space has some implications for related learning practices. Specifically, the study revealed the importance of authentic and engaged learning situations, rather than the direct use of VR technology, in triggering mental immersion and cognitive engagement. Therefore, the immersive VR-mediated learning space where virtual, physical, and mixed realities co-exist demands further attention to maximize technology investment for creating an authentic and engaging experience for learners. Schools with limited resources of immersive VR equipment and resources can organize group learning activities to benefit more students with the observational learning mode.

Additionally, the practice of immersive VR-mediated group learning requires further design and considerations of effective scaffoldings and strategies. Scaffolding is a notion that has been characterized by Vygotsky's Zone of Proximal Development (Belland, 2014; Ge & Land, 2004; Wood et al., 1976), which indicates the assistance that students need to accomplish a task that they cannot yet independently accomplish (Vygotsky, 1978). Due to the division of labor and combination of multiple realities in the VR-medaited group learning, students in such a learning environment needs support to overcome challenges and collaborate with others. This study examined the intervention of guided group reflection on students' interactions and learning outcomes, while more instructional strategies need to be designed and examined to support collaborative learning in immersive VR-mediated group settings.

Role Profiles in Immersive VR-mediated Group Learning

The differentiation of the Performer and Observer in immersive VR-mediated group learning leads to different experiences for the two roles. In addition to answering Research Question One, which explores the two roles' experience in immersive VR-mediated group learning, the two roles' profiles can be summarized from the findings. Table 5.1 suggests two role profiles to portray the Performer and Observer in VR-mediated group simulation. Similar to a learning profile indicating students' certain modes of learning and needed supports (Tomlinson et al., 2003), the role profile can be used to design responsive instruction and guidance in group learning where students have different challenges and needs due to the role assignment. Meanwhile, the differentiation of support to students with different resources and constraints is a response to enhance the quality of learning for all learners in the group.

Table 5.1

Role Profile in Immersive VR-mediated Group Learning

Role	Profile
Performer	• An *Explorer* with power in VR and limited sensory experience in real world • An *Adventurer* who exposes their simulation to others' observation • An *Agent* who enacts others' thoughts and decision-making in VR
Observer	• A *Discoverer* who explores the virtual world through the Performer's point of view and actions • A *Spectator* who influences both the Performer and others in the group • A noncontractual *Team Member* who can play multiple roles in the group

Specifically, the Performer is depicted as an *Explorer* with the power in Virtual Reality to make a difference; they can act freely as they wish to explore the virtual world. However, they have their constraints and a pre-determined goal as the *Explorer*: to accomplish the virtual tasks with full access to VR and the trade-off of decreased sensation in their physical space. Additionally, the Performer is an *Adventurer* in the group learning space who exposes their actions and related consequences to peers' observation, which can lead to various influences on the Performer. For example, others may support, disrupt, or even judge the Performer's actions and decision-making, impacting the Performer's experience and learning outcome. Furthermore, the Performer is an *Agent* who can enact others' thoughts in the virtual space. Since the Performer is the only person with power and control in Virtual Reality, peers in the group rely on the role to try out their desired actions and decisions in specific situations.

In contrast, the Observer is portrayed as a limited *Discoverer* who explores the virtual space from the Performer's views and actions. Therefore, the Observer's discovery in the virtual environment is compromised and requires an active effort to achieve an immersive experience. Meanwhile, the Observer is a close *Spectator* who can influence the Performer' and others' actions and overall experience with their presence and active involvement. In addition, the role is also a noncontractual *Team Member* who can play different roles in the group. For example, the

Observer can be a bystander who oversees the Performer's actions and related consequences in VR. In contrast, the Observer can be an imaginative player who acts in the virtual world without being immersed in VR. Meanwhile, the Observer can act as a commentator with opinions on the Performer's actions. The Observer can also act as a collaborator who shares the goal with the Performer to accomplish the assignment.

Implications of Role Profiles in Immersive VR-mediated Group Learning for Research

The use of role profiles in immersive VR-mediated group learning has some implications for research. Firstly, it is necessary to examine the accurary and validity of these role profiles in diverse group settings. The role profiles were developed based on the current study focusing on pedestrian safety education with elementary students in Chinese culture. However, students' experiences with different role in the VR-mediated group learning may vary based on their psychological development and cultural backgrounds (Piaget, 1972; Hofstede, 1986; Vygotsky, 1978). Therefore, it is important to investigate the generalizability of the findings from this particular learning context to other social and cultural environments.

Secondly, further research is needed to explore the effectiveness and mechanism of applying the role profiles in group learning. Learners have different preferences for learning mode, which can be influenced by various factors such as social, cultural, and physical differences (Kalantzis & Cope, 2016). As a result, personalized instruction and support are necessary to accommodate student learning profiles (Tomlinson et al., 2003). In a group setting, the assignment of different roles or divisions or labor can have an impact on individual learning experience and outcome. Thus, it is crucial to examine the relationship between student characteristics, role profiles, and learning outcomes. Additionally, while the role profile provides a means for personalized and responsive instruction in group learning, further research is needed

to investigate its effectiveness and related challenges.

Implications of Role Profiles in Immersive VR-mediated Group Learning for Practice

The use of role profiles in immersive VR-mediated group learning has a couple of practical implications. Firstly, providing learners with a profile of different roles in the group setting can help them make informed decisions about role selection. For example, an individual who prefers to be the *explorer* rather than a *bystander* may choose the role of Performer, while someone who values collaboration more than *advanture* may prefer to be an Observer. Similarly, for a group learning environment with different roles or divisions of labor, creating a role profile can be helpful for learners to make a decision that matches their needs and preference.

Secondly, teachers or facilitators can proactively adjust their approaches based on learner and role variance in group settings. With the selected role profile, teachers or facilitators can offer personalized instruction and support tailored to individual learning needs (Tomlinson et al., 2003). Additionally, teachers or facilitators of group learning activities can actively use students' learning profiles and role profiles to design differentiated or responsive support for individuals with specific needs. For example, Muehlenbrock (2006) proposed that the quality of group learning could be enhanced by incorporating information from learner profiles and the learning context when forming groups.

The Four Stages of Group Reflection

The study reveals four stages of group reflection, including (guided) retrospection and description of the experience, (guided) analysis and evaluation of the experience, (guided) group exploration and discussion, and (guided) learning and conclusion. Noticeably, the four stages are not sequential but interactive. Figure 5.3 suggests the relationship between the group reflection stages found in this study. Since group reflection is an activity accomplished by a group of

learners rather than an individual, group interactions and communications play a central role in the process. Therefore, (Guided) Group Exploration and Discussion co-exists with and influences the other three stages of group reflection. The (Guided) Retrospection and Description of the experience is the first step in the group reflection process, which allows the group to share their individual and shared impressions on the experience. The (Guided) Analysis and Evaluation of the experience is a critical stage in the group reflection process, helping the group examine and reconsider their knowledge and behaviors during the experience. Finally, the (Guided) Learning and Conclusion is the last stage in the process, which suggests the results of group reflection, such as new understanding and plan for future behaviors.

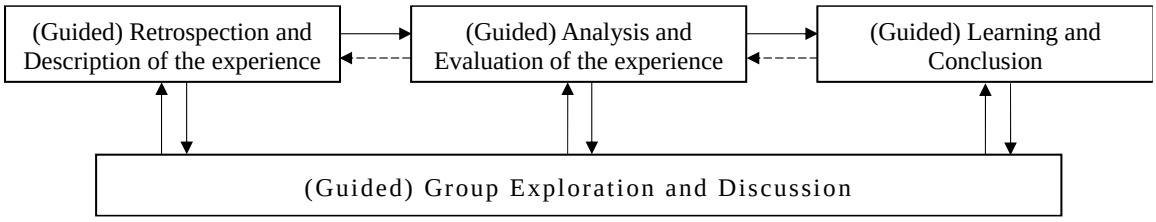


Figure 5.3

The Relationship between the Four Stages of Group Reflection

In addition, comparing the stage of group reflection with the general process of reflection leads to some new understandings of group reflection. Reflection has been disentangled into multiple stages or phases by a number of scholars (Atkin & Murphy, 1993; Bain et al., 2002; Boud et al., 1985; Boyd & Fales, 1983; Dewey, 1933; Gibbs, 1988; Korthagen & Vasalos, 2006; Rodgers, 2002). For example, Rodgers (2002) reclaimed and clarified Dewey's suggestion (1933) on the phases of reflection, which include present to experience, description of experience, analysis of experience, and intelligent action/experimentation. Boud et al. (1985) suggested three key stages of reflection, including the return to the experience, attending to

feelings, and re-evaluation of the experience. Although there were different models describing the general process of reflection, some similar stages can be found. Quinn (2000) suggested that different models of reflection involve three fundamental processes, which are retrospection, self-evaluation, and reorientation.

Accordingly, the group reflection stages found in this study validate the general process of reflection while highlighting the unique characteristics of the group environment. Notably, the finding provides experimental support for the statement that reflection proceeds with systematic phases rather than a causal thinking process. Regardless of the social environment, the general reflection process includes retrospection, re-evaluation, critical analysis, and reorientation for thinking and action (Finlay, 2008; Koole et al., 2011). The group reflection has one more stage of *(Guided) Group Exploration and Discussion*, which reveals the unique characteristics of the group environment while adding to the complexity of the reflection process.

Implications for Group Reflection Research

Group reflection indicates a group of two or more people reflecting through social interactions to construct meanings and attain understandings from individual and shared experiences (Cord & Clements, 2010; Hong et al., 2019). This type of reflective practice has been overlooked, with limited attention in research (Reynolds, 2017; Sharmahd et al., 2018). Accordingly, the findings of the four group reflection stages in this study have some implications for group reflection research and practice. Specifically, the four stages of (guided) group reflection require further investigation and validation in different learning contexts. This study focuses on immersive VR-mediated group learning where the group's experience is rooted in the interplay between immersed and observed experiences. Others learning settings, such as online group reflection, provides different affordances and constraints for groups to construct

experience and reflect together. Therefore, findings revealed in this specific study need further investigation in different contexts for generalization.

This study also comfirmed a couple of theoretical justifications for group reflection. For instance, the findings revealed that leaners had varying focal points during their VR simulation experiences, which facilitated analysis on collective experiences. Moreover, the study demonstrated that individuals could identify their misconceptions and overcome limitations through group reflection. These findings align with the theoretical perspectives that suggest group environments offer opportunities for reflection and can assist indiviudals in achieving what they may not be able to accomplish alone (Brown & Palincsar, 1989; Eshuis et al., 2019; Johnson & Johnson, 1999; Rodgers, 2002; Vygotsky, 1978). As a result, some of the theoretical foundation of group reflection outlined in the proposed conceptual framework (refer to Chapter 3) were empirically tested. However, additional research is needed to investigate the theoretical underpinnings of group reflective practices, particularly in diverse learning contexts.

Implications for Group Reflection Practice

The findings from the group reflection stage also have some implications for instructional design and reflective practice. Firstly, the study comfirmed the crucial role of support for group reflection, especially for young learners who may lack reflection and collaboration skills. Therefore, future practices should emphasize the importance of different scaffolding strategies to facilitate group reflection. For instance, this study proposes four categories of guidance (see Table 2.3) in the literature review, but further research and practice are needed to apply specific guiding strategies and tools for supporting reflective group practices.

Secondly, the four stages of group reflection highlighted the crucial role of Guided Group Exploration and Collaboration, emphasizing the practical focus that teachers and facilitators

should prioritize in group reflection activities. For example, the study highlights some practical challenges of group reflection that teachers and facilitators can address to avoid potential issues in related group reflection activities. By examining the influential factors that affect group collaboration, practitioners can design specific strategies and instructional support to help learners engage in meaningful group reflection. For instance, the study revealed that a lack of shared understanding of teamwork and certain social rules can hinder students' free exploration and achievement in group reflection. Therefore, educators can design certain strategies to help groups establish a collaborative and open atmosphere for individuals to reflect together effectively.

Similar Experiences and Learning Outcomes Obtained by Different Roles

The study found that learners obtained similar experiences and learning outcomes despite different roles assignments in immersive VR-mediated group learning. For example, the findings indicated that the Performers and Observers were mentally immersed and cognitively engaged in solving problems in VR. Both roles showed the motivation and agency to make decisions on how to act in specific situations, and they both developed a sense of ownership in completing the VR assignment. Meanwhile, the two roles were aware of the group community with different role assignments; they were engaged in active interactions with others and were influenced by their peers' presence and actions in the group. Such findings suggest that immersive VR-mediated group learning in which peers closely observe one student's simulation in VR is a success in providing immersive and engaging experiences for the group. In addition, tests after the group learning activity suggested similar learning outcomes for the two roles' knowledge and behavior acquisition. This outcome validates the hypothesis rooted in social cognitive theory, which proposes that observed learning can produce comparable effects to those of immersive, first-

person learning experiences (Bandura, 1986).

The study identified two primary reasons for the similar experiences and learning outcomes of different roles in immersive VR-mediated group learning. firstly, the Mixed Reality space was an important component that connected the Performer in the virtual world with the Observers in the physical environment, providing a collaborative space where learners with different resources could share information and interact with each other. Thus, the group accomplished the VR task together with co-constructed experiences. Secondly, guided group reflection was critical in transferring the observed and immersive experiences to shared understandings and meanings. Through group reflection, the group had opportunities to thoroughly examine and discuss their individual and shared experiences together, leading to similar learning outcomes. These findings suggest that mental immersion, peer collaboration, and group reflection are crucial for obtaining learning experiences and outcomes, rather than direct access to VR technology.

Unavoidably, the two roles had distinct experiences regardless of shared experiences and learning outcomes. With different role assignments, the Performer and Observer had different resources and challenges during the VR simulation and group reflection. For example, the Observer was not able to enact their thoughts in VR directly, while the Performer needed to overcome the disconnection between the virtual and real world. Meanwhile, the two roles were found with different challenges in group reflection. The Performer encountered the social pressure of being judged or commented on their actions, while the Observer lacked the social skills to deal with different opinions. Accordingly, specific support or guidance is needed to help overcome any challenges granted by the role assignment.

Implications for Immersive VR-mediated Group Learning Research

The findings of this study have some implications for research related to immersive VR-mediated group learning. Firstly, the study supports the idea that observed experiences can be equally effective as immersive experiences, but effective instructional design strategies, such as designing the Mixed Reality space and providing guided group reflection, are crucial in achieving this. Therefore, further research is necessary to explore different scaffolding techniques that support collaborative learning in environments where technology is not readily available. Furthermore, studies in various learning contexts and cultural settings are required to examine the generalizability of the findings from this specific study.

In addition, future research should examine different role assignments and the associated challenges that learners face in immersive VR-mediated group learning activities more extensively. For instance, this study revealed unique challenges faced by learners in a group setting where one member simulated in VR while others observed in a shared location. The Performer had reduced sensitivity in the physical environment, while the observer had limited sensations in the virtual world. Providing targeted support and guidance based on an understanding of these challenges can enhance the learning experiences and outcomes of all group members. Therefore, further research is needed to explore other VR-mediated group learning settings with diverse role assignments or divisions of labor to design environments that support the diverse learning needs of individuals within the group.

Moreover, it is worth noting that this study specifically targeted students aged seven to ten years old within a Chinese cultural background, and its findings are contextualized within this particular condition. It is important to recognize that students may have varying experiences in VR-mediated group learning based on their developmental stage. For instance, Bukowski et al.

(2000) discovered that attraction to aggressive peers increases as children enter early adolescence. Therefore, teenage students may interact differently compared to the younger children in this study. Furthermore, all peer experiences are influenced by the cultural macrosystem (Rubin et al., 2015), where cultural beliefs and norms play a significant role in shaping children's perceptions and experiences in peer interactions and relationships (Chen et al., 2018). In Chinese culture, interpersonal harmony and group cohesiveness are highly valued, which could influence children to prioritize prosocial behaviors in teamwork. In contrast, different cultural environments may lead to different peer interactions. Consequently, the findings of this specific study may have limitations in terms of their generalizability to other learning contexts. Therefore, further extensive research is required to investigate learners' experiences in various contexts.

Implications for Immersive VR-mediated Group Learning Practice

The findings of this study have a couple implications for the practice or immersive VR-mediated group learning. Firstly, the study suggests that designing group learning environments with limited VR resources can be a practical solution to address the problem of equipment shortage. Therefore, schools or organizations with limited resources for immersive VR can still serve a large population of students. However, instructional design efforts are necessary to create similar learning experiences and outcomes for individuals with varying resources within the group setting. Meanwhile, the current study examined observational learning in a shared physical space with group reflection to help students learn together, while other forms of practice can be developed to maximize the use of educational resources and serve more students.

In addition, for immersive VR-mediated group learning with different roles and divisions of labor, learners may face different challenges and obtain varying experiences. Thus, identifying

and addressing these challenges is critical to supporting meaningful and equitable learning outcomes for all group members. This study highlights some practical challenges that can be used to design successful group learning activities in practice. For example, the role of Performer may encounter judgment on their behaviors during group reflection, which may hinder the role's participation and learning investments in the group setting. Therefore, the facilitator or teacher in the group need to pay attention to potential emotional challenges or social attacks that the Performer may face to help the role work with others in the group.

Future Directions

This study explored a specific VR-mediated group learning setting in which students observe and reflect on one member's simulation in an immersive VR program. Two roles are examined in this study, including the Performer fully immersed in VR and the Observer closely presented in the surrounding area. Nine group cases are studied to investigate how learners with two roles (Performer vs. Observer) experience, reflect, and learn together to construct meaning and knowledge. Critical findings are revealed in this study to answer three research questions. The findings of the study contribute to both the theoretical understanding and practical applications of immersive VR-mediated group learning. In addition to drawing some implications for future research and practice in a larger scope, the study suggests a few directions to further investigate this specific VR-mediated group learning environment, which can also be the author's next steps in further unfolding how the group learns together with the limited VR resources.

One potential avenue for future research is to conduct a comparative case analysis to examine any factor that influence immersive VR-mediated group learning. The current study focuses on investigating the overall experiences and learning outcomes of learners with different

roles (Performer vs. Observer) in the group. Forty-five students from nine groups were recruited in the study with a separation of nine Performers and thirty-six Observers to answer three research questions. Thus, group variations are not examined in the current study to reveal any effects caused by group differences, such as group composition and cohesion. Therefore, further investigation and comparation bewteen group cases can help gain a deeper understanding of VR-mediated group learning beyond the scope of the current study. For example, a comparative case analysis could examine factors that influence peer interactions and collaboration in the group setting.

Additionally, immersive VR-mediated group learning consists of two sequential group activities—the immersive VR-mediated group simulation and group reflection. The current study examines the two activities independently to answer research questions that focus on group dynamics in two distinct learning phases: the simulation activity allows the group to construct an experience for their learning, and the reflection activity helps the group transfer their experiences into meanings and understandings. However, the two group activities are connected with each other to provide the overall learning experiences and results. For example, a group's interactions during the simulation activity could influence their behaviors and collaboration in group reflection. Therefore, further study is needed to investigate how immersive VR-mediated group simulation and group reflection are connected to contribute to individuals' learning.

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APPENDICES

Appendix A

A Summary of the Systematic Review of Group Reflection Studies from 2010 to 2020

Category	Definition/Explanation	References
Q1: How was Group Reflection Defined in Studies? (21/74 studies, 28% of the review studies*)*		
Collective reflection	Two or more people participating in a reflection exercise together, aiming at attaining a deeper understanding that would not be attainable by one person alone.	Chen et al., 2020; Collin & Karsenti, 2011; Cord & Clements, 2010; Foong et al., 2018a; Gutzan & Tuckermann, 2019; Hong et al., 2019
Collaborative reflection	The collaborative format of reflection which happens in a group, with social interactions to construct shared knowledge in a learning community.	AguirreGarzón, 2018; Jiang & Zheng, 2020; Lin et al., 2013; Min et al., 2020; Veen & de la Croix, 2016
Group reflection /reflective practice	A peer-led practice where practitioners come together to reflect on practice and engage in learning and mutual support.	Lees & Cooper, 2019; Staempfli & Fairtlough, 2019; van Lierop et al., 2018
Team reflection	A team of different roles evaluating past team activities to achieve better team performance	Fluijt et al., 2016; Schmutz & Eppich, 2017; Schmutz et al., 2018; Shin et al., 2017; Siegel & Schraagen, 2017; Otte et al., 2018; Wiedow & Konradt, 2011
Q2: What Theories Were Used to Justify Group Reflection? (19 / 74 studies, 26% of the review studies*)*		
Sociocultural theory	Group reflection is mediated by social interactions.	Bertling, 2019; Collin & Karsenti, 2011; Collin & Karsenti, 2019; Hong et al., 2019; Jiang & Zheng, 2020; Kuh, 2016; Min et al., 2020; Pawan & Fan, 2014
Social constructivism	Group reflection is a shared meaning-making process.	Elhussain & Khojah, 2020; Foong et al., 2018a; Foong et al., 2018b; Layen & Hattingh, 2020; McGarr et al., 2019; Ohlsson,

		2013
Community of practice	Group reflection forms a community of practice that develops mutual engagement, joint enterprise, and shared repertoire.	Kennelly & McCormack, 2015; Kim & Cavas, 2013; Kuh, 2016; Layen & Hattingh, 2020; McArdle & Coutts, 2010
Q3: What Activities Were Used to Facilitate Group Reflection?		
(Guided) Group discussion	(Guided) group dialogue/discussion regarding reflection, such as reflective seminars, reflection session, group reflection meetings, reflective practice workshops.	Aguirre Garzon, 2018; Alvarado Gutiérrez et al., 2019; Beylefeld & le Roux, 2015; Boerboom et al., 2011; Clara et al., 2019; Cord & Clements, 2011; Flores et al., 2014; Foong et al., 2018a; Foong et al., 2018b; Graham & O'Brien, 2020; IQBAL & MAHMOOD, 2010; Kennelly & McCormack, 2015; Layen & Hattingh, 2020; Murphy & Ermeling, 2016; Ohlsson, 2013; Pawan & Fan, 2014; van lierop et al., 2018; Veen & de la Croix, 2016
Group reflection in online settings	Group reflection activities such as posting and replying in online forums and writing collective blogs	Chen et al., 2020; Eshuis et al., 2019; Hong et al., 2019; Kalk et al., 2019; Kim et al., 2011; Krutka et al., 2014; Lord et al., 2017; Quiñones et al., 2018; Smit et al., 2017
Group reflection on individuals' practice	Group reflection based on peers' practice (e.g., presentation, performance) and observation within the group.	Epler et al., 2013; Janson et al., 2011; Kim et al., 2013; Lees & Cooper, 2019; Lin et al., 2013; McGarr et al., 2019; Williamson et al., 2019
Shared writing	A reflective paper/document created by the group/team regarding their reflection on the practice.	Elhussain & Khojah, 2020; Kelly, 2015; Miller & Maellaro, 2016
(Guided) Group reflection on cases/dilemmas	A (guided) reflective analysis on a case or dilemmas present to the group.	Binyamin, 2018; Daniëls et al., 2020; Golaghaie et al., 2019; Woolway et al., 2019; Yoon & Kim, 2010
(Guided) Debriefing	A post-experience analytic discussion in which participants are led to a purposive discussion on their experience,	Layen & Hattingh, 2020; Min et al., 2020; Siegel & Schraagen, 2017; Smit et al., 2017; Tutticci et al., 2018

	such as group reflection after a fieldtrip.	
Other reflection assignment	Group-based mindfulness (Chinnery et al., 2019), group visual reflection (Bertling, 2019), team reflection task (Domke-Damonte & Keels, 2015; Konradt & Eckardt, 2016; Shin et al., 2017), critical friends groups (Kuh, 2016), and intervision (Staempfli & Fairtlough, 2019)	
Q4: What Unique Features of Group Reflection Were Revealed in Empirical Studies?		
Social conditions	Certain conditions are needed for group reflection to happen, such as time, commitment, collaborative attitudes, and thoughtful facilitation.	Clara et al., 2019; Daniëls et al., 2020; Elhussain & Khojah, 2020; Graham & O'Brien, 2020; Jiang & Zheng, 2020; Layen & Hattingh, 2020; Yoon & Kim, 2010
Group size	Group size is an important boundary condition that moderates interpersonal interactions within the group.	Daniels et al., 2020; Schmutz et al., 2018
Group composition	Varied group compositions are found across studies. The diversity of group members impacted the dynamic and outcome of group reflection.	Eshuis et al., 2019; Konradt & Eckardt, 2016; Farrell, 2016; Yoon & Kim, 2010
Guidance from facilitators/teachers	The guidance provided by a facilitator/ teacher plays a significant role in the process and outcome of group reflection.	Alvarado Gutiérrez et al., 2019; Carthy et al., 2013; Clara et al., 2019; Daniels et al., 2020; Foong et al., 2018a; Foong et al., 2018b; Graham & O'Brien, 2020 Kim et al, 2013; Mc Carthy et al., 2013; Otte et al., 2018; van Lierop et al., 2018
Q5: What Implications Could Be Drawn from the Review Findings?		
A lack of theoretical examination on reflection	The review found only 21 out of the 74 studies defined the term used to indicate reflection in group contexts, multiple terms were used without clarification on their differences. Meanwhile, only 19 out of the 74 studies explicitly indicated a theoretical foundation for their practice of group reflection	
A lack of exploration on how group reflection functions with the features of reflection in group settings	The review found only a few studies have examined group reflection's characteristics (McArdle & Countts, 2010; Jiang & Zheng, 2020), stages (Bertling, 2019; Johnson & Fells, 2017; Murray, 2015; Schmutz & Eppich, 2017), types (Rantatalo & Karp, 2016; Yeşilbursaş, 2011), and process (Kim et al, 2013; Otte et al., 2018; Sharmahd et al., 2018), revealing group reflection was a system functioning by specific mechanisms.	

Group composition and guidance as two essential factors to examine how different people reflect together in groups	From the unique features identified by empirical studies, we recognized group composition and guidance on the practice because (a) the social condition concerning the larger sociocultural environments in which groups are situated is beyond our focus on examining group reflection based on interactions within groups and (b) group size a secondary group-level factor compared to group composition.

Appendix B

Debriefing Protocol

PHASE 1: First, set the question context by using the observation protocol. For example,

Challenge 1: When you saw a virtual friend in front of a street calling you to join him …

Challenge 2: When you saw a wide street …

Challenge 3: When you attempted to walk across a street with a school bus…

Then, use the following questions to lead the children's debriefing.

1. Can you tell me about everything you saw?
    a. What else?
    b. What did you hear?
        i. What else?
2. For each important cue they list, ask them more questions to know what the cues mean to them.
    a. What does it mean? (e.g., what does it mean when the light was green?)
3. At that point, what were you trying to do? Why?
4. What did you think would happen? / What were the consequences?

Note. Each challenge will have the set of the same questions.

PHASE 2: Explain to the participant the correct behaviors in each of the challenges they experienced.

Appendix C

Ten Pedestrian Traffic Scenarios Test (with Answers)

Directions: Select the response that best answers the question or statement.

1. When you see a pedestrian red traffic light at the crosswalk, what does it mean to you? [A]

   A. Pedestrians are not allowed to cross the crosswalk

   B. Pedestrians are allowed to cross the crosswalk

   C. The vehicles will stop to let pedestrians cross the crosswalk

   D. Pedestrians are allowed to cross the crosswalk as long as they raise their hands

2. A pedestrian blinking green light means: [B]

   A. the traffic light is out of order temporarily

   B. the green light is going to change to be the red light very soon

   C. people have to run to cross the street

   D. the green light will last for a long time

3. When you see a pedestrian green traffic light at the crosswalk, what does it mean? [B]

   A. Pedestrians are not allowed to cross the crosswalk

   B. Pedestrians are allowed to cross the crosswalk

   C. Vehicles will start to move

   D. The pedestrians and cars can move at the same time

4. The zebra crossing/crosswalk is: [A]

   A. A passageway that allows pedestrians to cross the road.

   B. A passageway that allows cars to cross the road.

C. A passageway that allows all cars and pedestrians to cross the road.

D. A road area that no one should enter

5. You notice the traffic light is red when you want to cross the road. What would you do? [D]

A. I would continue walking across the road.

B. I would cross the road very carefully while watching for traffic.

C. I would check the road traffic. If there's no car on the road, I will walk across the road.

D. I would stop crossing the road and wait for the green traffic light.

6. What would you do when the pedestrian light turns green when you wait at the crosswalk to cross the road? [C]

A. I will just follow people in front of me

B. I will not cross the crosswalk until the pedestrian traffic light turns red

C. I will check the road first to make sure all cars stop, and then I will cross the crosswalk

D. I will run to cross the crosswalk as quickly as possible

7. You find the green light blinking when you are about to cross the crosswalk. What would you do? [C]

A. I would hurry up and run across the crosswalk.

B. I would stay on my side and wait for a red light to cross the crosswalk.

C. I would stay on my side and wait for another green light to cross the crosswalk.

D. I would follow what other people are doing.

8. Your soccer ball rolls across the road to the other side, and there is a crosswalk 100 meters ahead. What would you do to get your soccer ball? [C]

A. I would chase my ball and get it on the road immediately.

B. I would cross the road very carefully when there is no car in order to get my ball.

C. I would walk to the crosswalk and cross the road according to the traffic light to get my ball.

D. I would raise my hand and cross the road carefully to get my ball

9. You plan to cross a road with a crosswalk when the traffic light is green, but you also notice that a car is backing into the crosswalk that may block your path. What would you do? [D]

A. I would continue walking across the road because I obey the traffic rules.

B. I would continue walking across the road and try to bypass the backing car.

C. I would wait for the car to leave and then run to cross the road.

D. I would wait for the car to leave, and then I would follow the traffic signal to cross the street.

10. What would not be the safe behavior you do before crossing the crosswalk? [C]

A. I should check both sides of the road to see if cars stopped.

B. I should check the pedestrian traffic light to see if it is green.

C. I should follow other people regardless of the traffic signal.

D. I should stand on the right side of the crossroad.

Appendix D

Interview Guide

Before the interview: Thank you for your participation! Since you have just completed the VR session, I want to ask a few questions regarding your experiences. Could we talk about your experience together?

Interview question:

1. How do you feel? Why?
    a. What else?
2. Can you remember anything you like/dislike? Why?
    a. If they have only responded with what they liked, ask them, "Is there anything you did not like?"
    b. If they have only responded with what they did not like, ask them, "Is there anything you did like?"
3. How do you like your learning in the group?
4. Next time when you cross the road, will you do the same thing you do in the VR? Why?
5. What did you learn today?
    a. Will you apply what you learned today when you cross the road?