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The Use of a Digital Question Board to Facilitate Student Questioning and Engagement in Large Lecture Classes: A Mixed-Methods Study

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Abstract

A lack of student questioning and engagement is faced by many universities, where a large lecture is a common practice. Emerging technologies bring about possibilities to fill this gap. This study applied constructivist learning theories and used a digital canvas as a Digital Question Board (DQB) for students to freely pose questions and respond using mobile technology. A mixed-methods study with a quasi-experiment was conducted to investigate the following research questions (RQs): (1) Do students demonstrate different questioning behaviors when provided access to a DQB from those students who are not provided with access to a DQB in large lecture classes? and (2) How does having access to a DQB during large lecture classes influence students' level of engagement?

The study was conducted in two groups of an introductory research methodology course in a large comprehensive university in eastern China (n = 253). The pre-post quasi-experiment lasted six weeks. The data from surveys, interviews, observation, and online posts (log data) were collected and analyzed. The results revealed that when the instructor discussed student questions after every 20–30 minutes in large lecture classes, students with DQB access had a significantly higher frequency of questioning than those without a DQB. The presence of the DQB enriched the types of questions and responses and encouraged mostly on-task learning questions. Having DQB access also greatly improved students' behavioral and cognitive engagement and facilitated emotional engagement. With technology, students employed a non-linear, constructivist questioning process and actively contributed to the co-construction of knowledge. The presence of the DQB reduced the social pressure of questioning in large lecture classes.

This research might contribute to the educational practices and theories as it depicted the patterns of student questioning in technology-mediated large lecture classes, proposed how to design constructivist instructional strategies better to encourage all students to freely pose questions and receive feedback without fear of embarrassment and being judged.

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Contents

Tables

Figures

Chapter 1: Introduction

Background

Student Questioning. Students might encounter ambiguity or difficulty in understanding instructors' instruction, learning materials, or while doing a learning activity in a lecture class. In such a situation, rather than giving up, it is adaptive for students to use others as a resource to secure the necessary help and continue the learning process (Nelson-Le Gall, 1985). They could seek help from either an instructor or peers through asking questions. Student questioning is student initiating, asking, or constructing questions, which can be described as an ordered event (van der Meij, 1994) and a social-interactional process (Newman, 1990). Being a proactive action, student questioning could be considered as a kind of help-seeking, which has been widely acknowledged as a critical self-regulated learning strategy (Butler, 1998; Karabenick & Knapp, 1991; Nelson-Le Gall, 1985; Newman, 1990; Ryan & Shin, 2011; Schunk & Zimmerman, 1994). Since Socrates first exemplified the use of questions, questions have been thought essential to the pursuit of inquiry. Aristotle proposed that knowledge consisted in answers to questions (Dillon, 1988a). Therefore, student questioning not only reveals students' perplexity in learning but also indicates their willingness to learn.

Student Engagement. In 1984, Astin (1999) proposed a developmental theory among college students that focused on the concept of involvement, which he later renamed engagement. Astin defined engagement as "the amount of physical and psychological energy that the student devotes to the academic experience" (Astin, 1999, p. 518). Today, student engagement has mostly been defined as investment or commitment, participation, or effortful involvement in learning (Newmann, 1992). Although there is still no consensus on the definitions and measures of student engagement, most researchers conceptualize engagement as a meta-construct, consisting of three sub-constructs: emotional, cognitive, and behavioral engagements (Fredricks et al., 2004). Behavioral engagement includes effort, intensity, persistence, determination, and perseverance in the face of obstacles and difficulties; cognitive engagement encompasses attention, concentration, focus, absorption, “heads-on” participation, and willingness to go beyond what is required; emotional engagement includes enthusiasm, enjoyment, fun, and satisfaction (Fredricks et al., 2004). Engagement in this study is defined as students’ effortful involvement in learning with positive emotion. It is widely acknowledged and empirically proved that student engagement is a critical contributor to students’ academic development (Kuh, 2009; Fredricks et al., 2004; Skinner & Pitzer, 2012). It contributes to the development of “durable long-term motivational mindsets and skillsets, such as an autonomous learning style or mastery orientation, self-regulated learning, a positive academic identity, and eventually ownership for one’s progress” of learning (Skinner & Pitzer, 2012, p. 24).

Statement of the Problem

Despite the importance and necessity of student engagement, a lack of student engagement is a common problem faced by many universities around the world (Sawang et al., 2017). Student questioning is even more restricted in large lecture classes (Baron et al., 2016). In large lecture classes, a well-recognized issue is passivity amongst students, which has received a wide range of criticism (Baron et al., 2016). Often, in such large classrooms with hundreds of students, it is quite easy for individuals to lose the focus of their attention toward the lecture and become disengaged. It is also difficult for those students to initiate their questions whenever they encounter perplexity. In large lecture classes, students’ inhibition of asking questions is widely recognized by many practitioners and researchers. Many college students choose not to ask questions, even if they are aware of the existing perplexity (Karabenick & Knapp, 1991), which is a particularly serious concern in Asian countries such as China. In fact, most lecturers and instructors probably know some students who never ask questions in class, but often come to them with questions after the lesson is over (van der Meij, 1994). Students who need help the most may be less likely to ask questions.

Context of the Problem

Although the lack of student questioning and student engagement in large lecture classes receive much criticism, they are still commonly practiced in many universities in China, and they are also typical in many universities worldwide these days (Baron et al., 2016). According to the Chinese Ministry of Education, in the stage of compulsory education, super-large classes had more than 66 students, large classes had more than 56 students (Zhong, 2018). Although the Chinese government did not clearly define the exact size of large classes in universities, other studies gave some examples of how large classrooms were defined. For instance, in Sawang et al.'s (2017) study, a classroom with 131 students was considered large. In Addison et al.'s (2009) study, the large classroom included approximately 150 to 190 students. While in Harunasari and Halim's (2019) study, the large classroom comprised only 41 students. More recently, Flaherty (2020) defined large classes as ones with 31 to 40 students, extra-large classes had 41 to 60 students, and oversize classes had more than 61 students. Despite the differences in how a large classroom was defined, large lecture classes were usually associated with a lack of student questioning and student engagement (Baron et al., 2016; Sawang et al., 2017). In this study, classes wish more than 60 students were considered a large class. In the meantime, three major barriers led to this problem.

Barriers That Led to the Problem

Scholarly literature suggests that three barriers inhibit student questioning and student engagement in large lecture classes: motivational or emotional obstacles, restrictions of lecture-centered pedagogy, and contextual limitations of a large class size.

Motivational or Emotional Obstacles. In the process of student questioning, cognitive factors influence whether students notice existing perplexity and successfully formulate a question. There were relations between students' questioning behaviors and their prior knowledge (van der Meij, 1990), skills level (Butler & Neuman, 1995), and verbal ability (van der Meij & Dillon, 1994). When students go to college, their skills are improved, and they are better able to monitor and reflect on their learning progress to determine their need for help. Thus, college students are less likely to be stuck in the initial stages of questioning (i.e., the awareness of a question). Instead, as Dillon (1988b) suggested, the last move in the asking stage—the expression of the question—was the most difficult one to take. In large lecture classes, when students were aware of the perplexity, their decision of whether to act upon this awareness was mostly filtered through both emotional and motivational factors (Karabenick & Sharma, 1994) such as perceived threats to self-esteem and social embarrassment (Karabenick & Knapp, 1991; Newman & Schwager, 1993).

Earlier studies suggested that questioning avoidance or tendencies were inversely related to whether learners perceived questioning among college students was threatening (Karabenick and Knapp, 1991; Ryan and Pintrich, 1997). More recent studies also showed that the idea of being embarrassed in front of the peers and the feeling of being reluctant to annoy their peers prevented them from asking questions in class (Baron et al., 2016; Harunasari & Halim, 2019). Alexitch's (2002) study with 361 first-year students revealed that learning-oriented students who reported good academic performance were more willing to ask questions, while highly grade-oriented students who were more likely to perceive questioning as threatening to their self-worth, and students who performed poorly, reported that they were less likely to ask questions. To summarize, students were afraid to pose their questions due to the fear of being shamed, the desire not to impose on the teachers' time, or the belief in some rule of conduct prohibiting asking questions at a specific time (e.g., van der Meij, 1994). Thus, students, who needed help most, were often the least likely to ask questions, i.e., students who had poorer academic performance or lower self-esteem (Ryan & Pintrich, 1997) and who felt embarrassed in front of their peers (Baron et al., 2016). While other students, especially those who showed good academic performance (Alexitch, 2002), avoided questioning if there was no need for it, or if they preferred to use other learning strategies (Karabenick & Knapp, 1991), or if they wanted to strive for independent mastery (Butler & Neuman, 1995).

In short, students were found mostly saddled with motivational and emotional obstacles to asking questions in large lecture classes, which made it difficult for instructors to provide contingent teaching to help them.

Restrictions of Lecture-centered Pedagogy. Pedagogical factors, such as instructional design, teacher behavior, and the resulting classroom discourse, encouraged or hindered student engagement and student questioning (Karabenick, 2003; Karabenick & Sharman, 1994). The traditional lecture or lecture-discussion is the most common teaching method in an academic setting, which has a long history in university teaching and was derived from ancient scholarly traditions that predate the university (Baron et al., 2016). The lecture-centered pedagogical format was considered antithetical to active student engagement (Baron et al., 2016). However, in modern China, it remains the most ubiquitous class structure in higher education. In such an environment, constructivist learning is restricted as students do not have much autonomy to actively construct their learning at a personalized pace and with their preferred learning strategies. Students have a lower expectation of teacher support, and they do not likely expect instructors to provide feedback to each of them individually. In large lecture classes, it is also difficult for instructors to instruct students who vary in academical ability (Baron et al., 2016).

For student questioning specifically, lecture-centered pedagogy influences both students' capacity to ask a question and their level of inhibition. In many large classrooms, instructors always set up rules on the frequency and nature of interactions to regulate classroom interactions, and students must obey these rules (van der Meij, 1994). Explicit and implicit rules also regulate the interactions between students and teachers. Although unwillingly, these rules might obstruct student questioning. For instance, in a regular face-to-face class, student questioning must be signaled by raising a hand, and during seatwork, a student must walk up to the teacher's desk in front of the classroom. Teachers make the act of posing a question in the classroom a highly conspicuous affair (van der Meij, 1988, 1994), which is likely to make students more hesitant or reluctant to initiate questioning. For some students, asking questions is viewed as "challenge to authority," "impolite," and "annoying" because it slows down the lecture (Baron et al., 2016, p. 62). Besides, most lecture-centered classes are designed for introductory courses rather than in-depth advanced courses. It is reasonable to assume that a well-structured and well-designed lecture might not lead to a higher frequency of student questioning.

Moreover, a passive learning process is often regarded as the norm in many large lecture classes in China; thus, it discourages students from actively interacting in class and asking questions. As van der Meij (1994) pointed out, in classrooms, the social-normative obstacles to questioning were very high; teacher and textbook questioning were the norms.

In short, the lecture-centered pedagogy commonly seen in large lecture classes restricts constructivist learning, i.e., precludes student questioning and student engagement.

Contextual Limitation of Large Class Size. Contextual limitations of large lecture classes also greatly inhibited student questioning and student engagement (Karabenick, 2003; van der Meij, 1988, 1994). According to Fassinger's (1995) comprehensive analysis with 1059 college students, class size is significantly related to students' class participation and interaction. Since the space is large, large classroom configurations discourage interaction and are regarded as "impersonal" (e.g., Gleason, 1986, p. 29). As Gleason (1986) described:

> Seats are arranged in rows, situated close together which makes it difficult to converse with persons seated directly at your side, equally difficult to interact with the back of heads in front of you, and impossible to carry on a conversation with the unseen people behind you. (p. 20)

Also, the larger the class is, the higher the challenges that teachers face to provide feedback to individuals and engage them in learning.

Asking a question in large lecture classes is much more difficult than asking the same question in small classes or posing it to an individual. Researchers suggest that asking questions can be particularly intimidating in large classes (Baron et al., 2016). Because of the importance of emotional, social, and personal costs in student questioning, in large lecture classes students might estimate that the probabilities of their asking questions could be small and the social, emotional, or personal costs were high (Tricot & Boubee, 2013).

In short, contextual limitations contribute to students' lack of engagement and reluctance to ask questions in large lecture classes. Students are more likely to experience social pressure and weigh the threats and costs of questioning in large classrooms.

Summary

Together, for college students in general, motivational, or emotional obstacles are presumed to play a dominant role in influencing whether students ask questions in large lecture classes. Lecture-centered pedagogy and contextual limitations of large lecture classes restrict student engagement and exaggerate motivational or emotional obstacles of student questioning. Because of the big class size, limited time and space, there are few opportunities for students to ask questions as well. As van der Meij (1994) suggested, it was not that students had no question to ask, but the conditions were unfavorable or were perceived as unfavorable for asking questions.

However, those barriers to student engagement and questioning in large lecture classes could hardly be resolved through traditional pedagogy. Meanwhile, constructivism sheds light on improving student engagement through prompting student questioning, which may lead to double and even multiple gains.

Theoretical Framework

From the constructivist perspective, both student questioning and student engagement are of great necessity and importance in learning: learning is constructed; students should use active techniques to create knowledge and then reflect on what they do and how their understanding changes; student questioning is an indicator of a student’s active involvement in the learning process, and such questioning might resolve the student’s perplexity and facilitate his or her cognitive processing.

Student Questioning Indicates Student Engagement

First, constructivism emphasizes that learners are active in constructing knowledge and meaning, which suggests that educators pay attention to students’ metacognition and encourage student self-awareness and strategic self-regulation. Student questioning requires students to monitor their learning process; activate and retrieve their previous knowledge; make connections with new information; examine whether perplexity or a gap exists and develop a question to transform the perplexity into a formulated and expressed question (Dillon, 1990). Grounded in and derived from the constructivist epistemology, from the perspective of generative learning theory, student questioning is considered as a generative learning activity in which learners generate organizational and reorganizational relationships among different environmental components and construct meaningful understanding and comprehension (Grabowski, 2004; Wittrock, 1989). This process is a signal of self-regulated learning (SRL), as it requires students to regulate their learning, constantly assess their understanding, and identify the gap between their existing experiences and new knowledge (Nelson-Le Gall, 1985). To troubleshoot a problem encountered during learning, self-regulated students develop questions and seek help. Self-regulated learning is considered an indicator of cognitive engagement (Fredricks et al., 2004).

In short, both being aware of the existing problem and expressing the question are indicators of students' active engagement in learning. If students successfully express their questions, it is a visible indicator of their behavioral engagement. Although in many cases students may not eventually utter questions, their awareness of the problem and willingness to ask questions can reveal their active engagement in learning--especially affective and cognitive engagement.

Student Questioning Facilitates Student Engagement

Second, student questioning accomplishes and improves engagement, as it requires students to challenge themselves with unknown knowledge or perplexity. The desire to go further than the requirements and preference for a challenge are valued as important components of cognitive engagement (Fredricks et al., 2004). According to Vygotsky's (1978) concept of the zone of proximal development (ZPD), learning improves within proximity to, yet slightly above, students' current level of development with the help of a more knowledgeable other. To put it simply, when learners have guidance and support, they can accomplish a task that they cannot yet do by themselves. Thus, students' questioning behavior actively situates them in the zone of proximal development--a range of events which challenge students within proximity to, yet slightly above, their current level of development. In other words, questions proposed by students not only indicate their deficiency of knowledge but, more importantly, reveal students' willingness to challenge themselves and show their preparedness to learn more, deeper, and further with the help of more capable and knowledgeable others. In this way, student questioning accomplishes student engagement and contributes to student learning (Newman, 1994; Schunk & Zimmerman, 1994), as it assists students in dealing with complex concepts that they either do not understand or feel that they are unable to comprehend on their own (Butler & Neuman, 1995; Kitsantas & Chow, 2007; Ryan & Pintrich, 1997).

When students go through the questioning process and obtain answers, they actively (re)construct new knowledge. Researchers also suggest that processing the answer into a new proposition is where learning occurs (Dillon, 1990; Nelson-Le Gall, 1981; Newman, 1994). Also, when students construct new knowledge from the full cycle of awareness-questioning-answering, they finish one loop of self-regulated learning and become more engaged.

Student Questioning Benefits Knowledge Co-construction

Third, the effect of student questioning on student engagement is limited to not only individual students who pose questions but also their peers. Social constructivists view learning as a social process that does not take place solely within an individual, but in a group in the process of peer interactions. Meaningful learning occurs when individuals are engaged in social activities. Student questioning takes place within a situation of social interaction, where students are expected to seek assistance by asking questions from a more knowledgeable source (e.g., a peer) when faced with difficulty. Without the involvement of the helper, the student questioning process cannot succeed (Puustinen et al., 2015). Meanwhile, more knowledgeable others can be instructors or peers. When students answer peers' questions, they organize and articulate the information and consider themselves as teachers (Webb, 1982). Answering questions from other students may help prime deeper cognitive processing, such as reflecting on one's understanding and elaborating beyond the assigned material to incorporate one's existing knowledge (Fiorella & Mayer, 2016), which in turn improves the engagement of the answerer/helper.

Moreover, student engagement is also accomplished through observing others' questioning. Even for students who do not pose questions ("listeners" or "lurkers"), peers' questions and responses enable them to monitor their own learning progress, be aware of their level of understanding and monitor their need for help (Karabenick, 1996; Keefer & Karabenick, 1998). They can validate their thinking if they have the same questions as their peers.' They can also modify their thinking through learning from other's perspectives, which will not only solve their confusion but also help them to be more self-regulated. According to constructivism, although being taught the same instruction, students internalize the knowledge differently based on their own experiences. Therefore, student questioning from an individual student benefits and improves engagement of peers, resulting in the co-construction of knowledge.

Besides, in a learning environment questions posed by students can reveal a more comprehensive and precise picture of their learning. It provides instructors with needed information about student learning, confirmation of what the instructor knows about the students, or course direction (Karabenick & Sharma, 1994). In this way, student questioning contributes to the formative assessment and allows instructors to monitor their students' progress in a better way and modify the instruction to provide contingent or point-of-need instruction to fit individual student needs. As Reeve (2013) suggests, with a dialectical activity student questioning affects change in and transforms the teacher's instructional behavior, just as the teacher's instructional behavior affects change in and transforms the quality and quantity of student engagement. Thus, student questioning enhances formative assessment, eventuates active learning, and changes the class dynamic.

Summary

From a constructivist perspective, student questioning signals students' active involvement and self-regulation in the learning process, which indicates their engagement. Meanwhile, through questioning, students posit themselves in the zone of proximal development, where they embrace challenges to learn more and better or to achieve a higher order of thinking with the help of others, which eventuates an improvement of engagement. Moreover, the socially interactive nature of student questioning also invites other students to join the zone of proximal development as answerers or observers, contributing to the co-construction of knowledge, which in turn results in an improved engagement of all students. In this way, student questioning benefits the engagement of individual students who pose questions and peers who observe or are involved in the questioning process.

To summarize, under the constructivism framework, student questioning signals and improves student engagement, benefiting the co-construction of knowledge. It is necessary and meaningful to facilitate student engagement by prompting student questioning and create a constructivist learning environment where they could comfortably help each other and construct knowledge together. However, large lecture classes with a lecture-centered pedagogy fall short of providing students with such a constructivist learning environment, which calls for a novel intervention.

Rationale for Technology-based Intervention

Although researchers have employed various strategies to facilitate student questioning and engagement, the effectiveness of these strategies relies on the expertise of the instructor and the successful implementation of the strategies. However, in large lecture classes, despite the barriers mentioned above, it is challenging and difficult for instructors to move away from the lecture approach, personalize the instruction and apply an adaptive teaching style to encourage constructivist learning. To do so requires advanced planning, significant effort, and instructional supports which include instructional designers/technologists, teaching assistants, and graders (Stoerger & Kreiger, 2016). Ideally, the simplest solution to this issue is to reduce the class size, but it may not be economically sound or logistically viable (Sawang et al., 2017). Flaherty (2020) also suggested that reducing class size might not be sufficient to prompt learning, whereas to use active learning strategies, and provide students personalized learning were the keys. Alternatively, in some universities with sufficient personnel resources, multiple teaching assistants can help with group discussions and lab experiments. However, for many other universities, a low instructor-student ratio remains a major concern. Therefore, there is a need for other methods that move beyond a traditional classroom pedagogy to facilitate student questioning and engagement in large lecture classes.

In the meantime, emerging technologies bring about more possibilities to facilitate student questioning and engagement in large lecture classes. It is evident in many empirical studies that the advances in educational technology have empowered teachers to engage their students in learning (Stuart et al., 2004; Sawang et al., 2017). Technologies have also been proved useful in facilitating help-seeking in college students (Kitsantas & Chow, 2007; Huang & Law, 2018; Mahasneh et al., 2012). However, studies rarely focus on student questioning, specifically in large lecture classes. There is also a lack of research that systematically investigates whether student engagement in large lecture classes could be fostered by student questioning. Meanwhile, the research on questioning patterns in class is mostly conducted in the context of elementary and middle schools (Butler, 1998; Newman, 1990). Not enough is known about questioning patterns employed by college students during technology-enhanced large lecture classes and the mechanism underlying student questioning. Nevertheless, those successful attempts of using technologies to improve learning shed light on how to facilitate student questioning and student engagement in large lecture classes.

Research Questions

Therefore, to cope with the limitations imposed by large lecture classes and fill in the gaps in the literature, based on the constructivist learning theory, this study used a digital canvas as Digital Question Board (DQB), which allowed students to freely pose questions and respond to others' questions using mobile technologies. An analytical framework was proposed to use technologies to facilitate student questioning and engagement from the constructivist learning perspective. A mixed-methods study with a quasi-experiment was conducted based on this framework to investigate the effectiveness of a DQB-based intervention in facilitating student questioning and student engagement in large lecture classes. The following research questions were proposed:

- RQ1. Do students demonstrate different questioning behaviors when provided access to a DQB from those students who are not provided with access to a DQB in large lecture classes?
    - RQ1.1. Do students have a higher frequency of questioning when a DQB is provided?
    - RQ1.2. What patterns of questioning are displayed when students ask questions with a DQB?
    - RQ1.3. What types of questions do students ask with a DQB?
- RQ2. How does having access to a DQB during large lecture classes influence students' level of engagement?
    - RQ2.1. How does having DQB access influence behavioral engagement?
    - RQ2.2. How does having DQB access influence cognitive engagement?
    - RQ2.3. How does having DQB access influence emotional engagement?

Concepts List

Below are the operational definitions of key concepts.

- Student Questioning: student initiating, asking, or constructing questions.
- Student Engagement: investment or commitment, participation, or effortful involvement in learning.
- Student Engagement in Large lecture Classes: students' effortful involvement in learning with positive emotion in large lecture classes.
    - Behavioral Engagement: positive conduct, participation, and involvement in learning tasks.

- Cognitive Engagement: investment in learning, self-regulation, or being strategic, a desire to go beyond the requirements, and a preference for challenge.
- Emotional Engagement: students' affective reactions in the classroom and feelings about learning experience.

Chapter 2: Literature Review

Student Questioning

Questioning is frequently used in classrooms by teachers, texts, who are not seeking knowledge; while those who need to seek knowledge-students-do not ask questions (Dillon, 1988b). Students often avail themselves of help when it is needed (Newman, 1990). It is necessary to understand what student questioning is first then examine how to prompt it. Flammer (1981) also stated that "understanding question asking should help to understand how people regulate their interaction with their material, social, cultural, and mental world" (p. 408).

Student questioning was mostly regarded as an ordered event (van der Meij, 1994). Researchers have proposed various models to depict the process of questioning or help-seeking (see Table 1). Among all models, awareness of a problem is widely acknowledged as the first step, followed by recognizing the need for help. The next steps are deciding whether, how, and to whom to ask for help or pose a question. All the models then depict the expression of a question or soliciting help as the next stage. While some researchers regard the answer or obtaining help as the final stage (e.g., Karabenick, 2011), other researchers also add the evaluation of help or learning as the ending step (Dillon, 1998; Nelson-Le Gall, 1981).

Table 1

Models of Student Questioning or Help-seeking Process

Models	**Processes**
Model of the help-seeking process (Nelson-Le Gall, 1981)	(1) awareness of a problem, (2) decision to seek help, (3) identification of potential helper(s), (4) employment of strategies to elicit help, and (5) reaction to help-seeking attempt(s).
Process of adaptive help-seeking (Newman, 1994)	(1) being aware of task difficulty; (2) considering all available information in deciding (a) the necessity of the request, (b) the content or form of the request, (c) the target of the request; (3) expressing the request for help in a way that is most suitable to the circumstance; and (4) processing the help that is received in such a way that the probability of success in subsequent help-seeking attempts is optimized.
Process of questioning (Dillon, 1998)	(1) a percept, (2) disjunction, (3) experience of perplexity, (4) interrogative mood, (5) verbal formulation, (6) expression of a question, (7) method, (8) answer, (9) question-answer proposition.
Help-seeking process (Karabenick, 2011)	(1) determine that a problem exists, (2) determine that help is needed, (3) decide to seek help, (4) establish the purpose or goal of seeking help, (5) decide whom to ask, (6) solicit help, and (7) obtain the requested help
Help-seeking in interactive learning environments (Aleven et al., 2003)	(1) Become aware of the need for help, (2) Decide to seek help, (3) Identify potential helper(s), (4) Use strategies to elicit help, 5) Evaluate help-seeking episode.

Dillon (1988b, 1990) also proposed a componential model of questioning to illustrate the process. As Table 2 shows, questioning involves three main stages: perplexity, asking, and answering. There are three processes with each of the three stages. Questioning begins with the awareness of perplexity, a discrepancy between new and previous percepts, or the person may encounter an unexpected outcome or find something puzzling. After being perplexed, the person would develop a question, transforming the perplexity into a formulated and expressed question. The final stage is searching and processing the answer into a new proposition, which is where the learning takes place. In each stage, three static components are important: assumptions of the questioner, question itself, and the answer itself. Moreover, Dillon (1990) further subdivides each component into a sentence, revealing what content is communicated in questioning, and an act, which reveals the motivational and social-communicative aspects involved.

Table 2

Componential Model of Questioning by Dillon (1990, 1998)

Dynamic components		**Static components**
Stages	**Processes**	
I: The onset of questioning (perplexity)	1) a percept, 2) disjunction, 3) experience of perplexity	Assumptions Sentence: presupposition Act: presumption
II: The development of a question (asking)	4) interrogative mood, 5) verbal formulation, 6) expression of a question	Question Sentence: formulation Act: expression
III: The search for and processing of an answer (answering)	7) method, 8) answer, 9) question-answer proposition.	Answers Sentence: answer Act: answering

Student questioning is also regarded as an important self-regulative strategy (Newman, 1990; Ryan & Shin, 2011). Thus, as a learning strategy, many empirical studies show that students' learning performance is related to their help-seeking behaviors (e.g., Alexitch, 2002; Kitsantas & Chow, 2007; Ryan & Shin, 2011; Webb & Mastergeorge, 2003). For instance, Webb and Mastergeorge (2003) found that for seventh graders, some help-seeking behaviors were important determinants of successful posttest performance: asking for specific explanations, persistence in seeking explanations and modification of help-seeking strategies, and application of the help received to the problem at hand. Ryan and Shin (2011) found that for sixth graders, help-seeking behavior predicted student achievement changes across students' first year in middle school; and adaptive help-seeking was a significant predictor of G.P.A. In higher education, Karabenick and Knapp's (1991) path analysis revealed that students who reported poorer academic performance were more likely to endorse nonadaptive strategies for dealing with their academic problems and reported less inclination to ask other questions for help. Alexitch's (2002) survey study showed that first-year undergraduates' academic performance was significantly associated with help-seeking attitudes and tendencies; learning-oriented students who reported good academic performance were more willing to seek help from others and less likely to lower their aspirations or goals (Alexitch, 2002). However, there was yet a lack of research investigating student questioning in higher education, neither regarding its patterns, nor its effects.

Summary

This section depicts the process of student questioning, which generally involves three stages: (1) awareness of a problem, (2) decision of seeking help, and (3) expression of a question. How student questioning prompts learning was also discussed. A review of empirical studies suggested that academic help-seeking was related to students' learning performance. However, inadequate research focused on student questioning patterns in large lecture classes. The later section *Gap in the Literature* more comprehensively addresses this issue.

Student Engagement

Student engagement has been studied at the level of learning within a single activity, focusing on what is happening now, to the level of a student's whole school experience (Henrie et al., 2015). Within each level, engagement also includes a range of factors, such as investment in the academic experience of college, interactions with faculty, involvement in co-curricular activities, and interaction with peers (Kuh, 2009). Kuh (2009) emphasized that two important facets of student success were in-class engagement and out-of-class engagement in educationally relevant activities. Skinner and Pitzer (2012) developed a model to depict their multilevel perspective on engagement, which includes (1) engagement with prosocial institutions, (2) engagement with school, (3) engagement in the classroom, and (4) engagement with learning activities. At the most general level, engagement refers to students' involvement in school as a prosocial institution, along with other institutions, such as school and family. At the second level, engagement with school refers to students' involvement in school activities, such as academic work, sports, and extracurricular pursuits. The third level, engagement in the classroom, focuses on involvement in a specific course, or even on a specific learning activity (level 4). Thus, the third and fourth levels of engagement are the focuses of this study. According to Skinner and Pitzer (2012), the third level is defined as “constructive, enthusiastic, willing, emotionally positive, and cognitively focused participation with learning activities in school” (p. 22).

Categories and Indicators of Student Engagement

There was also a significant variation in how student engagement was defined and operationalized across studies. Researchers focused on various forms of engagement, such as task engagement (Fisher et al., 1975), skills engagement, participation/interaction engagement, and performance engagement (Handelsman et al., 2005), courseware engagement (Spence & Usher, 2007), agentic engagement (Reeve & Tseng, 2011) and even the opposite of engagement: disaffection (Skinner & Pitzer, 2012). Among many, student engagement is mostly regarded as a meta-construct that includes different types of engagements or other theoretical constructs, and that Fredricks et al.’s (2004) classifications of engagement are most common cited. This study also followed their definitions of engagement.

Specifically, according to Fredricks et al. (2004), *Behavioral engagement* involves (1) positive conduct, (2) involvement in learning and academic tasks, and (3) participation in school-related activities; *Cognitive engagement* involves the investment in learning, self-regulation, or being strategic, a desire to go beyond the requirements, and a preference for challenge;

Emotional engagement involves students’ affective reactions in the classroom (to teachers, classmates, academics, or school). In other words, behavioral engagement includes the observable behaviors necessary to academic success; cognitive engagement is students’ focused effort and psychological investments in learning tasks; while emotional engagement focuses on students’ feelings about learning experience (e.g., Appleton et al., 2006). Below is a list of selected indicators most researchers used to indicate student engagement (Table 3).

Table 3

Selected Indicators of Student Engagement

	Fredricks et al. (2004)	Skinner & Pitzer (2012)
Behavioral Engagement	effort, intensity, persistence, determination, perseverance in the face of obstacles and difficulties	action initiation, effort, exertion, working hard, attempts, persistence, intensity, focus, attention, concentration, absorption, involvement
Cognitive Engagement	attention, concentration, focus, absorption, “heads-on” participation, willingness to go beyond what is required	purposeful, approach, goal strivings, strategy search, willing participation, preference for challenge, mastery, follow-through, care, thoroughness
Emotional Engagement	enthusiasm, enjoyment, fun, satisfaction	enthusiasm, interest, enjoyment, satisfaction, pride, vitality, zest

Student Engagement Benefits Learning

Student engagement is regarded as a powerful force in both student psychosocial development and academic success (Junco et al., 2011). Kuh (2009) states “student engagement and its historical antecedents . . . are supported by decades of research showing positive associations with a range of desired outcomes of college” (p. 698).

Lots of empirical studies confirmed that student engagement was positively related to students’ academic outcomes (Fredricks et al., 2004), such as academic achievement (Gunuc, 2014; Hughes et al., 2008; Reeve & Tseng, 2011), persistence in learning (Kuh et al., 2008), critical thinking and grades (Carini et al., 2006). Fredricks et al.'s (2004) comprehensive review of earlier research showed that behavioral engagement and cognitive engagement were correlated with higher achievement across various samples and ages (especially K-12). Hughes et al. (2008) found from a 3-year longitudinal study with 671 academically at-risk first graders that effortful engagement predicted achievement above the effects of prior levels of both conduct engagement and achievement. In a survey study with 365 high school students from Taiwan, Reeve and Tseng (2011) found that agentic engagement, emotional engagement, and cognitive engagement predicted independent variance in achievement. In a later study, Reeve (2013) found through 3-wave longitudinal research with 302 middle-school students that agentic engagement functioned as a proactive, intentional, collaborative, and constructive student-initiated pathway to greater achievement and motivational support.

In colleges, improvement in grades and persistence has been noted across a variety of populations with increased engagement (Kuh et al., 2008; Kuh, 2009). For instance, in a study with 1058 students at 14 four-year colleges and universities, Carini et al. (2006) found that the lowest-ability students benefited more from engagement than classmates, first-year students and seniors converted different forms of engagement into academic achievement, and certain institutions more effectively converted student engagement into higher performance on critical thinking tests. Using the *National Survey of Student Engagement* (NSSE), Kuh et al. (2008) conducted a large-scale, longitudinal correlational study with 6193 college students. Their results showed that student engagement in educationally purposeful activities was positively related to academic outcomes as represented by first-year student grades and by persistence between the first and second year of college. The effect of engagement was notably more substantial for students with less ability and students from minority backgrounds (Kuh et al., 2008). In another correlational research with 304 university students (first-year students excluded), Gunuc (2014) found significant relationships between the students' academic achievement and student engagement, especially cognitive engagement, behavioral engagement, and a sense of belonging. It was also found out that cognitive, behavioral, and emotional engagements predicted academic achievement and explained it with a rate of 10% (Gunuc, 2014).

In summary, most studies revealed the positive influence of school-level engagement on learning outcomes in postsecondary settings. Insufficient studies proved a significant relationship between student engagement and content-specific (short-term) learning performances. Most of the studies looked at average academic achievement scores (e.g., Gunuc, 2014; Kuh et al., 2008). For those who did find a significant and positive influence of engagement on learning, most of the relationships were weak in strength (e.g., Carini et al., 2006). Fredricks et al. (2004) concerned that because much of this research was cross-sectional, the causal direction had not been identified and that any causality may be bidirectional over time. Moreover, it seems that the benefit of engagement on learning is more likely to be a long-term improvement rather than short-term knowledge gains. As Skinner and Pitzer (2012) suggest, engagement is the direct (and only) pathway to cumulative learning, long-term achievement, and eventual academic success.

Measurement of Student Engagement

Based on different constructs and indicators of student engagement, researchers employ many ways to measure engagement. In face-to-face learning contexts, surveying students or obtaining observations from teachers are the most used methods.

Surveys are easy to distribute and are more scalable, especially when compared to human observation. Survey items in previous studies ranged from asking students how they would rate their perceived level of engagement (e.g., Guertin et al., 2007) to assessing their behavioral, cognitive, and emotional aspects of engagement (e.g., Chen et al., 2010; Yang, 2011). Most surveys were completed by students; few were used to collect perceptions of engagement from teachers (e.g., Hughes et al., 2008). Table A1 in Appendix A lists instruments that researchers developed to measure student engagement at the course level. Among many, the most frequently used instrument was the NSSE developed by Indiana University (see Kuh, 2001). Although it was an institution-level survey, researchers also used it to compare the impact of different instructional interventions on student engagement (Henrie et al., 2015). For instance, to understand what was going on at the classroom level, Ouimet and Smallwood (2005) adapted from the NSSE to develop an instrument that focused on specific classes. In addition to the items adopted from NSSE items, some items also addressed study habits, study styles, and tools used to enhance learning, Web use, and interest level. It was suggested by Ouimet and Smallwood (2005) that using or modifying these additional items helped practitioners personalize the items and make the data more pertinent to their real situation.

To study student engagement of technology-mediated learning experience, researchers were enriched with a variety of technology-based measures. For instance, in a research that focused on embedding information and communication technology (ICT) in learning, Reading (2008) generalized some indicators of engagement in ICT-rich learning environment and proposed an engagement measurement plan (Table A2). Although this plan only included certain types of measurement methods, Reading (2008) suggested that an Engagement Measurement Plan should be included whenever an ICT-rich learning environment was planned for a teaching activity. The challenge for teachers was to find relevant indicators and measurement methods that were easily applied in the context. Many other researchers also attempted to use various methods to measure engagement in the technologies-enhanced learning environment.

Behavioral Engagement. In the technology-mediated learning environment, there are unique behavioral indicators such as eyes on the device, fingers on the keyboard, frequency of logins to a website, number of clicks, number of postings, responses, & hits, number of questions asked (e.g., Ouimet & Smallwood, 2005). The most used measure for behavioral engagement is the *observable quantitative measure* that targets frequency indicators through direct human observation and video recording. Observational measures tend to focus on engagement at the activity level, which is useful for researchers interested in studying engagement within an activity or a small moment. Frequency measures can also be useful for tracking how a certain quality of engagement changes over time or how degrees of engagement vary among individuals or groups. The most acknowledged advantage of quantitative observational methods is that it allows researchers to measure students' behavioral engagement as it occurs obtrusively, with less learning disruption. However, to gather data in person, the cost required to conduct direct human observation (e.g., training observers) might sometimes discourage its use. It is also challenging to observe students' behaviors when some learning activities happen online.

Log Data for Behavioral Engagement. In this situation, *computer-recorded methods* become especially useful for measuring student engagement in the technology-mediated learning environment. Currently, most learning platforms can automatically track and report on student activity, providing ready-made frequency data, capturing data behind the scenes as students learn. Such a method is advantageous as it is scalable and cost-effective, eliminating the need for manual counting (Henrie et al., 2015). As Table 4 shows, many researchers used computer-recorded indicators to measure student engagement in the technology-mediated learning environment.

Table 4

Computer-recorded Behavioral Engagement Indicators

Name of computer-recorded indicators	Authored by
Attendance	Heafner & Friedman, 2008; Stewart et al., 2011
Assignment completion, reading materials	Harunasari & Halim, 2019; Heafner & Friedman, 2008; Reading, 2008
Time on task	Wise et al., 2012
Number of on-task or off-task behaviors	Fisher et al., 1975
Number of posts	Aagard et al., 2010; Giesbers et al., 2014
Number of votes	Aagard et al., 2010
Number of reads, scans, posts, or edits in a discussion board	Wise et al., 2012
Number of access (hits) to core learning content	Stewart et al., 2011
Number of questions asked	Aagard et al., 2010; Baron et al., 2016; Harunasari & Halim, 2019; Ouimet & Smallwood, 2005; Pohl et al., 2012; Reading, 2008
Number of clicks	Wise et al., 2012
Number of logins	Aagard et al., 2010

Although log data could help depict students' authentic behaviors in the technology-enhanced learning environment, the observable quantitative measure has its limitations. Researchers concern that it usually records manifested behaviors, which may not by themselves provide an adequate understanding of the quality of engagement (Appleton et al., 2006). Therefore, it is necessary to include other measurements to explain and enrich the quantitatively observed findings.

Survey Instruments for Behavioral Engagement. *Quantitative self-report surveys* are used to measure behavioral engagement in the technology-mediated learning environment, especially in occasions where a direct observation or automatic recording is not applicable, such as in a large classroom, when assessing students' anonymous interactions, browsing behaviors, investigating students' prior questioning behaviors, or examining students' general behavior of questioning in multiple classes, or online settings.

Instruments that measure students' behavioral engagement usually contain items that either assess the frequency or likelihood of certain behaviors. For instance, researchers assess the *frequency* of certain behaviors through frequency-type Likert items, such as "how often have you asked questions during your Physics 181 class?" (e.g., Ouimet & Smallwood, 2005; Wakefield et al., 2011; Yates et al., 2015). Some survey items assess the *likelihood* of students' certain behaviors, such as "to what extent do the following behaviors describe you?" Those behaviors include raising hand in class, asking questions, helping fellow students (Handelsman et al., 2005), asking other students for help with the work for this class, asking the instructor for help with course work, getting help with general study skills (Karabenick & Knapp, 1991), participating actively in small-group discussions, posting in the discussion forum regularly (Dixson, 2010). Some items ask the exact *amount of time*/frequency doing certain behaviors, such as "On average, about how many hours do you spend in a seven-day week preparing for your class studying?" (Ouimet & Smallwood, 2005). Lastly, some studies use *agreement* items that ask students to indicate the extent of their agreement with each statement from strongly agree to strongly disagree (e.g., Barkatsas et al., 2009; Yang, 2011).

One limitation of the self-report survey is that it does not allow researchers to observe engagement in action unobtrusively. It might divert students from learning and may disrupt the very engagement researchers try to measure (Henrie et al., 2015). Secondly, timely data on student engagement in large lecture classes are difficult to obtain via surveys. As midcourse or end-of-term self-report surveys are often lengthy, they require an inconvenient amount of time for students to complete. Moreover, the data is obtained at the end of the course or learning activity, not amid it. Variance in student engagement across time is also challenging to capture through surveys. Short surveys repeated periodically is one way to capture variance in student engagement across time. However, such an approach requires significant efforts from students completing them.

Cognitive Engagement. Because cognition is not readily observable, it must be either inferred from behavior or assessed from self-report measured (Fredricks et al., 2004). Some of the cognitive engagement indicators that are not always externally visible/observable and require self-reporting include students' psychological investment and self-regulation in learning. In comparison, some of the cognitive indicators could be represented by the behavioral indicators, such as on-task behavior that reveals students' cognitive attachment; content of students' posts or assignments that shows their improved understanding or mental functions on the revised Bloom's Taxonomy. Thus, qualitative measures such as content analysis could be adopted to analyze and determine student cognitive engagement, especially in the technology-mediated learning environment. Moreover, although not widely used, researchers also suggest that cognitive engagement could be assessed through a quantitative analysis of the learning progress (e.g., Fredricks et al., 2004; Yang, 2011).

Survey Instruments for Cognitive Engagement. Nevertheless, the *self-report survey* is regarded as the most valid mean of studying the cognitive aspects of student engagement, as it focuses on the mental energy or cognitive strategies students apply in the learning process, and their perceptions of their experience (e.g., Appleton et al., 2006; Fredricks & McColskey, 2012).

There is a variety of instruments that measure students' cognitive engagement. Some survey items assess students' *learning strategies*, such as "How often have you summarized what you learned in class or from course materials?" (NSSE). "(I am) taking good notes in class"

(Handelsman et al., 2005), “I would participate in E-meeting to increase my listening and speaking ability,” (Yang, 2011). Some items evaluate students’ *higher-order learning*, such as “How much has your coursework emphasized applying facts, theories, or methods to practical problems or new situations?” (NSSE). As for *collaborative Learning*, some items are “How often have you asked questions or contributed to course discussions in other ways?” “How often have you asked another student to help you understand course material?” (NSSE). In addition, some items assess students’ *reflective and integrative learning*, such as “How often have you tried to better understand someone else’s views by imagining how an issue looks from his or her perspective?” (NSSE), and “The learning activities enhanced my deep thinking and helped me to reflect on my learning.” (Yang, 2011). Moreover, as Fredricks et al. (2004) suggest, researchers should consider including survey items from the *self-regulation* literature or observational techniques that assess the quality of engagement.

Qualitative Content Analysis of Cognitive Engagement. Students’ cognitive engagement could also be inferred from their behavior. Therefore, in the technology-mediated learning environment, *qualitative content analysis* of digital data from the technology platform is increasingly used (Giesbers et al., 2014; Junco et al., 2011). Some researchers conducted a content analysis of students’ computer-recorded behaviors while learning (e.g., Yang, 2011), while others conducted content analysis or discourse analysis of interviews or focus groups (e.g., Paulus et al., 2006). For instance, the *topic-relevant question* students posed was considered an indicator of their cognitive engagement; their responses to a post quiz were also analyzed to examine whether they had a better understanding of the material, as another indicator of cognitive engagement (Harunasari & Halim, 2019). As Appendix A shows, researchers either categorized students’ written or verbal communication using *preexisting frameworks and* *taxonomies* (e.g., Lim et al., 2006) or *identifying themes inductively* to indicate students' cognitive engagement.

To examine fourth graders' engagement in a 3D multiuser virtual environment (3DMUVE), Lim et al. (2006) employed Bangert-Drowns and Pyke's (2001) descriptive taxonomy of engagement. Originally this taxonomy was used to measure students' engagement in working individually on assigned software at the computer, including student–software transaction, manipulation of the soft-ware, body posture, and off-task behavior.

In a frequently cited article, Zhu (2006) defines cognitive engagement as "attention to related readings and effort in analyzing and synthesizing readings" demonstrated in discussion messages, which involves seeking, interpreting, analyzing, and summarizing information, critiquing, and reasoning through various opinions and arguments; and making decisions (Zhu, 2006, p. 454-445). Based on this clarification, Zhu (2006) then develops a framework to analyze interaction types that occurs during online discussions and examine levels of student cognitive engagement in each discussion (see Table A3 in Appendix A). This framework categorizes students' questions as vertical, aiming to seek information; and horizontal, which attempts to initiate a conversation. Statements are classified into six different types, according to Bloom's learning hierarchy (1956). In addition, there are three other categories: Reflection, Mentoring, and Scaffolding.

In a study investigating whether facilitating feedback significantly impacted students' cognitive engagement, Guo et al. (2014) adapted the *Framework for Reflective Pedagogical Thinking* developed by Sparks-Langer et al. (1990) as the coding scheme to assess students' (110 K-12 teachers) cognitive engagement level through both original and replying posts (see Table A4 in Appendix A). This framework was developed to assess schoolteachers' ability to use concepts and principles to explain teaching activities and classroom events. It was based on Gagne's (1968) hierarchy of thinking and Van Manen's (1977) idea of critical reflection.

In another study examining the association between autonomous motivation and engagement in asynchronous and synchronous communication, Giesbers et al. (2014) conducted a content analysis to analyze individual students' (N = 110) contributions to asynchronous online discussion and revealed evidence of knowledge transfer and learning. The authors used a validated coding scheme developed by Veerman and Veldhuis-Diermanse (2001) (see Table A5 in Appendix A). This scheme employs non-task-related and task-related discourse as the main categories. Non-task-related messages are further divided into four subcategories. Task-related messages are further divided into three categories. In that research, Veerman and Veldhuis-Diermanse (2001) were specifically interested in messages containing explicit knowledge construction expressions.

Exploratory Analysis of Cognitive Engagement. Qualitative measures enable researchers to conduct *exploratory studies* that attempt to measure or define student engagement, rather than using existing frameworks and taxonomies (e.g., Bangert-Drowns & Pyke, 2001; Paulus et al., 2006). Some studies analyzed content exploratorily to supplement the quantitative measures (e.g., Barr, 2017; Junco et al., 2011; Welch & Bonnan-White, 2012).

For instance, Bangert-Drowns and Pyke (2001) developed a taxonomy of engagement by observing students from pre-K through six-grade, working individually on assigned software at the computer, in an urban elementary school for science technology. They firstly gathered immediate fieldnotes on the student–software transaction, manipulation of the soft-ware, body posture, and off-task behavior. These notes were collated and studied for emerging themes, and the 7-level taxonomy of engagement was formulated. Paulus et al. (2006) analyzed *text from an* *asynchronous discussion board*, students' *written reflections,* and students' *responses in interviews* to explore what engagement was like when graduate students learned from stories in an online environment. Rather than defining the nature of student engagement a priori to develop a survey, the authors used qualitative measures to approach engagement inductively. In a study with 125 pre-health professional major students enrolled in a first-year seminar course, Junco et al. (2011) conducted a semester-long experimental study to determine if using Twitter for educationally relevant purposes influenced college students' engagement and grades. Junco et al. (2011) not only selected 19-items from the NSSE to measure student engagement through pre- and post-surveys but also conducted a content analysis of *samples of Twitter exchanges* to enhance their findings through detailed scenarios. In a study with 335 participants, Barr (2017) explored the cognitive engagement of participants' comments from three *open-ended questions*. From the collapse of all comments, one of the dimensions emerged, suggesting the influenced cognitive engagement (Barr, 2017).

Qualitative measures are effective for describing the nature of engagement. Through qualitative measures, researchers can gauge when cognitive processes such as reflection, interpretation, synthesis, or elaboration are shown in student-created artifacts. As a research technique, content analysis is acknowledged for the objective, systematic, quantitative description of the manifest content of communication (Berelson, 1952, p. 519). One challenge with using qualitative methods, however, is that they are difficult to scale. Extensive resources are needed to collect data. It is often necessary to analyze data manually, limiting the amount of data researchers choose to examine.

Emotional Engagement. Some of the indicators of emotional engagement researchers have investigated in a technology-mediated learning environment include boredom, cheering, collaborative social interaction, enjoyment, enthusiasm, excitement, fun, happiness, interest, passion, pleasure, and desire to use the tool again.

Survey Instruments for Emotional Engagement. Like cognitive engagement, self-report surveys are useful for understanding the emotions students experience (Appleton et al., 2006; Fredricks & McColskey, 2012). For instance, Sun and Rueda (2012) conducted a study to investigate the relationship between student engagement, situational interest, self-efficacy, and self-regulation for undergraduate and graduate students in blended and online courses. They used an adapted version of the engagement scale developed by Fredricks et al. (2003) that measured behavioral, cognitive, and emotional engagement. They found strong relationships between student engagement and situational interest and self-regulation. They also found that online activities may be a means of increasing students' emotional engagement. Many other engagement instruments also include items or sections of emotional engagement in their study (e.g., Handelsman et al.,2005; Kay & Knaack, 2009). For example, some questions focus on students' interests in learning, such as "How interested are you in your Math course material?" (Ouimet & Smallwood, 2005), "I am interested to learn new things in maths" (Barkatsas et al., 2009), and "I really desire to learn the material" (Handelsman et al., 2005). Some items assess motivation or encouragement during their learning experience, such as "I found the learning object motivating" (Kay & Knaack, 2009), "In maths, you get rewards for your efforts" (Barkatsas et al., 2009), and "the learning activities enable me to share my feelings with my peers and the teacher" (Yang, 2011). Some items are about students' willingness to use the instructional materials or apply to another context, such as "Applying course material to my life" (Handelsman et al., 2005), and "I would like to use the learning object again" (Kay & Knaack, 2009). Besides, there are also some survey items focus on specific emotional aspects related to interventions, such as “I liked the overall theme of the learning object” (Kay & Knaack, 2009), and “It is easier for me to understand the characters’ feelings through short clips.” (Yang, 2011).

Survey could not capture all the emotional indicators. Content analyses and discourse analyses of interviews, open-ended questions, or learning materials became increasingly popular for measuring emotional engagement.

Exploratory Analysis of Emotional Engagement. Emotional engagement may also be measured through visible expressions of positive emotion, such as from open-ended survey questions (Welch & Bonnan-White, 2012), from semi-structured interviews (Harunasari & Halim, 2019; Paulus et al., 2006), during the online discussions (Paulus et al., 2006; Yang, 2011), and students’ reflections or essays for a learning activity (Yang, 2011).

For instance, Kay and Knaack (2009) used two open-ended questions to supplement their survey items of engagement: “What, if anything, did you LIKE about the learning object?” and “What, if anything, did you NOT LIKE about the learning object?” From which, three category labels were identified: compare (Student compares the intervention to another method of learning), engage (Student refers to the program as being OR not being fun/enjoyable/engaging/interesting), and technology (The student mentions a technological issue with respect to using the intervention). Each comment was then rated from very negative (-2) to very positive (2).

In Welch and Bonnan-White’s (2012) study investigating whether Twitter in a large-lecture format university course produced a difference in levels of self-reported student engagement, in addition to the scale instruments, the authors also analyzed students’ answers to four open-ended questions to assess students’ attitudes towards Twitter, or as the authors termed it “Twitter enjoyment”: (1) Describe your experience with Twitter over the past semester. What did you like? What did you not like? (2) Compare this course to your other general education courses that did not use Twitter. Did you find yourself enjoy this class more or less? Did it affect your involvement during lectures or outside of the classroom? (3) Besides the fact that you got points for using Twitter to answer questions, do you think it affected your grades and/or classroom performance any other way? If so, how? (4) Did you ever use Twitter to ask a question or make a comment during the lecture? Do you think the ability to do this added to your classroom experience? Then the researchers analyzed students' answers to these questions, developed themes, and classified students into ones that expressly stated liking or enjoying Twitter and ones who expressed not enjoying Twitter. Similarly, Yates et al. (2015) used a series of open-ended questions to ask participants to provide further details of their experience in the use of microblogging, including the use of microblogging in lectures compared with those that did not use it, effect on learning experience, connection to peers and what worked well and not so well. The authors then coded the responses into various themes and concluded that microblogging encouraged nursing students to post questions during lectures, thus increasing student contribution and engagement. More recently, Harunasari and Halim (2019) measured emotional engagement through a semi-structured online interview where the students' perspectives were gathered through open questions. Then students' responses were coded as either: positive response, neutral responses, or negative responses. As emotional engagement can hardly be observed, interviews could help understand how students feel during their learning experience, especially their detailed personal emotions (e.g., Creswell, 2015). Glesne (2011, pp.104) claims that the opportunity to learn about what you cannot see and explore alternative explanations of what you do see is the unique strength of interviewing in qualitative inquiry. Harunasari and Halim (2019) also suggest students can reflect on their own experience and report on what they believe or what they remember have promoted engagement in their classroom through a semi-structured online interview. With semi-structured interviews, researchers can be confident of getting comparable data across subjects (Bogdan & Biklen, 2007). Table A6 in Appendix A shows selected examples of exploratory content analysis of emotional engagement.

Other Engagement. Since the focus of engagement varied, so were the constructs and indicators. For example, in Guertin et al.'s (2007) study, students were asked to rate their overall general (perceived) level of engagement in the experimental session. Spence and Usher (2007) rated a student's courseware engagement for how much the student engaged with the software feature if they did use it. Laakso et al. (2009) categorized students behaviors recorded from a screen capturing software into four engagement levels according to the extended engagement taxonomy. To measure agentic engagement, researchers developed the Agentic Engagement Scale (AES) (Reeve, 2013; Reeve & Tseng, 2011). Addison et al. (2009) used six items to measure students' perceived attention, engagement, participation, and enjoyment, using the agreement Liker scales.

In fact, many researchers pointed out that the line between various engagement was blurred and most measures did not distinguish a target or source of engagement (Fredricks et al., 2004; Henrie et al., 2015). Occasionally within the same article, engagement was defined in one way but operationalized and measured in another (Henrie et al., 2015). In many studies, constructs of engagement overlaid with each other. For example, Zhu (2006) created a detailed framework for cognitive engagement in discussion boards, but the lowest levels overlaid with behavioral engagement indicators. In Yang's (2011) study, besides behavioral, cognitive, and emotional engagement, Yang also looked at the progress engagement, which overlaid with emotional and cognitive engagement. Similarly, when Handelsman et al. (2005) assessed students' skill engagement, some of the items might also be regarded as behavioral engagement or cognitive engagement, such as "Study on a regular basis," "Put forth effort," and "Listening carefully in class."

Despite the variation and overlay of engagement measurements, there is no measurement method that was the best for all situations. Each approach has its strengths and limitations (Fredricks et al., 2004; Henrie et al., 2015). Researchers suggest that the uses of both quantitative and qualitative methods, in combination, provide a better understanding of the research problem and question than either method by itself (Creswell, 2015, p. 535; Miles & Huberman, 1984, p. 42). Even, some scholars have argued that the term engagement should be used only for work that includes multiple components to ensure that the richness of real human experience is understood (Fredricks et al., 2004). Harunasari and Halim (2019) also suggest including at least one indicator from each of the engagement components, choosing relevant indicators aligned with the learning outcomes, using more than one form of self-reporting, teacher-reporting and observational methods of measurement. To use a variety of measurement methods and to measure engagement from multiple angles might lead to a more comprehensive understanding. As Henrie et al. (2015) conclude, measuring engagement across more than one indicator may produce the most productive information for researchers, instructional designers, and educators.

Summary

This section reviews student engagement and its measurement in the literature. In general, student engagement is viewed as a meta-construct that includes three types of engagements: behavioral engagement, cognitive engagement, and emotional engagement. Most studies revealed the positive influence of school-level engagement on learning outcomes in postsecondary settings. Insufficient studies proved a significant relationship between student engagement and content-specific (short-term) learning performances. Because of the complexity of student engagement, many researchers suggest measuring engagement across more than one indicator, using both quantitative and qualitative methods. Technology also enriches the methods of measurement. For the current study, log data, survey instrument, interview and observation were all employed to produce a more comprehensive understanding of student engagement.

Theoretical Framework Connecting Questing and Engagement in Learning

Constructivism's View of Learning

Constructivism is the philosophical paradigm that guides this study. In education, constructivism became popular in the early 1990s. Constructivism claims that reality is more in the mind of the knower, that the knower constructs a reality, or at least interprets it, based upon his or her apperceptions; how one constructs knowledge is a function of the prior experiences, mental structures, and beliefs that one uses to interpret objects and events (Jonassen, 1991, p.10). Therefore, students need to be actively engaged in the learning process.

The essential core of constructivism is that "the reality is made, not found" (Bruner, 1996, p.19). This core has roots that extend back through many years and many philosophers (e.g., Dewey, 1938; Hegel, 1807/1949; Kant 1781/1946). Philosophically, constructivism relies on an epistemology that emphasizes subjectivism and relativism. Thus, from a constructivist perspective, learning is done by students constructing knowledge out of their experiences, rather than being taught by others. The product of constructive learning, therefore, is people's interpretation (Jonassen, 1995), and the goal of education is to help students become better "architects" and "builders" of knowledge (Bruner, 1996, p.20). Students should be the center of learning while the instructor should take on the role of facilitator. Constructivist learning theories emphasize “learner autonomy,” which was first coined by Holec (1981), who defined it as the ability to take charge of one’s learning, including setting learning objectives, self-monitoring, and self-evaluation. Constructivist learning pedagogy also promotes active learning and encourage student engagement. In a constructivist classroom, the focus of learning shifts from the teacher to students; the classroom is no longer a place where a teacher pours knowledge into students. Students are urged to actively involved in their learning process. The teacher functions more as a facilitator who coaches, mediates, prompts in the classroom.

Constructivism can be traced back to educational psychology in the work of Piaget’s (1971) theory of cognitive development, which led to the development of cognitive constructivism. Piaget focuses on how humans make meaning in relation to the interaction between their experiences and their ideas, i.e., individual cognition, as distinct from development influenced by other persons (Piaget, 1971). He describes the learning process as individuals constantly assimilate and accommodate in the process of adaption, and eventually arrive at a state of equilibration.

Cognitive constructivism focuses on (a) the procedures or processes of learning, (b) how what is learned is represented or symbolized in the mind, and (c) how these representations are organized within the mind. According to cognitive constructivism, the reality is knowable to the individual, knowledge acquisition is an adaptive process and results from active cognizing by the individual student. Knowledge is the result of the accurate internalization and (re)construction of external reality. Learning is the process of building accurate internal models or representations that mirror or reflect external structures that exist in the “real” world (Doolittle, 1999).

Building on cognitive constructivism, social constructivism suggests knowledge is first constructed in a social context and is then appropriated by individuals, emphasizing the social origins of cognition and the importance of sociocultural learning. Social constructivism extends constructivism by incorporating the role of other actors and culture in development. Vygotsky (1978), one of the most influential social constructivists, proposes that, in the process of constructing knowledge, the true direction of development of thinking is not from individual to the societal, but from the societal to the individual. According to social constructivists, students are not isolated individuals; the process of sharing individual perspectives (collaborative elaboration) results in students constructing understanding together that would not be possible alone. Thus, social constructivist scholars view learning as an active process where students make meanings through the interactions with each other and with the environment they live in. Social interaction is an integral part of knowing and learning and always occurs within a socio-cultural context, resulting in the knowledge that is bound to a specific time and place (Vygotsky, 1978).

To summarize, cognitive constructivists emphasize accurate mental constructions of reality. Social constructivists emphasize the construction of an agreed-upon, socially constructed reality. Despite the differences, constructivism regards students as active creators of their knowledge who construct their understanding and knowledge of the world, through experiencing things and reflecting on those experiences, which calls for student engagement in the learning process.

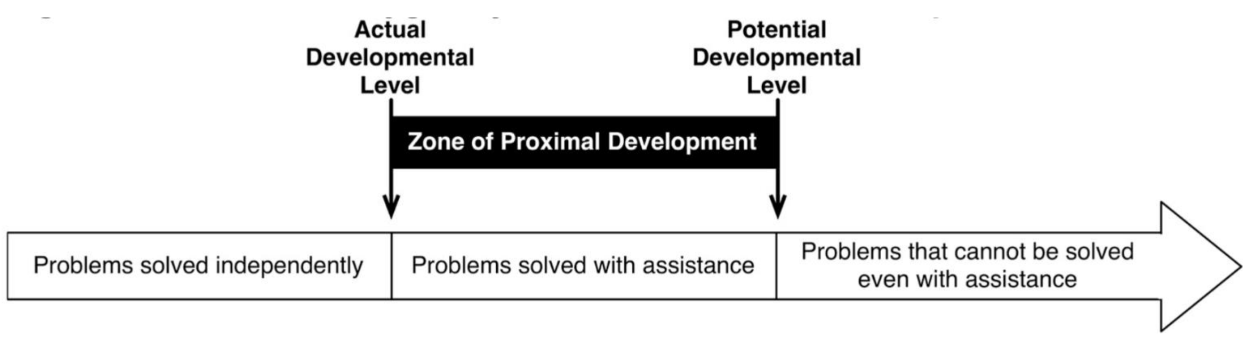
Vygotsky's Zone of Proximal Development

Vygotsky critiques the learning assessment that only looks at individual problem solving and argues that the knowledge progress achieved by cooperation with others could reveal more about the capabilities of students (Fosnot & Perry, 1996). Based on the social constructivism perspective, Vygotsky (1978) further proposes the zone of proximal development (ZPD) where students are challenged within proximity to, yet slightly above, their current level of development (Figure 1). In his words, ZDP is defined as: "…the distance between the actual developmental level as determined by independent problem solving, and the level of potential development as determined through problem-solving under adult guidance, or in collaboration with more capable peers" (Vygotsky, 1978, p. 86). In other words, ZDP is an area of learning that occurs when a person is assisted by a more capable other, such as a teacher or peer, with a higher skill set.

In short, student questioning indicates student engagement and facilitates learning as students actively challenge themselves and develop their learning with the help of more capable others. By experiencing the successful completion of challenging tasks, students gain confidence and motivation to embark on more complex challenges (Vygotsky, 1978).

Figure 1

Illustration of Vygotsky's Zone of Proximal Development



Student Questioning Facilitates Student Engagement

Student Questioning Triggers Point-of Need Teaching. Cognitivism views students as information processors; questioning is necessary as it helps students resolve perplexity then continue processing information to accomplish knowledge acquisition. Thus, cognitive psychologists have demonstrated that question-asking is fundamental to knowledge acquisition (e.g., Flammer, 1981). Constructivism emphasizes the individual differences in learning because students construct meaning out of their own experiences based on their different genetic predispositions, social environment, family condition, and life experiences. Even in the same classroom, each student has individual learning objectives, approach, progress, and perplexity, which varies from one student to the other. Therefore, only questions raised by students themselves can reveal a comprehensive and accurate understanding of their learning processes because they are the center of learning. With student questions, instructors are enabled to provide point-of-need teaching. According to Earl (2006), point-of-need teaching is described in the assessment process as an integral part of the feedback loop for learning "with the emphasis in many assessment events shifting from making judgments that categorize students, to using them as windows into learning" (p. 12). Through point-of-need teaching, if instructors could resolve students' misconceptions in a timely way, students are more likely to be engaged in the learning process rather than being lost or giving up when they encounter problems. Therefore, student questioning makes room for point-of-need teaching, helps make instructional feedback contextualized, specific, meaningful, and timely for students. In short, student questioning solves students' perplexity, aids students' cognitive processing, benefits their construction of knowledge.

Student Questioning Indicates Self-regulation. When students encounter new knowledge, they must reconcile it with their prior knowledge to decide whether to change what they believe or discard the new information as irrelevant. In any case, to do so, students must actively ask questions, explore, and assess what they know. Thus, student questioning indicates students' active, effortful involvement in the learning process, i.e., their engagement. As students actively assess their understanding, comparing what is known to the new knowledge, it also indicates students' self-regulated learning (SRL), an important indicator of cognitive engagement.

Self-regulation is based on the construct of metacognition, which consists of (1) knowledge of cognition (i.e., knowing what one knows, knowing what one can do, and knowing what to do and when to do it) and (2) regulation of cognition (i.e., the on-going task of planning, monitoring, and evaluating one's own learning and cognition) (Schraw, 1998). Specifically, to activate prior knowledge, students should "pause and think about what you already know, ask what you do not know" (Schraw, 1998, p. 120). Built on self-regulation, SRL depicts the active learning process as learning guided by metacognition, strategic action (planning, monitoring, and evaluating personal progress against a standard), and motivation to learn (e.g., Zimmerman, 1990). In Zimmerman's (1990) words, SRL is a "cyclical process in which students monitor the effectiveness of their learning methods or strategies and react to this feedback in a variety of ways, ranging from covert changes in self-perception to overt changes in behavior such as altering the use of a learning strategy (p. 5). SRL is therefore considered an indicator of cognitive engagement, as it involves mental manipulation and self-organization of experience and requires that students actively regulate their cognitive functions, mediate new meanings from existing knowledge, and form an awareness of current knowledge structures (Doolittle, 1999). In this way student questioning indicates self-regulation and prompt the instructor to have a dialogue with the students about learning strategies, clearly aim at informing future learning, which might lead to an improved SRL skill (Fletcher, 2018).

Student Questioning Contributes to Knowledge Construction. Cognitive constructivism values interaction as it facilitates students' internalization of knowledge; social constructivism emphasizes social interaction as a basis for knowledge construction. Both cognitive and social constructivism regards scaffolding of immense importance in facilitating learning. Cognitive constructivism suggests that teachers should provide for and encourage multiple perspectives and representations of content, such as from peers; while from a social constructivist perspective, learning results from students' co-construction of meaning. Thus, there is no privileged "truth," not even the instructor. Students could and should learn from each other, which calls for collaborative questioning and learning. *Student questioning could trigger interaction between students which leads to the co-construction of knowledge*. Student questioning might also lead to better learning outcomes as students make meaning through questioning. For instance, Karabenick (1996) conducted a series of studies to examine social influences on metacognition, testing whether students' knowledge that co-students had questions about material they were simultaneously viewing affected students' own judged levels of comprehension. His results confirmed the influence of co-student questioning on comprehension monitoring: students' awareness of peers' questions about material they were studying affected judgments of their own level of comprehension (Karabenick, 1996). Therefore, peers' questions could help students monitor their own understanding, and they are more likely to develop a more comprehensive understanding through multiple perspectives generated from Q&A between students.

Summary

Constructivism highly values the center role of students and individual differences among them as they create/construct their own learning out of their experience, rather than being taught by others. Social constructivist learning theories emphasize the importance of sociocultural learning and focus on how interactions with adults, more capable peers, and cognitive tools are internalized by students to form mental constructs through the ZPD. Learning should involve social interaction and students should play an active role.

Therefore, according to constructivism, learning requires student engagement; students should construct their knowledge actively rather than just mechanically receive knowledge from the teacher or the textbook. Student questioning indicates student engagement as it signals students actively reveal their ZPD, willing to face the challenge. Student questioning also facilitates engagement and learning as it solves students' perplexity, benefits their self-regulation, provides instantaneous feedback to the instructor to enhance the point-of-need teaching, and encourages peers to learn from multiple perspectives, facilitating their learning.

Empirical Studies of Using Technologies to Facilitate Student Questioning and Engagement

The emerging of computer-based and mobile technologies brings more flexibility and possibility for classroom interaction. Numerous empirical studies show that the use of technologies could lead to increased help-seeking or student questioning frequency (e.g., Huang & Law, 2018; Kitsantas & Chow, 2007; Mahasneh et al., 2012), and enhanced student engagement (e.g., Sawang et al., 2017) in large classrooms. This section presents examples of using technologies to facilitate student questioning and engagement.

Collaborative Technologies

Practitioners widely use collaborative technologies to encourage interaction and collaboration between students. They also facilitate help-seeking in higher education. Many researchers found that compared to traditional learning environments (i.e., in-person), students had higher instances of questioning behavior with electronic means (e.g., Karabenick & Knapp, 1988; Kitsantas & Chow, 2007). Researchers suggested that students viewed mediated sources as more accessible than face-to-face sources (Karabenick & Knapp, 1988). It was also evident in many studies that student questioning benefited *emotional engagement* in the technology-enhanced environment. For instance, Kitsantas and Chow (2007) surveyed 472 college students from either distance, distributed, and traditional classes. Their results showed that students enrolled in courses with an online computer component reported feeling less threatened to ask questions for help than students in traditional learning environments (Kitsantas & Chow, 2007). Similarly, Mahasneh et al. (2012) found that students in the online section were less concerned about social embarrassment. Reeves and Sperling's (2015) survey with 226 college students also confirmed that the threat of asking questions for help was only negatively associated with sources of help that required face-to-face interaction. Moreover, results from Er at al.'s (2015) two studies with undergraduates (N = 387, 356) enrolled in flipped classes suggested that students did not use technologies only for asking questions, they utilized it as a learning repository. Huang and Law's (2018) qualitative analysis of open-ended questions from 41 college students enrolled in an online technology course also confirmed this unique pattern in the online setting: getting help from existing peer-help discourses. For students who opted to seek help from peers, many got help from the existing body of peer-help information (Huang & Law, 2018). To summarize, many empirical studies suggest that web-based collaborative technologies facilitate help-seeking in higher education and some of which lead to improved student engagement.

Audience Response Systems

Audience Response Systems (ARS) benefit student engagement in large lecture classes. In the past decade, ARS has received increasing acceptance among educators as an effective way of using technology to improve participation, interaction, contingent teaching, and student engagement (Boscardin & Penuel, 2012; Caldwell, 2007; Draper & Brown, 2004; Han, 2014; Kay & LeSage, 2009; Sawang et al., 2017; Stuart et al., 2004). ARS appeared in research literature under many names, such as student response systems, audience response system, classroom response system, electronic feedback system, and mostly just as clickers (Hunsu et al., 2016; Kay & LeSage, 2009). In general, ARS is a technology that permits students to answer electronically displayed questions using a remote-control device, a presentation program on laptops, or an application on smartphones. It allows instructors to gather students' synchronous responses during a lecture. With such responses, the instructor can gauge the level of students' understanding of the content of the lecture. If a substantial proportion of the students did not understand an essential part of the lecture, the lecturer could go back and further explain those concepts (Sawang et al., 2017). In return, students can get immediate feedback on their level of understanding regarding the content assessed through ARS-questions.

Many researchers suggest that the benefits of ARS on students' engagement are associated with its anonymity (Barr, 2017; Caldwell, 2007; Draper & Brown, 2004; Kay & LeSage, 2009; Stuart et al., 2004). ARS with the anonymous feature creates a secure environment for students to respond to instructor's questions without fear or concerns of embarrassment (Boscardin & Penuel, 2012), being wrong, being judged (Barr, 2017; Caldwell, 2007), or being singled out (Boscardin & Penuel, 2012), thus reducing (peer) pressure and anxiety associated with answering questions in class (Barr, 2017; Kay & LeSage, 2009).

In the meantime, although the effect of ARS on student engagement and learning was evident in some empirical studies, the findings were not consistent, and many researchers found that the effect might vary because of many personal factors. For instance, in Addison et al.'s (2009) study with 174 students involved in an introductory biochemistry class, there was no measurable difference in class mean composite examination score for students taught with clickers than for those taught in traditional lectures. Although most students strongly indicated that the use of clickers enhanced their learning experience, students in the lowest achievement categories were less likely to agree that the clickers helped their learning or performance in examinations. Thus, the authors concluded that the in-class use of clickers improved the performance on examinations of only the highest-achieving students (Addison et al., 2009). While more recently, Sawang et al.'s (2017) path analysis from a study with 131 first-year students reveals that (1) individuals with a positive attitude toward the ARS use and those who felt a social pressure to use the ARS were more likely to intend to use it than those low in these variables; (2) the actual use of the ARS was directly associated with the level of student engagement; (3) extraversion was related to student engagement: compared to extrovert students, introvert students felt more engaged. Despite the differences, the influence of ARS on student engagement is widely acknowledged (Caldwell, 2007; Draper & Brown, 2004; Han, 2014; Kay & LeSage, 2009).

Backchannels

Backchannels encourage student questioning in large lecture classes. In the recent decade, digital backchannels were shown effective in promoting student participation and engagement in large classes by many researchers (e.g., Harunasari & Halim, 2019; Yates et al., 2015). Kassner and Cassada (2017) defined backchannel as conversational devices used by listeners to signal engagement. Carpenter (2015) defined it as online interaction spaces that run parallel to spoken remarks. Baron et al. (2016) defined backchannel in their study as software that allows a secondary, digital conversation to take place during a university lecture. In general, a backchannel is a software that allows the audience to interact with the speaker using digital devices rather than verbally, such as social media and microblogging platforms, such as Twitter (a popular micro-blogging platform), Edmodo, and Facebook. The audience could post text to a website that is either projected onto a screen in the room or available on the speaker's desk. Unlike answering the speaker-composed questions in the ARS, with backchannels, the audiences can contribute questions. Backchannels were seen successful in conferences to encourage participation without disrupting the presenters. Practitioners in higher education then started adopting the tool in their classes (e.g., Aagard et al., 2010), but only in trial runs or elective courses (Baron et al., 2016). More recently, in addition to using social media software as backchannels, specialized software had also been designed (e.g., Baron et al., 2016; Harunasari & Halim, 2019). The advances in technology enriched the features of backchannels, enabled the customized design, and allowed instructors and students to use them in a variety of ways. Students could alert the lecturer that they were "lost" by clicking a "lost" button (Baron et al., 2016). They could also "like" or "dislike" posts (Aagard et al., 2010; Bergstrom et al., 2011; Pohl et al., 2012), vote on questions (Baron et al., 2016), moderate posts (Holzer et al., 2014), and post questions anonymously (Baron et al., 2016).

Increasing studies suggested that incorporating the backchannel affected student engagement, some of which revealed a change of the classroom dynamics and improves engagement. For instance, Junco et al. (2011) conducted a semester-long (14 weeks) experimental study and found evidence that Twitter can be used as an educational tool to significantly engage students and to mobilize faculty into a more active and participatory role. Pohl et al.'s (2012) pilot experimental study recruited students from a range of academic backgrounds and took place in a computer laboratory with all students logged in to the backchannel software. Their results showed that around three times more questions were asked in the experimental group compared to the control group. Baron et al.'s (2016) mixed-method study with one hundred students revealed that the backchannel increased the number of questions asked in class, resulted in a broader range of students participating in such interactions, and helped some students to be more focused. Particularly, their analysis of focus groups revealed that students tried to answer backchannel questions themselves, before the lecturer did, to test their knowledge, and then "liked" the question if they could not answer it. In this way, students were taking quizzes and asking for help if they could not provide their answers (Baron et al., 2016). Besides, Harunasari and Halim's (2019) study with 41 college students revealed that digital backchannel had a direct positive relationship with students' engagement and self-directed learning. In addition, many studies showed students were enthusiastic about backchannels and supported its adoption across more courses (Bergstrom et al., 2011; Holzer et al., 2014; Yates et al., 2015). Harunasari and Halim's (2019) study revealed that the backchannel offered students a sense of engagement and that students felt more positive about classroom discussions. Baron et al.'s (2016) in-depth focus group revealed more affective outcomes: a backchannel activity led to a group of students interacting with each other, and the lecturer, to grapple with and understand difficult concepts, which resulted in some students claiming they were now more comfortable asking questions verbally and would do so in the future even though the backchannel might no longer be used in the course. Studies with backchannels also reveal that public anonymity/private accountability options bring students positive experiences, such as in Yates et al.'s (2015) study, students like the anonymity that the technology provided, allowing them to ask questions without fear of appearing less competent than their peers.

Overall, there were successful attempts of using backchannels to facilitate large lecture classes, although most of which were in the trial round. However, not enough students focused on student questioning and engagement. The next section reveals the influence of backchannels on student questioning and engagement was not consistent across studies.

Summary

This section presents empirical studies of how technology intervention influences student questioning and student engagement. In general, collaborative technologies were found effective in facilitating help-seeking in higher education as they provided students with alternative channels to voice their questions. It was evident in many empirical studies that the use of ARS in large lecture classes improved student engagement. There were also successful implementations of backchannels to facilitate student questioning in large lecture classes. However, as the next section discusses in detail, there are still gaps in the literature that calls for the current study.

Five Gaps in the Literature

According to the literature review, there are five major research gaps in studies using technologies to facilitate student questioning and student engagement.

Student Questioning Pattern in Large Lecture Classes. Empirical studies on student questioning in colleges mostly focused on students' academic help-seeking rather than student questioning in large lecture classes (e.g., Kitsantas & Chow, 2007). The research on questioning patterns in class were mostly restricted to elementary and middle schools (e.g., Nelson-Le Gall, 1981; Newman, 1990; Newman & Schwager, 1993; Puustinen et al., 2015; van der Meij & Dillon, 1994). Not enough is known about questioning patterns employed by college students in technology-enhanced large lecture classes. Although some studies examined types of questions students asked in backchannels, their results were inconsistent and not inclusive. For instance, Pohl et al. (2012), in their experimental study, found limited off-task content, some feedback, and that the most substantial proportion of contributions were questions. Most questions represented a lower-order style of thinking. Bergstrom et al. (2011) categorized responses as either on-task or off-task and found that the latter was sufficiently prominent that they did, on occasion, disrupt the lecture. Holzer et al. (2014) found that organizational messages, such as requesting lecture slides or asking for a light to be turned on, were ‘liked’ the most out of any other types of posting. Messages relating to actual course content were rated less frequently. There was also a high proportion of “irrelevant” content early on after the introduction of the backchannel. However, this declined over time, possibly at least partly due to the lecturer having discussed this issue in class (Holzer et al., 2014). There is still a lack of comprehensive investigation to examine the student questioning in large lecture classes.

Insufficient Use of ARS for Student Questioning. As an instructor-initiated learning activity, ARS has some limitations. Studies show that the pedagogical and technological knowledge and skills of the instructor significantly moderated the effect of ARS (Han, 2014; Hunsu et al., 2016). Firstly, adequate time is needed for instructors to learn and set up the ARS technology, conduct ARS-based learning activity while maintaining adequate coverage of course material (Kay & LeSage, 2009). Instructors also need to receive appropriate training and spend efforts practicing how to effectively identify and analyze ARS data to re-examine their instructional activities and realign their course design to optimize the course content, goals, and pedagogical approaches with the ARS (Han, 2014; Hunsu et al., 2016). Those attempts might bring instructors extra workload. Secondly, the effectiveness of ARS-based formative assessment depends on the quality, difficulty level, and types of ARS-questions and how instructors react to the results (Boscardin & Penuel, 2012; Han, 2014; Hunsu et al., 2016). Instructors need to give considerable attention to developing good ARS questions that thoroughly capture students’ misunderstanding or perplexity, responding to instantaneous student feedback, facilitating group discussion, allowing the opportunity for students to explain their answers, and adjusting instruction after feedback (Boscardin & Penuel, 2012; Hunsu et al., 2016). Even for very experienced instructors, it is challenging. Thirdly, as ARS-questions are all preset by the instructor, students barely have the autonomy to express their confusion in a customized way. Also, class size significantly moderated the effect of ARS (Han, 2014; Hunsu et al., 2016). Given limited Q&A time and space in a large lecture class, the ARS questions might hardly capture all the puzzles, ambiguity each student might encounter. There is a need for technology that enables each student to freely express their perplexity, and respond to others' questions, which might shift the instructor-centered formative assessment to a student-centered learning activity, which facilitates the co-construction of knowledge. In short, using ARS was insufficient in facilitating student questioning.

Influence of Backchannels Lacks Sufficient Evidence. There were increasing research studies on the effect of backchannels on student participation and classroom interaction. However, most studies with backchannels were case studies and only looked at subcategories of engagement, such as the evaluation of the activity (e.g., Yates et al., 2015), participation in the software (Holzer et al., 2014). Rarely studies focused on impacts of backchannels on multiple dimensions of student engagement. Among studies that addressed engagement, the measure of engagement was limited to activity in the class (Baron et al., 2016). Most of which focused only on questioning behavior (and "like" or "vote" behaviors) as the only indicator of behavioral engagement (e.g., Yates et al., 2015). Inadequate attention has been drawn to students' answering and browsing behaviors. Some studies lacked validated instruments or employed limited data collection methods (e.g., Aagard et al., 2010; Harunasari & Halim, 2019; Yates et al., 2015).

Besides, the positive influence of backchannels on student engagement was not consistent. For example, Aagard et al.'s (2010) two-semester experiment suggested that in two of the three large classes where they implemented a backchannel, there was a correlation between the number of posts via the backchannel and course grade - those who used the software tended to be those who obtained higher marks. Wakefield et al.'s (2011) mixed-methods study revealed diverse student perceptions of the use of Twitter; both very positive views of the tool as a means of supporting discourse and those views of the tool having a little benefit to student's learning. Concluded from a fifteen-week long quasi-experiment in an introductory sociology and anthropology courses, Welch & Bonnan-White (2012) found that there was no significant difference in any form of engagement when Twitter was part of the course than when it was not. They surveyed students using five sub-scales: Academic, Peer, Intellectual, and Beyond-Class engagement. Similarly, the qualitative data in Yates et al.'s (2015) study provided mixed results concerning the students' perceived value of microblogging to their learning experience. Some students found the use of microblogging unreliable and distracting (Yates et al., 2015). As for emotional engagement, Henrie et al.'s (2015) comprehensive analysis reviewed that emotional engagement indicators were more frequently studied in the K12 context but rarely in the higher education context. Most of the measurements in studies with backchannels were not explicitly targeted at emotional engagement in learning, but students' general attitude and feeling of the use of the backchannels. To sum up, the influence of backchannels on student engagement and student questioning lacks sufficient evidence which calls for research using various measurement methods.

Unobtrusive Uses of Backchannels Had Limited Effect. Most studies with backchannels emphasized that the students could contribute questions without interrupting the instructor at the point they were delivered. They were mostly used as an “unobtrusive” learning aid. This unobtrusive nature of backchannels could be regarded as “safe learning” - traditional technology-enhanced instruction where there is slight change in this traditional relationship between student and technology (Koszalka & Ntloedibe-Kuswani, 2010). Although students could contribute their feedback and questions to the instruction, as instructors did not specify how they would give a response, such as the frequency and occasions, students might lack the expectation of how their questions would receive responses and help the instructor to modify the instruction. In other words, the instructor still was the one who controlled the flow of instruction. It was still an instructor-centered approach. Therefore the “unobtrusive” role of backchannel failed to provide students with enough autonomy to control their learning process. There is still a gap in previous literature regarding how the use of backchannels, especially if peer-interaction and peer-instruction are enabled, influences peer students’ engagement and learning outcomes. The possibility of using m-technologies for “disruptive learning” was not thoroughly examined by the previous attempts. To sum up, unobtrusive uses of backchannels had limited effect on student engagement and student questioning.

Voluntary Participation Was Not Guaranteed. Many studies with technology-based intervention did not provide students with the opportunity to participate in learning activities *voluntarily*. For instance, some studies with backchannels required a student’s participation by the course designs for course credits. This phenomenon was also seen in studies with ARS. Although students in most empirical studies acknowledged the benefits of ARS in facilitating their learning, some of them reported negative attitudes towards being monitored through ARS-based learning activity (Kay & LeSage, 2009). Even if most studies with ARS guaranteed that participation in ARS was voluntary, some students still felt being monitored.

Some studies that investigated the influence of backchannels on student engagement did not focus on students' questioning but nested various learning activities together. For instance, In Aagard et al.'s (2010) study, an instructor used the backchannel to have discussions in class, asking questions related to lecture material; another instructor used the backchannel for student questioning during the lecture; Another instructor used backchannel to help students feel more comfortable answering broad, open-ended questions related to sensitive topics. In Junco et al.'s (2011) experiment, Twitter was not only used for questioning purposes but also used for a variety of learning activities, such as class discussion, book discussion, class reminders, campus event reminders, and optional assignments. Thus, it made it impossible to investigate its influence on student questioning and engagement precisely. Similarly, in Welch and Bonnan-White's (2012) study, many instructional interventions nested together, which made the interpretation of their effect on student engagement difficult. In the experimental group, students were asked to post their responses to a course Twitter backchannel dedicated to each assignment. Students in the experimental condition could also use Twitter to tweet during course films, ask questions during lectures, and send questions about course materials or procedures to their instructor. Instructors also posted websites, stories, and comments relevant to course material to a class Twitter feed (Welch & Bonnan-White, 2012). Thus, although asking questions might be voluntary in studies with backchannels, other required backchannel-based learning activities made it impossible to ensure voluntary participation. Therefore, those studies failed to examine, at the activity level, how the implementation of a backchannel could influence students' engagement.

In summary, voluntary participation was not guaranteed in many empirical studies. Without voluntary participation, it was not likely to truly examine students' spontaneous uses and their active engagement in learning with this tool.

Summary

There were still gaps in literature around using technologies to facilitate student questioning and student engagement in large lecture classes. (1) Inadequate studies investigated student questioning pattern in large lecture classes. (2) Using the ARS was insufficient in facilitating student questioning. (3) The influence of backchannels on student engagement lacks sufficient evidence. (4) Unobtrusive uses of Backchannels had limited effect on student engagement and student questioning. (5) Voluntary participation was not guaranteed in many empirical studies.

It is reasonable to assume that the effects of technologies on student engagement and student questioning have not been fully explored, which calls for further investigation. Despite the discrepancy in the literature, those various attempts of using technologies to facilitate large lecture classes have essential implications for supporting student questioning and engagement in large lecture classes.

Chapter 3: Methodology

Context and Participants

This study took place in a large comprehensive university in eastern China, which is recognized as one of the Chinese top public research universities under the patronage of the Ministry of Education. It has 30 full-time schools and colleges. As of December 2020, there were 16,273 full-time undergraduates and18,935graduate students enrolled in this university; among its 4,000 faculty, 1,969 are professors and associate professors ("Overview," 2020). Each year, a large number of student enrolments drove the university to provide large classrooms. This study was conducted in the Faculty of Education, where most students were female, which led to the gender imbalance.

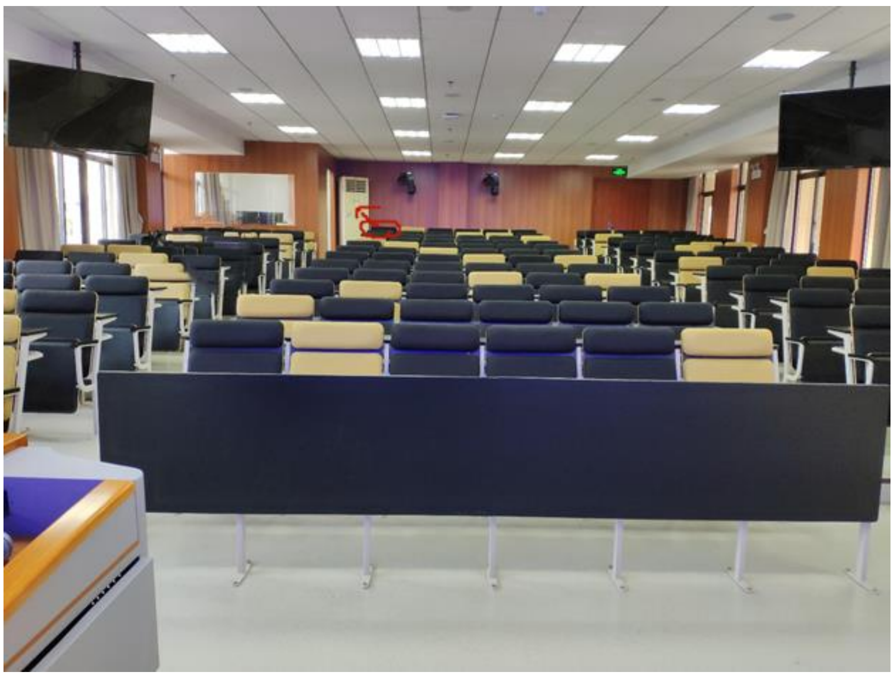
This study was implemented in an introductory research methodology course. The course's objective was to meet the needs of first-year undergraduate students who had little exposure to educational and psychological research methods in the field. This course gave an overview of research methods in this regard and aimed at helping students develop a brief understanding of the processes through which research projects were constructed. The course's major topics included *ways of thinking about building knowledge*, *sampling methods, exploring the literature*, *survey methods*, *quasi-/experimental methods*, *qualitative and mixed methods*, con*ventional and emerging research tools*, and *evaluation and other methods*. After the course, students were expected to gain a solid foundation upon pursuing further studies on research methods.

As an introductory course, the format of the course was lecture-based. The course was offered in the summer term and lasted for seven weeks. Each week, the instructor gave a 3.5 hour-long lecture, with 5-minute breaks after around one hour. There was no discussion session.

The final week (the week after the experiment) focused on reviewing. The experiment took place in a conference-room style classroom (Figure 2), where seats and tables were fixed. The instructor gave lectures at the teacher station in front of the class with PPT projected on the whiteboard.

Figure 2

The Classroom of the Experiment



The sample consisted of 253 first-year students enrolled in the course. Among the 209 students who finished a pre-test survey regarding their previous technology experience, most of them had used smartphones to participate in class interaction (97.6%) and for learning purposes after class (98.6%). The study was approved through the university institutional review board. A graduate assistant collected the consent forms at the beginning of the first class. All the students agreed to participate in this study.

Research Design

This study employed a mixed-methods design, including quantitative and qualitative data to answer the research questions and test the research hypotheses. According to Morse (2010), this mixed-methods study was considered a QUAN + qual study because (1) the study followed deductive reasoning which started out with a theory and statements then moved towards specific conclusions; (2) both quantitative and qualitative data were collected simultaneously with dominant quantitative analysis. Within the QUAN +qual mixed-methods study, a 6-week-long, two-group comparative, pre-post quasi-experiment was conducted in two sections of this course to investigate the influence of a DQB-based intervention on students' questioning and engagement. This design helped to investigate the influence of technology-based intervention in real-life settings.

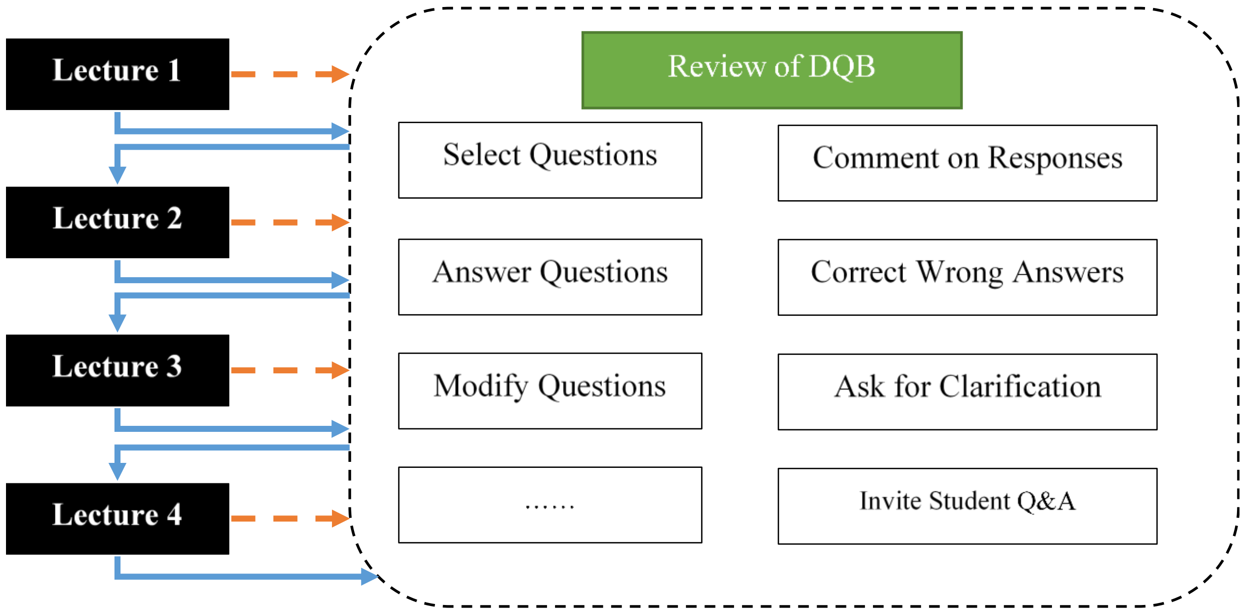
Intervention

This study created a Digital Question Board (DQB) for students to freely pose questions and respond to others' questions using mobile technologies. Students could use the DQB whenever they want in class. The instructor informed students at the beginning that he would allocate 5-10 minutes for Q&A sessions after every 20-30 minutes' lecture to answer students' questions. The instructor emphasized that participation in the DQB was *voluntary*; students were still welcome to ask questions orally. Figure 3 illustrates the procedure of the weekly intervention.

Blue arrows in Figure 3 show the flow of instruction. The instructor gave a lecture then review the DQB to respond to students' questions. During a Q&A session, the instructor tried to answer questions from multiple students. If there was not enough time to answer all the questions, the instructor made a random selection to let students have equal opportunities to get answers or the instructor's attention. To ensure anonymity, the instructor avoided asking who posted anonymous questions. Red arrows indicate that the instructor could also review the DQB during a lecture when necessary.

Figure 3

The Flow of Instruction within the Weekly Intervention



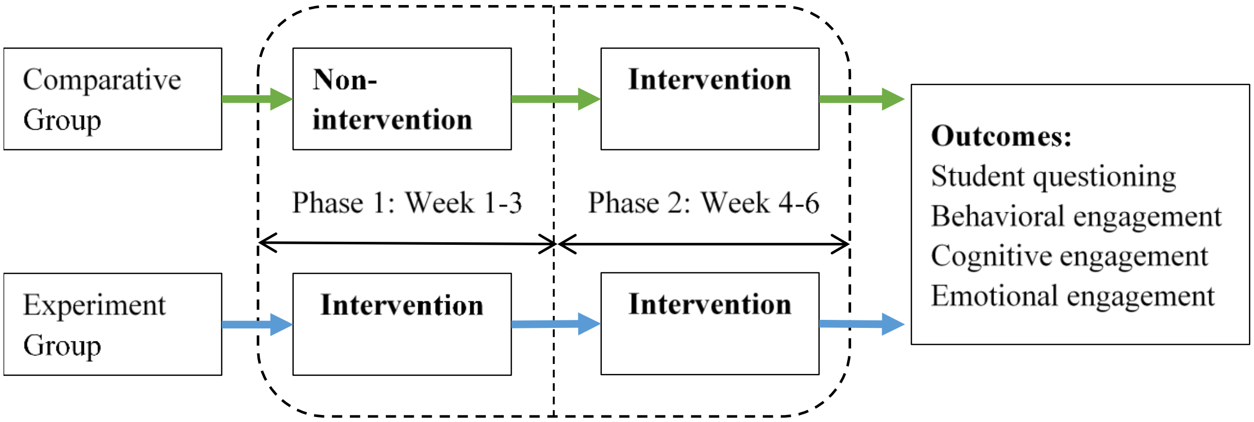
Note. Each lecture lasts for 20-30 minutes. Each Q&A session lasts for 5-10 minutes, depending on the number of questions and responses.

Experiment Design

The quasi-experiment lasted for six weeks and had two phases; each phase lasted for three weeks. The two sections were randomly assigned into either the experimental group or the comparative group in the unit of a whole class. There were 117 students in the experiment group (male = 16; female = 98; not mention = 3) while 136 students in the comparative group (male = 15; female = 121). In *Phase 1*, only students in the experiment group had DQB access (intervention). In *Phase 2*, students in both groups had DQB access. The instructor discussed student questions after every 20-30 minutes in both groups. Figure 4 illustrates the overall design of the quasi-experiment.

Figure 4

Design of the Experiment



To prevent bias in research results, the researcher utilized a double-blind procedure: neither the participants nor the instructor knew what the intervention was and who received a particular intervention. The instructor used the same instructional strategies and discussed questions after every 20-30 minutes in both groups.

This research design allowed for the comparison of the class dynamics with and without a DQB provided. The comparison between two phases for the experimental group would elaborate on whether the possible influence of the DQB diminished after three weeks or continued to be useful throughout the semester. It was also a way to ensure that all the students had equal opportunities to benefit from this intervention. Although the comparative group participants did not have DQB access in the first three weeks, they were not disadvantaged. Researchers suggested that writing a question in the online environment might require a deeper level of thinking about the question, writing it up and confirming the question again before sending it

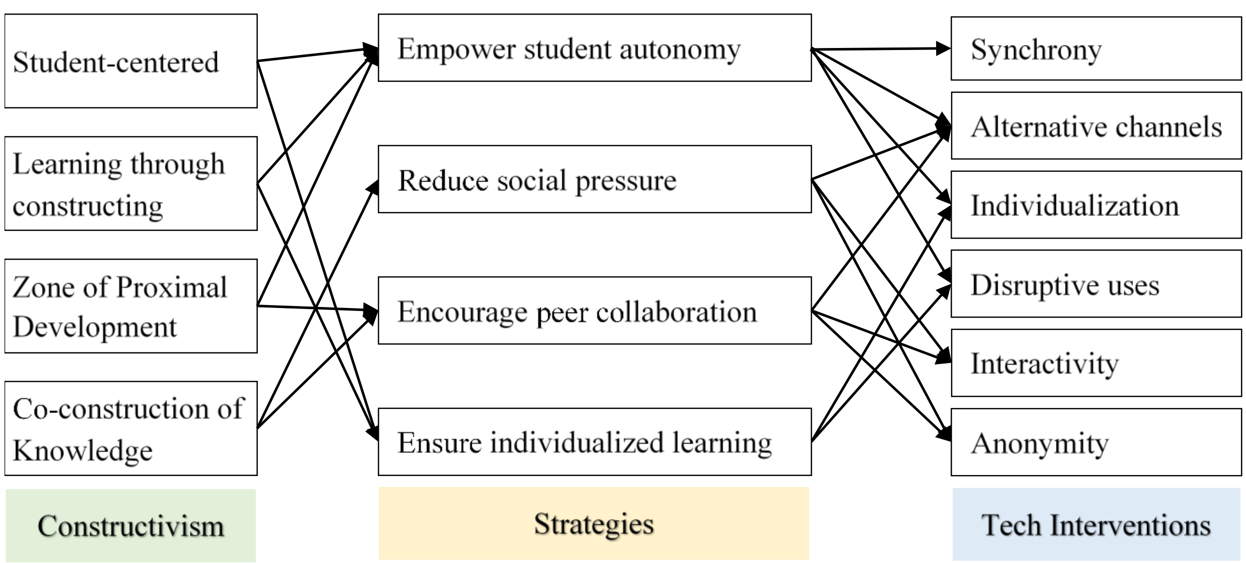
(Mahasneh et al., 2012). Thus, the effectiveness of DQB access in facilitating student questioning was to be investigated.

Analytical Framework

This section presents an analytical framework of using technologies to facilitate student questioning and engagement from constructivist learning perspectives (Figure 5). Based on the analytical framework, four rationales are drawn from the literature to guide the effective use of technologies.

Figure 5

Analytical Framework of Technology Interventions to Facilitate Student Questioning and Engagement



(1) Use M-technologies to Improve the Efficiency of Questioning and Enable Student Autonomy. Constructivism learning theory emphasizes that "learning" is the center, and learner autonomy should be given full play. When students encounter difficulty in learning, they should be enabled autonomy to ask questions whenever they are puzzled or uncertain, rather than only being assessed through an instructor-initiated approach. They should also be enabled autonomy to ask questions in multiples ways and seek help from multiple sources. Therefore, m-technologies should be used as they break through the contextual limitation of large lecture classes and enable students to explore, review, choose and access resources they need immediately when they have questions or ideas, outside of the traditional classroom environment (Koszalka & Ntloedibe-Kuswani, 2010). In addition, the synchrony and collaborative nature of m-technologies allow multiple students to ask their questions simultaneously, unlike the oral expression that requires students to take turns to ask questions. Students would be less concerned about annoying their peers or occupying too much lecture time because of asking questions in large lecture classes. In this way m-technologies could provide students autonomy of questioning, make student questioning individualized and improve the efficiency of questioning.

(2) Use Collaborative Technologies to Make Space for Co-construction of Knowledge. Constructivist learning theories suggest that in the context of collaborative learning, group members who have higher levels of understanding can help the less advanced members learn within their zone of proximal development (Vygotsky, 1978). Even if students are not more knowledgeable than their peers, their questions could be beneficial because constructivism suggests each student learns differently. When a concept is first introduced to a student, individuals may interpret it differently, leading to different questions. By seeing peers' questions, students have the potential to view other peoples' thinking and their difficulties (Baron et al., 2016), improving the likelihood that students will determine that they are inadequate and need help (Keefer & Karabenick, 1998, p. 227). It also allows students to review the posts in later time to reinforce their learning, which might benefit students of different processing time. Therefore, collaborative technologies should be used to build supportive learning communities, facilitating students' questioning and engagement in class, making space for the co-construction of knowledge.

(3) Use Technologies with Anonymity to Reduce the Social Pressure of Student Questioning. Most students who might not verbally ask questions in the traditional class environment are influenced by how asking a question in class would potentially be seen by their peers (Baron et al., 2016). If student questioning leads to negative consequences, such as being laughed by peers or judged by the instructor, students are less likely to continue this learning strategy. Thus, for student questioning, a low-threat environment is needed for students to freely ask questions without being embarrassed or afraid of being wrong. The cost of questioning should be minimized. To do so, many studies reveal that technologies create a low-threat environment for students who tend to be reluctant to ask questions for assistance (e.g., Harunasari & Halim, 2019). Unlike in face-to-face condition, in the online environment, the emotional or personal costs are very low (Tricot & Boubee, 2013). Being anonymous also allowed participants to think about the question instead of what their peers might think should they answer incorrectly (Barr, 2017). To summarize, technologies with anonymity should be used to reduce the social pressure and create a low-threat environment for student questioning, encouraging "naturally occurring exchanges" (Puustinen et al., 2015).

(4) Uses Technologies Disruptively to Shift the Control of Learning to the Students. Constructivism acknowledges the student's active role in the personal creation of knowledge and the importance of experience (both individual and social) in this knowledge creation process (Doolittle, 1999). To make sure that students are active constructors of knowledge, rather than "safe" uses of technologies, m-technologies should be used for immersive and collaborative learning, or what Koszalka and Ntloedibe-Kuswani (2010) called "disruptive learning" as it disrupts the traditional paradigms of teacher directedness in favor of personalized approaches where students engage their competencies and resources while regulating their learning. Therefore, in large lecture classes, rather than using technologies as backstages, the instructor should show students the necessity and importance of student-initiated questioning, and how he or she will react to their questions. Specifically, during a lecture, it is ideal for the instructor to prepare a particular time for Q&A in advance and inform the students of the frequency and occasions when he or she will check the questions proposed by students. The instructor also needs to allocate appropriate time for discussions triggered by students' questions.

Summary. In sum, as shown in Figure 5, from constructivism perspective, four rationales are drawn from the literature to guide the effective use of technologies to facilitate student questioning, and student engagement: (1) use m-technologies to improve the efficiency of questioning and enable student autonomy. (2) use technologies with anonymity to reduce social pressure of student questioning. (3) use collaborative technologies to make space for co-construction of knowledge. (4) uses technologies disruptively to shift the control of learning to the students. Next, this study employed this framework to design a technology-enhanced intervention to facilitate student questioning and engagement in large lecture classes.

Implementation

Technology

Based on the analytical framework. The DQB was created on Padlet. It is a digital canvas that enables unlimited users to post multimedia information, share and collaborate using smartphones. Padlet is a *user-friendly* tool, like an online discussion board, which can be utilized by both instructors and students with ease. The instructor could set up a "wall" for students to post questions and comments during and after the lecture.

Padlet is a device-agnostic tool, available on the web and for free on iOS, Android, and Kindle devices. Students could access Padlet through an app installed on their smartphones or using URLs or QR codes shared by the instructor.

Padlet provides students *multiple ways to ask questions* and interact, such as to post multimedia content, insert external resources, upload materials, vote on other's posts, or click the "❤" icon under each post to "like" the post. Students could also modify their initial posts whenever necessary.

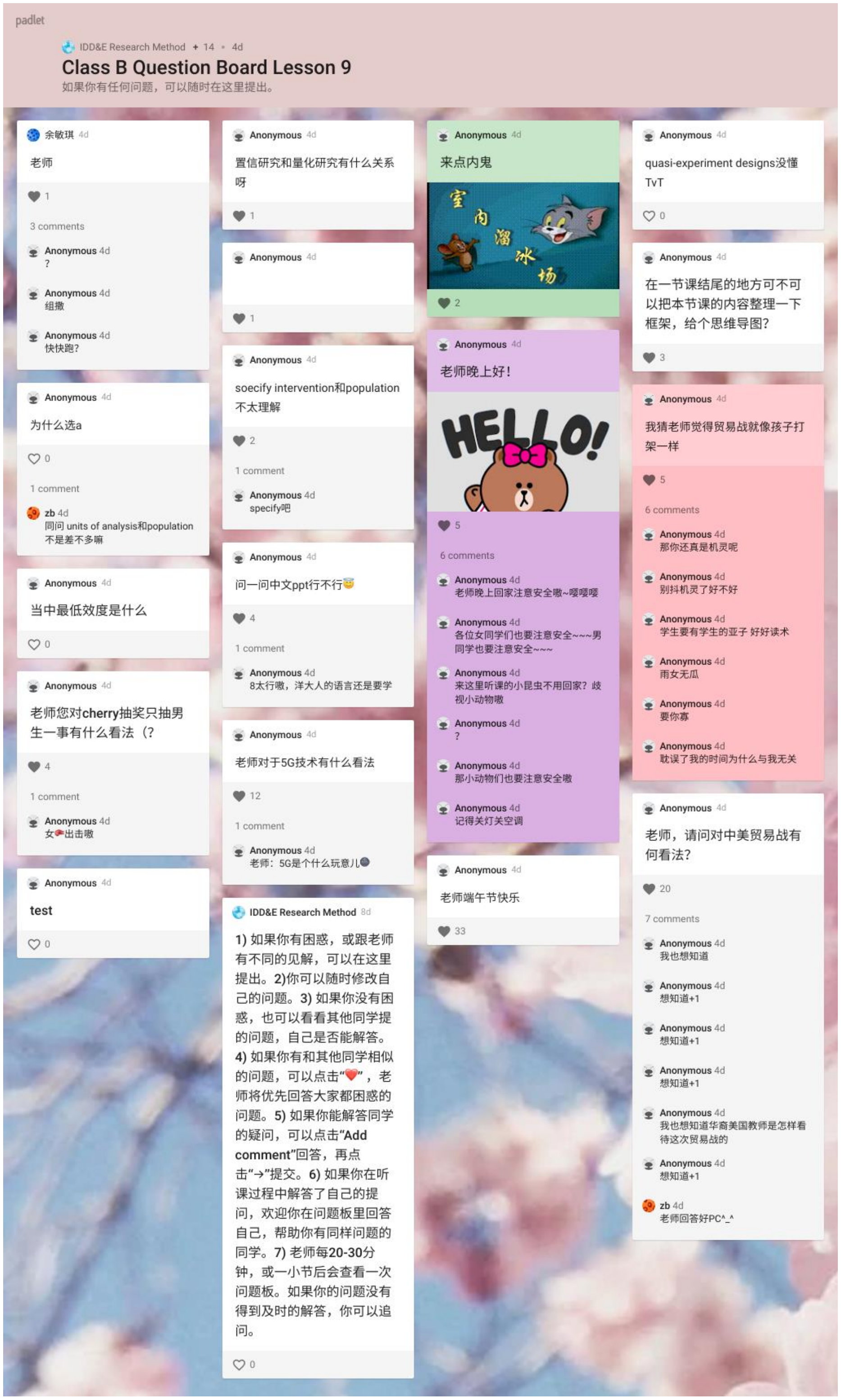
Padlet does not require signup (account-creation), which means students can easily access the DQB with no registration. It is also a way to protect their privacy, as it enables students to be *anonymous*. If students sign up, they could also choose from pseudonyms, real names, or be anonymous.

Padlet enables *synchronous* communication as all the posts display immediately. As a DQB, students could post questions instantly whenever they encounter perplexity; the instructor and peers could access the DQB anytime to answer or comment on the questions. Students could also access the DQB after class.

Figure 6 illustrates a DQB used in the weekly class. Students' questions were displayed in blocks. Each block began with the author of the post, followed by the time the post was created. Anonymous posts were automatically named "Anonymous." Below the author was the title (optional) and contents. Below the content was the number of responses followed by each response. New questions were displayed at the top left.

Figure 6

Screenshot of a DQB in Padlet Using a Laptop



Preparation

Before the experiment, various smartphones from varied brands were used to test the accessibility, usability, and functionality of the DQB in the local context. Researchers suggest that instructor should analyze students' previous experience with technologies, especially for educational purposes, familiarize them with the tool/learning platform of choice (Corlett et al., 2005; Huang & Law, 2018; Mahasneh et al., 2012), and then inform them about the functions before they can appropriately use them (Aleven et al., 2003). Therefore, a pre-test was conducted to understand students' experience of using smartphones. Online orientation was also provided before the semester began to help all the participants download the APP used for the DQB and be familiar with it.

The instructor had never used this type of technology before, so he received an orientation regarding the uses of the DQB. The training protocol is attached in Appendix B. A teaching assistant helped the instructor prepare instructional materials, including setting-up question boards with appropriate graphics (e.g., background, theme), embedding QR codes and hyperlinks in the PowerPoint slides (Figure 7), and sharing links to the class chatroom[1] to allow students accessing the DQB more efficiently.

Depending on the number of pages in the weekly PPT slides, there were usually three to four slides that contained QR codes and hyperlinks; and in most cases, they were right after a unit of a lecture. In this way, students could access the DQB with ease without searching for the codes or links. It was also a way to keep the instructor aware of his lecture's length and make the frequency of reviewing the DQB comparatively consistent.

[1] The chatroom was not used for communication in class, but for general announcement and notification, such as a notice of the change of class time, a summary of homework assignment, etc.

Figure 7

Screenshot of a PPT Slide with a QR Code and a Link to a DQB

Research Hypotheses

Based on the literature review and research design, because of the complexity of engagement measurement and the context and participants, research questions (RQ) are broken down into sub-questions and sub-hypotheses, depending on the specific variables measured. For research questions that investigate the influence of the intervention on outcome variables, research hypotheses (RH) are proposed. For exploratory research questions, there is no hypothesis:

- RQ1. Do students demonstrate different questioning behaviors when provided access to a DQB from those students who are not provided with access to a DQB in large lecture classes?
    - RH1.1. There is a difference in the frequency of questions between students with or without DQB access.

    - RQ1.2. What patterns of questioning are displayed when students ask questions with a DQB?
    - RQ1.3. What types of questions do students ask with a DQB?
- RQ2. How does having access to a DQB during large lecture classes influence students' level of engagement?
    - RQ2.1. How does having DQB access influence behavioral engagement?
        - RH2.1.1. There is a difference in the frequency of responses between groups with or without DQB access.
        - RH2.1.2. There is a difference in the frequency of interaction between groups with or without DQB access.
        - RH2.1.3. There is a difference in the number of students who voluntarily browse, question, and answer questions between Week 4-6 and Week 1-3.
        - RH2.1.4. There is a difference in the assignment completion rate between students with or without DQB access.
    - RQ2.2. How does having DQB access influence cognitive engagement?
        - RH2.2.1. If students have DQB access, there is a higher level of self-regulation after six weeks, controlling for self-esteem, self-efficacy, and pre-test self-regulation.
        - RH2.2.2. There is a difference in the proportion of on-task questions between students with DQB access and ones without DQB access.
        - RQ2.2.3. What types of responses do students post with DQB access, and do they facilitate interaction?

        - RQ2.2.4. How does having DQB access influence cognitive engagement, as reflected in students' interviews and surveys?
    - RQ2.3. How does having DQB access influence emotional engagement?
        - RQ2.3.1. How does having DQB access influence emotional engagement as reflected in students' DQB posts, interviews, and surveys?
        - RQ2.3.2. What is the level of emotional engagement for most students?
        - RH2.3.3. Students with 6-week DQB access had more positive attitudes than students with 3-week DQB access.

Measurement

This section introduces the measurement to each of the research question or research hypothesis.

Student Questioning

The measurement of student questioning includes three dimensions: (1) the frequency of questions, (2) the patterns of questioning, and (3) the content of questions. The frequency of questions referred to the numbers of questioning observed, recorded, and reported in the surveys. Patterns of questioning examined in what conditions or occasions did students ask questions with the DQB and how they used the DQB for questioning. The content of questions investigated the types of questions students asked and distributions of different types of questions.

Student Engagement

Behavioral Engagement. The indicators of behavioral engagement in this study focused on widely examined student behaviors such as *assignment completion rates* (Heafner & Friedman, 2008) and behaviors frequently assessed in the digital platform, e.g., *number of posts* (Giesbers et al., 2014), *number of questions asked* (Aagard et al., 2010; Baron et al., 2016; Pohl et al., 2012), and interactions between students. The frequency of interaction, i.e., numbers of questioning, answering, likes, was measured through (1) log data automatically recorded in the DQB and interactions observed by observers; (2) self-report surveys. Log data and direct observation captured students' observable behaviors. The self-report survey items targeted students' unobservable behaviors, such as *browsing* and *anonymous questioning or answering*. In general, the higher frequency of interaction indicated a higher level of behavioral engagement in large lecture classes. The *numbers of students who browsed questioned and answered in the DQB* also helped illustrate students' behavioral engagement in the unit of a whole class. The primary reason is that: as the weekly lecture dealt with content topics of different levels of difficulty, they triggered an uneven distribution of student questions, i.e., in some weeks, fewer questions were observed because the content was easy for most students to understand, not because students were unwilling to ask. Thus, to compare the frequency of questions/answers between phases was not convincing enough. On the other hand, it was useful to investigate whether the presence of the DQB encouraged a broader range of students to either browse or interact in large lecture classes. Therefore, by the end of Phase 1 and Phase 2, students in the experimental group were asked about whether they had voluntarily browsed, asked, or answered questions in the DQB in the past three weeks. The comparison between students' self-reported behaviors between two phases could help to examine whether students voluntarily used the DQB even after a possible novelty effect.

Cognitive Engagement. The measurement of cognitive engagement included four dimensions: (1) the level of self-regulation in lecture classes, (2) the types of questions that reflected cognitive engagement (e.g., on-task questions), (3) the types of responses that reflected cognitive engagement (e.g., answers to questions, follow-ups), and (4) the evidence of cognitive engagement reflected in open-ended surveys and interviews.

Self-regulation. Self-regulation is one primary sub-construct of cognitive engagement. As was suggested by Fredricks et al. (2004) that researchers should consider including survey items from the *self-regulation* literature when assessing cognitive engagement. Thus, this study used an instrument to measure students' self-regulation in lecture classes, which was adapted from one subscale of the *Motivated Strategies for Learning Questionnaire* (MSLQ; Pintrich et al., 1991). This scale consisted of ten items that assessed college students' self-regulation, specifically during lecture classes at the course level. Students rated themselves on a 7-point Likert scale from 1 (not at all true of me) to 7 (very true of me). Compared to other instruments (e.g., NSSE), this measure focused more specifically on students' self-regulation levels in class, which was of interest to validate the research assumption. The alpha coefficient obtained for this scale was .775, which was considered reliable.

Comprehensive studies revealed that personal variables such as self-esteem and self-efficacy influenced student questioning and engagement in classes (e.g., Butler, 1998; Butler & Neuman, 1995; Ryan & Pintrich, 1997). Thus, students' self-esteem and self-efficacy were measured as controlling variables when studied students' self-regulation. Exact items on each scale are included in Appendix C. *Self-esteem* was measured through the *Rosenberg Self-Esteem Scale* (Rosenberg, 1965), which consisted of 10 items (α = .85) that measured global self-worth by measuring both positive and negative feelings about the self. This scale had been used in several previous studies on student questioning (e.g., Karabenick & Knapp, 1991). All items in the original scale were answered using a 4-point Likert scale format ranging from strongly agree to strongly disagree. In this study, students answered using a 7-point Likert scale from 1 (not at all true of me) to 7 (very true of me). *Self-efficacy* was measured through a subscale of the revised version of Motivated Strategies for Learning Questionnaire-Adapted Chinese version for adult learners (MSLQ-CAL) by Tong et al.'s (2017). Students rated themselves from 1 (not at all true of me) to 7 (very true of me). This scale investigated self-efficacy for learning and performance, which consisted of 8 items (α = .932).

Types of DQB Posts. Students' mental functions reflected their cognitive engagement. The on-task behavior reveals students' cognitive attachment; the content of students' posts or assignments shows their improved understanding or mental functions on the revised Bloom's Taxonomy (e.g., Fredricks et al., 2004; Yang, 2011). Therefore, students' cognitive engagement was also measured through *the content and types of DQB posts*. Precisely, DQB posts were measured regarding how they were related to the lecture content and how they facilitated learning. A coding scheme developed by the author adapted from multiple researchers was used to measure DQB questions and will be introduced in the next section. Due to the limited time during each weekly lecture, there were few DQB responses. Thus, rather than using existing frameworks, instead, like what Barr (2017), and Paulus et al. (2006) did in their studies, an exploratory analysis was conducted to examine students' cognitive engagement reflected in DQB responses.

Evidence of Cognitive Engagement. The last component of cognitive engagement measurement was *evidence of cognitive engagement reflected in open-ended surveys and interviews.* The data came from interviews and three open-ended survey questions on students' reflection, attitudes, opinions, and learning experiences with the DQB. Their learning experiences included whether the use of the DQB benefited their learning, whether the presence of the DQB encouraged them to interact more, and whether the use of the DQB helped them resolve learning perplexity.

Emotional Engagement. This study assumed the technology-enhanced intervention could reduce students' social pressure of student questioning in large lecture classes. Therefore, the measurement of emotional engagement focused on whether such intervention brought students positive emotion regarding their learning experience, such as enjoyment (Yang, 2011), interests (Handelsman et al., 2005), and desire to use the tool again (Kay & Knaack, 2009). To measure positive emotional engagement, researchers examined visible expressions of positive emotion during online discussion boards (e.g., Paulus et al., 2006; Yang, 2011); self-reported evidence from surveys (Welch & Bonnan-White, 2012), and indicators from semi-structured interviews (Harunasari & Halim, 2019; Paulus et al., 2006).

Thus, this study measured students' emotional engagement through (1) evidence of emotional engagement reflected in open-ended surveys, interviews and DQB posts; (3) three Likert questions in the post-test survey regarding students' general attitudes toward learning with the DQB. The coding framework for emotional engagement will be introduced in the next section.

Summary of Measurement

Measurement of *student questioning* involves three aspects: frequency of questions, patterns of questioning, and content of questions. The measurement of *behavioral engagemen*t consists of four dimensions: the frequency of responses, the frequency of interaction, the number of students who browsed, questioned, answered, and the assignment completion rate. The measurement of *cognitive engagement* includes three aspects: students' self-regulation in lecture classes, the evidence reflected in open-ended surveys and interviews, and types of questions/responses that reflected cognitive engagement. For *emotional engagement*, the measurement involves evidence reflected in open-ended surveys and interviews, self-report attitude from the survey, and proof of emotional engagement reflected in DQB posts. Table 5 on the next page illustrates the indicators and measurement methods for student questioning and student engagement in the current study. The next section introduces data collection methods for each of the variables.

Table 5

Measurement Overview

Research Questions	Instruments / Coding Scheme
RQ1. Student Questioning	
RH1.1. Frequency of questions	Observed and recorded frequency
RQ1.2. Patterns of questioning	Conditions, occasions, habits
RQ1.3. Content of questions	Types and distributions of questions
RQ2.1. Behavioral Engagement	
RH2.1.1. Frequency of responses	Observed and recorded frequency
RH2.1.2. Frequency of interactions	Observed and recorded frequency
RH2.1.3. Number of students who browsed, questioned, and answered	Reported percentage of students
RH2.1.4. Assignment completion rate	Weekly rates of individual students
RQ2.2. Cognitive Engagement	
RH2.2.1. Self-regulation	MSLQ (Pintrich et al., 1991)
RH2.2.2. /RQ2.2.3. Content of DQB posts	Self-developed scheme & exploration
RQ2.2.4. Indicators of cognitive engagement	Exploration
RQ2.3. Emotional Engagement	
RQ2.3.1. /RQ2.3.2. Indicators of emotional engagement	Exploration
RH2.3.3. Attitudes toward the DQB uses	3 Likert questions in post survey

Data Collection

A mixed-method approach to data collection was used in this study. Data from surveys, interviews, observation, and online posts (log data) were collected to answer the research questions and test the research hypotheses. This design combined the advantages of each form of data. In this way, one data collection form supplied strengths to offset the weaknesses of the other form, resulting in a better understanding of the research problem (Creswell, 2015, p. 542).

The DQB offered automatic logging of questions and responses on a timely basis and thus generated a mass of both quantitative and qualitative data. Surveys were adopted to measure students' self-report variables and obtain students' broader impression of the DQB uses, which generate mostly quantitative analysis and some qualitative comments. Then a series of interviews were conducted to generate more in-depth qualitative data. Besides, observational notes were kept throughout the class, focusing on students' face-to-face questioning frequency. Further details on the collection of the four sources of data are listed below.

Log Data –DQB Posts

Log data from the Padlet and Qualtrics platform captured students' observable questioning and answering behaviors. Log data in Qualtrics collected students' assignment completion rates. Log data were automatically recorded throughout the semester and exported after the final week. As the Padlet platform did not allow tracing back the author of each anonymous post, DQB posts could not be linked to the individual student. Therefore, the exact number of posts from each student could not be determined with absolute confidence. However, this was partially compensated in the post-survey by asking students to self-report the usage and frequency of their DQB activities, scaling the results appropriately. This substitute solution was also successfully executed by other researchers (e.g., Baron et al., 2016).

Online Survey

Online surveys were conducted before and after each experimental phase using an online survey platform, Qualtrics. A small amount of participation grade points was allocated to the surveys as compensation to encourage students' participation. Students were ensured that completing the survey would guarantee the grade points, they would not be evaluated by their responses, and the confidentiality would also be secured. As listed in Table 6, the response rates were high across three surveys. However, some incomplete responses led to inconsistent sample sizes for specific items. All the instruments were translated into Chinese and proofread by two Chinese native-speakers, one professor, and one post-doc researcher. Participants received invitations to complete each survey through WeChat, with hyperlinks.

Table 6

Distribution of Online Surveys and Contents

Survey	**Pre-test survey**	**1st post-test survey**	**2nd post-test survey**
Time	Before the experiment	End of Phase 1 (3rd week)	End of Phase 2 (7th week)
Contents	Background information Self-esteem scale Self-efficacy scale Self-regulation scale	Self-regulation scale Experience of learning with the DQB	Self-regulation scale Experience of learning with the DQB Reflection of the learning experience
Response Rate (n = 253)	98.02% (N = 248)	91.7% (N = 232)	96.05% (N = 243)
Incomplete Response	10	21	2

Pre-test Survey. The pre-test survey was conducted at the beginning of the semester before the intervention. It was used to generate a more comprehensive understanding of participants' personal background information and prior technology experience. The pre-test survey had the following sections: (1) *background information*, (2) *self-esteem scale*, (3) *self-efficacy scale*, (4) *self-regulation scale*. *Background information* included gender, name, ID, smartphone brands, questioning behaviors in other classes, and previous experiences with technologies. *Background information* would help researchers to examine how the influence of DQB access on students differs by several factors.

First post-test survey. The first post-test survey was at the end of Phase 1 (after the first three weeks). It investigated students' *learning experience with the DQB* and *self-regulation*. The *learning experience with the DQB* included students' self-reported frequency and instances of interactions in the DQB, which targeted students' unobservable behaviors, such as *browsing* and *anonymous posts*. Some of the questions asked frequency-type Likert items, such as "During the weekly 3.5-hour lecture class, how frequently did you browse the DQB?" Some items asked the student the exact number/frequency of certain behaviors. Similar questions have also been used by Ouimet and Smallwood (2005). Using multiple items to measure the same behavior was also a way to improve the reliability of self-reported behaviors. For instance, in addition to the question "Have you ever voluntarily asked questions in the DQB in the past three weeks?" students needed also answer to two more questions: "How many questions did you ask anonymously/with your real name?" Comparing students' answers from the three questions led to more reliable and accurate self-reported data.

Second post-test survey. The second post-test survey was at the end of Phase 2 (after the experiment). This survey covered the same sections included in the first post-test survey and an addition section: the *reflection of the learning experience*, which had three open-ended questions regarding students' attitudes, opinions, beliefs, and values of the DQB uses in facilitating their learning and three Likert questions about students' attitude toward learning with the DQB. Besides, the *experience of learning with the DQB* section was expanded with more items regarding (1) *technical problem*, (2) *strategies for help-seeking*, and a section (3) *reflection of the learning experience*. *The technical problem* collected information regarding whether students met any difficulty using the technology. *Strategies of help-seeking* examined how students resolved their perplexity in previous classes. The responses to the open-ended questions were used to analyze students' cognitive and emotional engagement.

Data Validation Setup. To facilitate the later data cleaning process, before the data collection, researchers set up a series of validation criteria using Qualtrics features to make data more relevant and valid and increase the question response rate.

Request Response for Missing Data. If the respondents missed or skipped a question, the survey system asked if the respondents would like to go back and answer the skipped question before leaving the survey.

Require Responses in Specific Formats (Set up Limits). For text entry questions (open-ended questions), responses were restricted in certain ways, such as specific content type, maximum length, and character range. For instance, for some questions that asked respondents to elaborate on what "other" means, they could only input text in the textbox. In this way, only data allowed for that variable can be entered, which improved data cleaning efficiency. If respondents entered inappropriate data, the system asked them to revise or skip this question.

Logic Settings. Logic settings made the survey more customized and convenient for each respondent. It was also helpful to collect contingent responses. For instance, if students selected "no" to the question "Have you ever browsed the DQB in class during the past three weeks?" they were not asked about the specific behavior in the DQB but the reasons why they decided not to use the DQB in class. This technique was also employed in Spence and Usher's (2007) study. The logic setting benefited later contingency cleaning. Researchers double-checked the validation setups before the distribution of the survey.

Semi-structured Online Interviews

To gain a detailed understanding of participants' attitudes, opinions, feelings, and experiences, semi-structured in-depth online one-to-one interviews were conducted with twelve students after the final class. Interviews were conducted in Chinese and audiotaped or videotaped. The duration of interviews varied from 35 minutes to one hour due to the semi-structured type of questions, which was regarded as a proper length before diminishing returns set in for both parties (Glesne, 2011, p.114). The twelve student interviewees were selected through a norm-referenced cluster sampling. The participants were divided into three groups based on their questioning frequency (low, medium, high). Then a simple random sample (N = 4) of the groups was selected. As all the students in two groups had DQB access, and only differed by the length, the sampling did not differentiate groups. Each participant was personally approached and invited by the researcher through WeChat[2], with a small amount of RMB as incentives. Initially, nine invited students refused to participate in the interview, mostly because they were about to travel for summer vacations. Researchers then invited other students randomly from the same groups.

To get deep and rich responses from the interviewees, probe questions were asked as needed. Each participant replied to the same research questions, and the interviewer explored more information based on their responses. The value of this type of interview allowed for opportunities to explore areas the interviewers had not previously considered (Reinharz, 1992). Thus, during each interview, the interviewer also asked additional questions according to each participant's response. Moreover, interviewees were also encouraged to share comments that

[2] WeChat is a Chinese multi-purpose messaging, social media and mobile payment app developed by Tencent.

were not requested or covered by the interviewer and provided suggestions for up-coming students who would take this course.

The design of interview questions was based on Patton's (1990) six categories: behavior or experience questions, opinion, or value questions, feeling questions, knowledge questions, sensory questions, and background/demographic questions, which Madison (2005) considered as a tried-and-true guideline that was helpful in developing questions. The interview protocol was developed based on the literature review and feedback from two research assistants. The protocol covered a broad range of questions and included the following major sections: (1) background information, e.g., English proficiency, goal-orientation; (2) reflection and attitude towards this course; (3) opinions and attitudes regarding large lecture classes in general; (4) learning strategies such as note-taking, reviewing; (5) experience and reflection of learning with the DQB based on Welch and Bonnan-White's (2012) open-ended questions. A collection of interview questions is presented in Appendix D. Preliminary interview questions were reviewed and modified by two other researchers to ascertain that questions are intelligible. Some of the questions were excluded, and some were reviewed according to the research questions.

Observation

Observation is the process of gathering open-ended, firsthand information by observing people and places at a research site, and it enables researchers the opportunity to record information as it occurs in a setting to study actual behavior (Creswell, 2015, p. 214). To figure out how DQB access influenced the class dynamics and whether it encouraged more Q&A instances than a regular lecture class, researchers should observe the lecture with and without the intervention (following the method of Bergstrom et al., 2011). Thus, two teaching assistants observed all the classes to record face-to-face interactions between students and the instructor, focusing on student questioning instances. They were considered nonparticipant observers, as they were involved in the participants' learning activities but sat in the classroom to watch and record the phenomenon as “outsiders” (Creswell, 2015, p. 214). Both observers were female graduate students in the same university but had limited research experience. An observation protocol was developed (Appendix E), and online training was conducted before the first class to familiarize them with the observation protocol, and DQB uses. They received the lecture slides ahead of time each week so that they could refer to the content when taking notes about students’ questions and answers. During each class, the observers took field notes regarding (1) students’ face-to-face interactions, (2) discussions associated with DQB, (3) the instructor’s general pedagogy, instructional strategies, and mood. The focus of class observation was the incidence of interactions in face-to-face conditions, such as how the students asked questions and how the instructor responded to students’ questions or answers. The observation of the instructor's behavior was not used to answer the research questions but to evaluate whether the instructor provided the same instruction in two groups to enhance the fidelity.

Data Storage and Retrieval

Padlet platform automatically recorded log data throughout the semester. After the data collection, each week’s DQB data were exported as both CSV, PDF, and PNG files. Survey responses were automatically recorded in the Qualtrics system and stored in the Qualtrics cloud. After the data collection, raw response data were downloaded from Qualtrics as a CSV file. Collected data from multiple questionnaires were linked. Then the combined data were saved as new working files (CSV format). The researcher then examined the files to identify any inappropriate data that violated the limits or criteria of each variable, such as negative numbers in “frequency of questions in the DQB” or numbers beyond “0” or “1” in dichotomous variables.

Audiotape recordings were transcribed into text. Transcripts of interviews were kept in DOC files. Responses to open-ended questions and text data were exported into Excel files.

All files were then saved on researchers' computers with two copies in different drives to back up. All files were password-protected, and passwords were known only to the researchers. Files were saved on a private computer and backed up to online server folders designated for this project. After data analysis was complete, all electronic documents were archived to a flash-drive and stored in locked cabinets. Original data in Qualtrics and Padlet were deleted permanently. After five years, all raw data will be destroyed per APA recommendations, and the ID number-name file was destroyed after data collection and data cleaning.

Summary of Data Collection

Because of the complexity of engagement, each category involved multiple indicators that required different collection methods. Table 7 aligns research questions, research hypotheses with indicators, variables, and data sources.

Quantitative data from log data, surveys, and observations yielded specific numbers that can be statistically analyzed. It can produce results to assess the frequency and magnitude of trends of student questioning and behavioral engagement. The qualitative analysis from log data, surveys, interviews, provided actual words of participants, offered many different perspectives on the study topic, and provided a complex picture of the situation (Creswell, 2015). Qualitative analysis also unfolded students' reflection of how the DQB-based intervention influenced their cognitive and emotional engagement. The mixed-methods research design allowed for some degree of 'triangulation' across the data sources, enabling researchers to develop "a complex" picture of social phenomenon (Greene & Caracelli, 1997, p. 7). The next section introduces how the data were analyzed.

Table 7

Alignment of Research Questions with Data Collection Methods

Research Questions	Indicators/ Variables	Data Sources
RQ1. *Do students demonstrate different questioning behaviors when provided access to a DQB from those students who are not provided with access to a DQB in large lecture classes?*		
RH1.1. There is a difference in the frequency of questions between students with or without DQB access.	Frequency of questions	Log data, Observation
RQ1.2. What patterns of questioning are displayed when students asking questions with a DQB?	Patterns of questioning	Log data, Survey, Observation
RQ1.3. What types of questions do students ask with a DQB?	Content of questions	Log data, Observation
RQ2. *How does having access to a DQB during large lecture classes influence students' level of engagement?*		
RQ2.1. Behavioral Engagement		
RH2.1.1. There is a difference in the frequency of responses between groups with or without DQB access.	Frequency of responses	Log data, Observation
RH2.1.2. There is a difference in the frequency of interaction between groups with or without DQB access.	Frequency of interaction	Survey, Log data, Observation
RH2.1.3. There is a difference in the number of students who voluntarily browse, question and answer questions in Week 4-6 than in Week 1-3.	Numbers of students who browsed, questioned, and answered	Survey
RH2.1.4. There is a difference in the assignment completion rate between students with or without DQB access.	Assignment completion rate	Log data
RQ2.2. Cognitive Engagement		
RH2.2.1. If students are provided DQB access, there is a higher level of self-regulation at the end of the experiment controlling for self-esteem, self-efficacy, and pre-test self-regulation.	Self-regulation	Survey
RH2.2.2. There is a difference in the proportion of on-task questions between students with DQB access and ones without.	Content of DQB questions	Log data
RQ2.2.3. What types of responses do students post with DQB access, and do they facilitate interaction?	Content of DQB responses	Log data
RQ2.2.4. How does having DQB access influence cognitive engagement, as reflected in students' interviews and surveys?	Indicators of cognitive engagement	Survey, Interview

Research Questions	**Indicators/ Variables**	**Data Sources**
RQ2.3. Emotional Engagement		
RQ2.3.1. How does having DQB access influence emotional engagement as reflected in students' DQB posts, interviews, and surveys?	Indicators of emotional engagement	Log data, Survey, Interview
RQ2.3.2. What is the level of emotional engagement for most students?	Indicators of positive or negative emotional engagement	Survey
RH2.3.3. Students with 6-week DQB access had more positive attitudes than students with 3-week DQB access.	Attitudes toward the use of the DQB	Survey

Data Analysis

This section describes the data analysis methods for each of the research questions or hypotheses. As this mixed-method study involves various data sources and multiple analysis methods, they will be presented firstly by the research questions then the specific methods.

RQ1. Student Questioning

RH1.1. Frequency of Questions. Two types of frequency data were summed to test the hypothesis that *there is a difference in the frequency of questions between students with or without DQB access*: (1) computer-recorded frequency of questions posted in the DQB and (2) oral questions observed and recorded by the observers. As the Padlet platform did not allow researchers to trace back the author of each anonymous post, the unit of analysis was class rather than individual student. Due to the nonparametric data type, the Mann-Whitney U test compared the average difference of questions between groups in Phase 1, and between phases in the comparative group.

RQ1.2. Student Questioning Pattern. To investigate RQ1.2. "*What patterns of questioning are displayed when students asked questions with and without a DQB?*" the descriptive analysis presented *how students used the DQB*, *how students decided to browse the DQB*, and *how students resolved their problems*.

RQ1.3. Types of Student Questions. To examine RQ1.3.*: "What types of questions do students ask with a DQB?*" the *content of questions* was analyzed through content analysis based on a coding framework developed by the researcher. This framework was adapted from Zhu's (2006) Analytical Framework for Cognitive Engagement in Discussion, Newman's (1994) classification of adaptive and non-adaptive help-seeking, Guo et al.'s (2014) cognitive coding schemes, and Veerman and Veldhuis-Diermanse's (2001) discourse analysis coding scheme. The analysis was related to a specific context. For instance, the time of each post that automatically recorded in the DQB helped identify whether each question was deliberately proposed based on the lecture content.

DQB questions were firstly categorized as on-task and off-task questions as the main categories. According to the revised Bloom's Taxonomy, on-task questions were further divided into six types of questions, ranging from the remembering to the creating. Within the off-task category, questions were further divided into (1) peripheral and (2) irrelevant questions. Peripheral questions were not closely related to the lecture content. However, they facilitated learning in the lecture classes. It contained questions about the exam, instructional materials, lecture instruction, and assignment. On the other hand, irrelevant questions included questions that were closely related to neither the lecture content nor facilitated learning in large lecture classes. Some of the questions were unrelated questions, questions about the class arrangement. Table 11 in Chapter 4 provides examples for each of the coding categories and examples of questions.

RQ2. Student Engagement

RQ2.1. Behavioral Engagement. To answer RQ2.1.: *"How does having DQB access influence behavioral engagement?"* four hypotheses were tested.

RH2.1.1. *There is a difference in the frequency of responses between students with or without DQB access.* Like the analysis of student questioning frequency, to test the hypothesis, the unit of analysis was class. Due to the nonparametric data type, the Mann-Whitney U test compared the average difference of responses between groups in Phase 1. Another Mann-Whitney U test compared the difference of responses between two phases in the comparative group.

RH2.1.2. *There is a difference in the frequency of responses between students with or without DQB access.* Firstly, a five-point Likert question in the pre-test survey collected students' self-reported frequency of interaction in other classes. This variable helped show the difference in self-reported weekly interaction between groups before the experiment. The Kruskal-Wallis H test compared the difference. Secondly, to test the hypothesis, the unit of analysis was class. The frequency of interaction included both students' questioning and responding. Thus, students' frequency of oral or the DQB-based questioning and responding were summed into a new variable, "interaction." Due to the nonparametric data type, the Mann-Whitney U test compared the average difference of interaction between the experimental group and the comparative group in Phase 1. Another Mann-Whitney U test compared the average difference of interaction between Phase 1 and Phase 2 in the comparative group.

RH2.1.3. *There is a difference in the number of students who voluntarily browse, question and answer questions between Week 4-6 and Week 1-3.* This hypothesis investigated whether DQB access encouraged *a broader range of students* to either browse or interact. Thus, the numbers of students in the experimental group who browsed, questioned, and answered were compared between the two phases. Due to the matched-group nature of the test, Wilcoxon signed-rank tests were used.

RH2.1.4. This hypothesis tests whether *there is a difference in the assignment completion rate between students with or without DQB access*. It compared individual students' phase-average *assignment completion rates* between groups in two phases. Because of the nonparametric type of variable, the comparison was made using the Mann-Whitney U test.

RQ2.2. Cognitive Engagement. To answer RQ2.2.*: "How does having DQB access influence cognitive engagement?"* both quantitative and qualitative methods were involved. Two sub-hypotheses and two sub-questions were proposed.

RH2.2.1**.** This hypothesis assumes that *if students are provided DQB access, there is a higher level of self-regulation at the end of the experiment controlling for self-esteem, self-efficacy, and pre-test self-regulation.* Each student's total score of *self-regulation* was summed from ten items. After the normality check, multiple regression was conducted to examine the possible influence of DQB access on students' self-regulation, controlling for self-esteem, self-efficacy, and the natural growth of students' self-regulation. The inclusion of "*Group"* as a controlling variable helped show whether the influence differed by groups, suggesting the difference of influence between six weeks and three weeks. The inclusion of "*whether students browsed the DQB voluntarily"* as a controlling variable helped show whether the influence differed by students' uses.

RH2.2.2. The second hypothesis assumes *there is a difference in the proportion of on-task questions between students with DQB access and ones without.* To measure DQB posts regarding how they were related to the lecture content and how they facilitated learning, the researcher analyzed the content of the questions through a content analysis based on a coding framework developed by the researcher, as was introduced in the analysis for student questioning. The distribution of on-task questions indicated students' cognitive engagement. Therefore, descriptive analyses and chi-square tests were used to map out whether there was a significant difference in the distribution of on-task questions between groups after Phase 1 and Phase 2, respectively. Comparison in Phase 1 showed the difference of influence between the shorter and longer presence of the DQB.

RQ2.2.3. The third sub-question investigates *what types of responses students post with DQB access, and whether they facilitate interaction.* As the cognitive engagement was also reflected in the students' responses, the *content of responses* was analyzed through exploratory content analysis. Table 18 in Chapter 4 provides examples for each of the coding categories and examples of responses.

RQ2.2.4. Lastly, the fourth sub-question examines *how DQB access influences cognitive engagement, as reflected in students' interviews and surveys.* Interview transcripts and responses to open-ended questions from surveys were examined exploratively to identify cognitive engagement indicators during their learning experiences with the DQB.

RQ2.3. Emotional Engagement. The influence of the DQB-based intervention on students' emotional engagement was mostly analyzed qualitative analysis, exploratorily. To answer **RQ2.3.:** *"How does having DQB access influence emotional engagement?*" One hypothesis and two sub-questions were proposed.

RQ2.3.1. This sub-question investigates *how DQB access influences emotional engagement as having reflected in students' DQB posts, interviews, and surveys.* The *content of DQB posts* was analyzed through exploratory content analysis. Typical cases were presented to illustrate the trend. Interview transcripts and responses to open-ended questions from surveys were examined exploratively to elaborate on students' *emotional engagement indicators* during their learning experiences with the DQB. In addition to examining overlapping themes in the open-ended data and interviews, the number of themes, or the number of times the participants mentioned themes were also analyzed (Creswell, 2015). The researchers coded themes with a coding scheme synthesized and adopted from earlier researchers (Harunasari & Halim, 2019; Kay & Knaack, 2009; Paulus et al., 2006; Welch & Bonnan-White, 2012; Yang, 2011). The framework developed as more themes emerged along with the analysis. Then a finalized coding scheme was shown in Chapter 4.

RQ2.3.2. This question examines *the level of emotional engagement for most students*. In addition to coding students' responses into different themes, two coders respectively rated students' responses on a five-point Likert scale (-2 = very negative, -1 = negative, 0 = neutral, 1 = positive, 2 = very positive). This process helped quantify qualitative data to illustrate most students' overall emotional engagement.

RH2.3.3. The hypothesis tests whether *students with 6-week DQB access had more positive attitudes than students with 3-week DQB access*. In the post-test survey, three Likert questions asked students' attitudes toward the DQB uses, including satisfaction of the overall learning experience with the presence of the DQB, perceived usefulness of the DQB in facilitating learning, and perceived effectiveness of browsing. T-tests were used to examine whether students between groups had a statistically different level of positive emotion regarding the DQB uses in facilitating their learning.

Data Analysis Methods

Qualitative Analysis. The qualitative analysis was done using MAXQDA, a software program designed for computer-assisted qualitative and mixed methods data. To ensure inter-rater reliability, the two coders (a doctoral student and a post-doc researcher analyzed) all the DQB posts, all responses to open-ended survey questions, and 30% interview transcripts. Both coders were Chinese native speakers, majored in education, and were familiar with the study context. They were trained in using the coding scheme and received financial compensation for their work.

The content analysis of DQB questions was conducted using the coding scheme developed by the researchers. Two coders coded the data, respectively. When there was a difference between the coders, e.g., where categories or ratings were not the same, the coding was shared and reviewed a second time by each rater. Next, researchers met and discussed the differences until achieving agreement: to reach inter-rater reliability of 99% for categories and 100% for the rating values (e.g., Kay & Knaack, 2009).

For exploratory analysis of DQB posts, this study followed previous researchers' method: to collate data first and study the emerging themes to approach engagement inductively (e.g., Bangert-Drowns & Pyke, 2001; Paulus et al., 2006; Welch & Bonnan-White, 2012; Yang, 2011). Two coders summarized themes identified from DQB responses inductively. Next, researchers met and discussed the differences until they reached an agreement and classified them into different categories to form a coding scheme. The coding scheme for the exploratory analysis of DQB posts was finalized after the analysis was done. The detailed coding schemes are explained in Chapter 4.

For the qualitative analysis using interview transcripts and open-ended questions from surveys, the coding procedure included six major steps as recommended by Creswell (2015, p. 244): (1) To obtain a general idea, the researcher read each transcription several times and wrote some memos as ideas came to mind. (2) Two transcriptions were randomly selected and further analyzed by two coders, respectively, to get a more specific idea. (3) Two coders started to code the two documents, identifying words and phrases that described the underlying meaning of text segments and labeling the segments with codes. (4) Codes from the two documents were listed, grouped, and reduced to manageable numbers. (5) The researcher then used the list to code the rest transcriptions and modified the list whenever new codes emerged. (6) After all the codes were determined, similar codes were aggregated/collapsed into themes to get the main idea. Then the coding scheme was developed accordingly.

Quantitative Analysis. The quantitative analysis was done using SPSS. In SPSS, an examination was first done for any violations of contingency. For example, if one respondent selected "No" to the question "Have you ever browsed the DQB voluntarily?" but entered an exact number to the question "How many questions have you asked in the DQB?" then the data would not be included in the data analysis. Next, reversed-coded items were recoded. Multiple *factor analyses* were conducted to investigate instruments' validity, including the self-esteem scale, self-efficacy scale, and self-regulation scale. The total scores of each of the scales were summed up from contingent variables.

Then *univariate descriptive analyses* were done, including frequency distributions and measures of central tendency (mean, median, and mode), dispersion (range, variance, and standard deviation), the shape of the distribution (skewness and kurtosis), depending on the levels of measurements for major variables. This process checked the normality of ratio data and identified any outliers. During this stage, some of the data were collapsed together to make descriptive data more explicit or comparable.

To reveal the possible associations between independent variables, dependent variables, background/controlling variables (such as self-esteem), *bivariate, and multivariate analyses* such as correlational analysis were done next. In this stage, cross-tabulations, contingency tables, and scatterplots were made to illustrate the relationship between pairs of variables. According to the descriptive analysis results, the appropriate method for inferential analysis was decided, e.g., nonparametric, or parametric, to answer proposed research questions.

Summary of Data Analysis

Both quantitative analysis and qualitative analysis were conducted to answer the research questions and examine the research hypotheses. Table 8 on the next page illustrates the variable, data source, unit of analysis, level of measurement, and analysis methods. Specifically, quantitative data analysis examined the pattern of student questioning and behavioral engagement. Qualitative data analysis involved identifying different data themes and coding all data accordingly (Miles & Huberman, 1984). It was useful for generating an in-depth understanding of students' cognitive and emotional engagement. The next chapter presents the results.

Table 8

Data Analysis Overview

RQ(s)/ RH(s)	Indicators/ variables	Data source	Unit of analysis	Levels of measurement	Analysis method(s)
RQ1. Student Questioning					
RH1.1	Frequency of questions	Log data, Observation	Class	Ratio	Mann-Whitney U
RQ1.2	Student questioning pattern	Log data, Survey, Observation	Class/ Individual	Nominal	Descriptive analysis
RQ1.3	Types of student questions	Log data, Observation	Class	Text	Content analysis
RQ2. Student Engagement					
RQ2.1. Behavioral Engagement					
RH2.1.1	Frequency of responses	Log data, Observation	Class	Ratio	Mann-Whitney U
RH2.1.2	Frequency of interaction	Log data, Observation, Survey	Class	Ratio/ Ordinal	Mann-Whitney U/ Kruskal Wallis H
RH2.1.3	Number of students who browsed, questioned, and answered	Survey	Class	Ratio	Wilcoxon signed-rank test
RH2.1.4	Assignment completion rate	Log data	Individual	Ratio	Mann-Whitney U
RQ2.2. Cognitive Engagement					
RH2.2.1	Self-regulation	Survey	Individual	Ratio	Regression
RH2.2.2	On-task questions	Log data	Class	Text	Content analysis/ Chi-Square test
RQ2.2.3	DQB responses	Log data	Class	Text	Content analysis
RQ2.2.4	Indicators of cognitive engagement	Survey, interview	Individual	Text	Qualitative analysis
RQ2.3. Emotional Engagement					
RQ2.3.1	Content of DQB posts	Log data	Class	Text	Content analysis
	Indicators of emotional engagement	Survey, interview	Individual	Text	Qualitative analysis
RQ2.3.2	Indicators of emotional engagement	Survey	Individual	Text	Qualitative/ Descriptive analysis
RQ2.3.3	Attitudes toward the use of the DQB	Survey	Individual	Ratio	T-test

Chapter 4: Findings

This chapter discusses the main results from data analysis that address two major research questions: (1) Do students demonstrate different questioning behaviors when provided access to a DQB from those students who are not provided with access to a DQB in large lecture classes? (2) How does having access to a DQB during large lecture classes influence students' level of engagement?

The pre-post quasi-experiment lasted for six weeks. The instructor discussed questions after every 20-30 minutes in both groups. In Phase 1, only students in the experiment group had DQB access. In Phase 2, students in both groups had DQB access. As multiple analysis methods were used to answer each research question, findings are arranged and presented based on each research question in this chapter.

RQ1: Student Questioning Behaviors

This section presents results from the quantitative analysis and content analysis of students' DQB posts and self-reported surveys. The data and subsequent analysis answered the research question RQ1: "Do students demonstrate different questioning behaviors when provided access to a DQB from those students who are not provided with access to a DQB in large lecture classes?" This research question has one sub-hypothesis and two sub-questions.

- RH1.1. There is a difference in the frequency of questions between groups with or without DQB access.
- RQ1.2. What patterns of questioning are displayed when students ask questions with a DQB?
- RQ1.3. What types of questions do students ask with a DQB?

RH1.1: Higher Frequency of Student Questions in the Group with DQB Access

Results confirmed RH1.1 that there was a difference in the frequency of questions between groups with or without DQB access. Altogether, there were 304 initial DQB questions throughout the six weeks, and then 20 questions in the final week (the week after the experiment). Table 9 shows the frequency of questions between groups by phases, including both oral questions and questions recorded in the DQB. At the end of Phase 1, students in the experimental group altogether asked around three times more questions as compared to the comparative group. This finding was consistent with Pohl et al.'s (2012) study.

Table 9

Frequency of Questions between Groups in Two Phases

Phase	Group	Week			Total	*Mean Rank*	*U*	*Z*	*r*
		W1	W2	W3					
1	Experimental (DQB)	38	40	26	104	84.5	0**	-8.79**	.75
	Comparative (No DQB)	11	15	6	32	16.5			
		W4	W5	W6					
2	Experimental (DQB)	24	8	12	44	38.32	696**	-7.93**	.61
	E-Comparative (DQB)	83	17	24	124	100.89			

** $p < .01$

Note. For clarification, the comparative group in Phase 2 was named "E-comparative group" to indicate that it also had DQB access for Q&A from Week 4 to Week 6.

A Mann-Whitney test indicated that across three weeks, the number of questions in the experimental group was greater than that in the comparative group ($U = 0$, $p < .01$). According to Fritz et al. (2011), the effect size can be calculated by dividing the absolute (positive) standardized test statistic *Z* by the square root of the number of pairs (Equation 1).

$$r = \frac{Z}{\sqrt{N}} \qquad (1)$$

Here, the effect size is 0.75, which is a large effect according to Cohen's classification of effect sizes, which is: 0.1 (small effect), 0.3 (moderate effect), and 0.5 and above (large effect).

When students in the E-comparative group started to use the DQB in Phase 2, they posted significantly more questions than they did in Phase 1 ($U = 0$, $p < .01$), with a large effect size ($r = .76$). As Table 9 shows, the frequency of E-comparative group questions also overweighed that in the experimental group ($U = 696$, $p < .01$), with a large effect size. Results suggested that: there was a difference in the frequency of questions before and after the presence of the DQB.

Results confirmed RH1.1 that there was a difference in the frequency of questions between groups with or without DQB access. Within three weeks, there was a higher frequency of questions in the group with DQB access than the group without DQB access. In other words, compared to regular large lecture classes, students had a higher frequency of questioning when a DQB was provided.

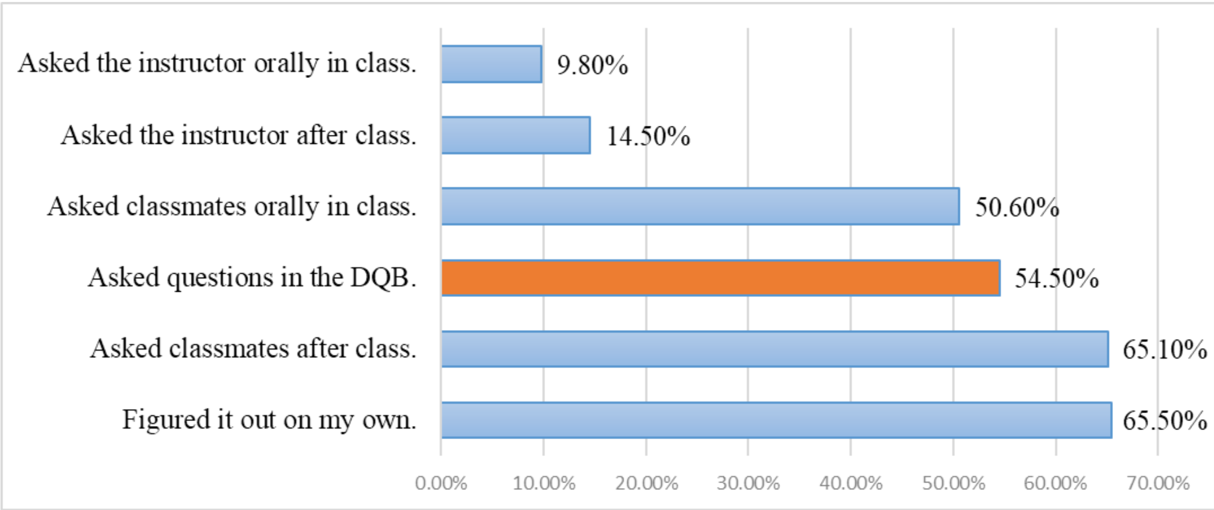
RQ1.2: Patterns of Student Questioning

The analyses of student questioning patterns included three aspects: students' preference for help-seeking strategies, questioning conditions, and browsing behaviors.

Help-seeking Strategies. As Figure 8 shows, students reflected in surveys that they employed various strategies to seek help when they encountered questions. More than half of all students preferred to figure it out themselves or asked classmates after class. Using the DQB ranked the third place as students' preferred way of seeking help. Less than one-tenth of students asked the instructor orally in class.

Figure 8

Students' Preferred Ways of Seeking Help, N = 253

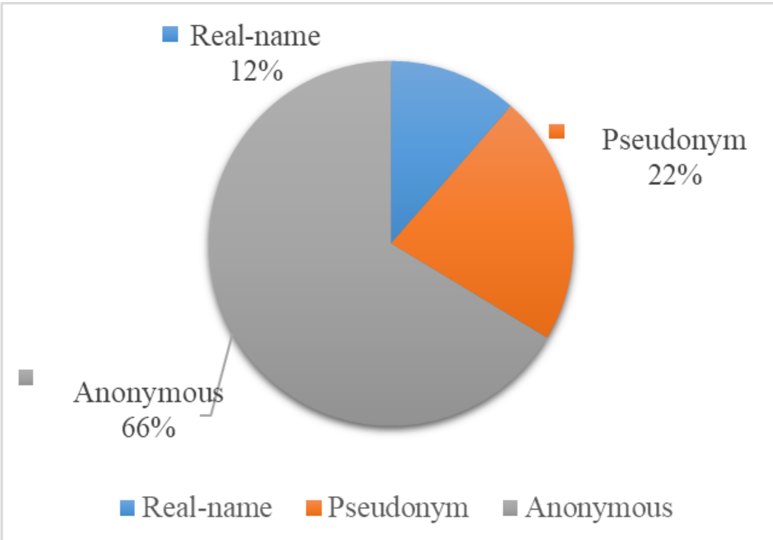


Note. Students answered to the question "When you encountered perplexity in class, what did you do to resolve your problem/confusion (check all that apply)?"

Conditions of Student Questioning. The majority (97.2%) of questions were asked in class, while nine were posted after class. As Figure 9 shows, most DQB questions were anonymous or with pseudonyms. Very few questions were identified. Students asked more questions in anonymous conditions.

Figure 9

Distribution of Questions by Conditions, N = 324



Browsing Behaviors. As shown in Table 10, most students browsed the DQB two to five times during the weekly lectures. Around one quarter of all students only browsed the DQB during the Q&A session. In Phase 2, the average class frequency of browsing was not significantly different between the two groups (t (64) = 1.94, p = .06).

Table 10 *Frequency of Students' Voluntary Browsing of the DQB during Weekly Class*

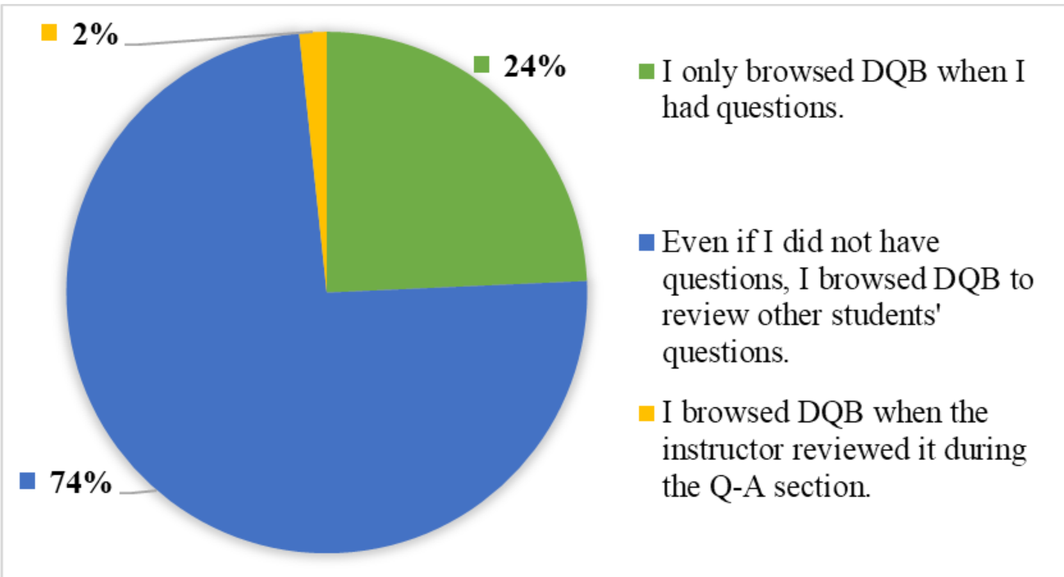
Phase	Group	Frequency of Browsing						*n*	Missing
		0	**≦ 1**	**2 ~ 3**	**4 ~ 5**	**6 ~ 7**	**≧ 8**		
1	**Experimental (DQB)**	2 24.8%	3 3.0%	31 30.7%	26 25.7%	13 12.9%	3 3.0%	101	16
2	**Experimental (DQB)**	26 23.4%	5 4.5%	45 40.5%	23 20.7%	11 9.9%	1 0%	111	6
2	**E-comparative (DQB)**	39 29.8%	5 3.8%	50 38.2%	30 22.9%	6 4.6%	1 0.8%	131	5

Note. Students who did not voluntarily browse the DQB during lectures, also browsed it during Q&A sessions when the instructor displayed the DQB.

As Figure 10 illustrates, in the post-test survey, when asked about "How did you browse the DQB?" less than one-quarter of them browsed it only when they had questions. Only 2% of all students browsed the DQB only when the instructor reviewed it during Q&A sessions. Instead, most students browsed the DQB to see what questions other students posed, even if they did not have questions.

Figure 10

How Did Students Decide to Browse the DQB (N = 177)?



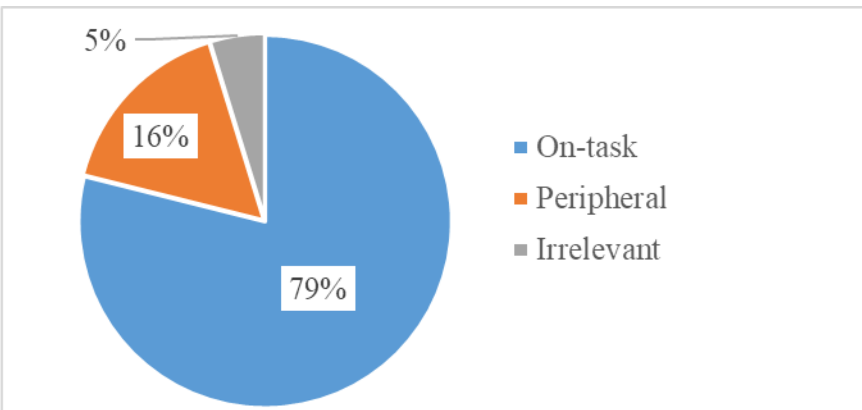
To summarize, this section presents descriptive analyses of students' questioning patterns to answer RQ1.2. In general, students used a variety of strategies to solve questions, among which using the DQB ranked the third. They asked most questions in anonymous conditions. Most of the students voluntarily browsed the DQB two to five times in a weekly class. They browsed the DQB to see other students' questions even if they did not have questions in mind. These findings will be incorporated and discussed in the next section to explain students' engagement.

RQ1.3: Enriched Student Questions and Dominant On-task Questions with DQB Access

Altogether, there were 457 posts in the DQB, among which 324 were initial questions, and 133 were responses. Content analysis showed that among 324 initial questions, 25 were incomplete posts, and five were social comments; therefore, they were excluded from the further content analysis of DQB questions. The remaining 294 initial questions were classified into three major types: on-task questions, peripheral questions, and irrelevant questions. Figure 11 illustrates the overall distribution of student questions throughout the experiment. Regardless of groups and phases, students asked mostly on-task questions in the DQB, then followed by peripheral questions and only a few irrelevant questions.

Figure 11

Distribution of All Student Questions, N = 294



On-task Questions

Table 11 presents the cognitive coding scheme for student questions and examples of each type of questions. On-task questions were further coded into five levels based on the revised Bloom's Taxonomy. As Figure 12 shows, among 232 on-task questions, the majority were about "understand," which were lower-level thinking questions, according to the revised Bloom's Taxonomy (Anderson & Krathwohl, 2001; Bloom, 1956). There were 7% of questions about "analyze," 6% of questions about "remember," 4% of questions about "apply," and 2% about "evaluate." There was no "create" question in the DQB throughout the semester.

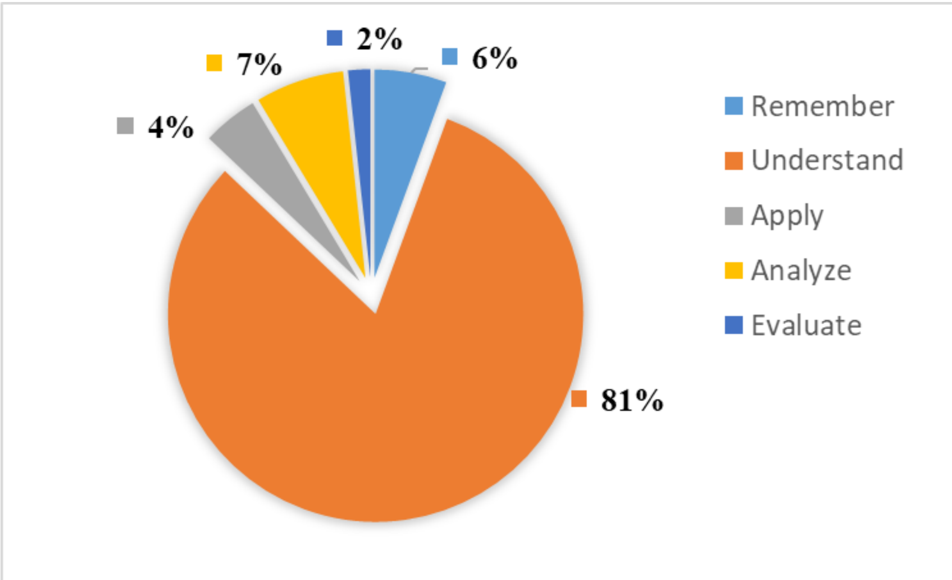
Table 11

Cognitive Coding Scheme for Student Questions

Category	Descriptions	Examples
On-task (Revised Bloom's Taxonomy)		
-Remember	Request retrieve relevant knowledge from long-term memory.	*"What does A stand for and B stand for?"*
-Understand	Request construct meaning from instructional messages, including oral, written, and graphic communication.	*"What is the difference between a sample population and a sample? Is the sample a person?"*
-Apply	Request carry out or use a procedure in a given situation.	*"How to use the deductive method to conclude the opinion of national security?"*
-Analyze	Request break material into its constituent parts and determine how the parts relate to one another and an overall structure or purpose.	*"For the alternative[1] intervention (time sequence disordered), how to determine which intervention is more effective?"*
-Evaluate	Request make judgments based on criteria and standards.	*"Regarding the interactive intervention (time sequence disruption), how can we evaluate which intervention method is more effective?"*
-Create	Ask to put elements together to form a coherent or functional whole; reorganizing elements into a new pattern or structure.	None
Peripheral		
-Exam	Ask about exams/grading.	*"When will be the midterm exam?"*
-Instructional materials	Ask about instructional materials, such as PPT.	*"May I have the PPT in advance?"*
-Lecture	Ask about the lecture style or instructional strategies.	*"Could you please talk slowly?"*
-Assignment	Ask about the assignment.	*"What is the homework for tonight?"*
Irrelevant		
-Unrelated	Questions or statements that were not related to the lecture content.	
-Arrangement	Ask about the class arrangement.	*"When is our next class?"*
-Technical	Ask about technical problems.	*"How to change color?"*

Figure 12

Types of On-task Questions Based on the Revised Bloom's Taxonomy, n = 232



Peripheral Questions

With a Kappa value of 0.71, the 62 off-task questions were further classified into peripheral questions and irrelevant questions. Peripheral questions (n = 48) were defined as questions that closely facilitated students' learning but not directly related to the content about which the professor was lecturing.

There were many questions about the instructor's lecture style and instructional design. Students directly reflected on the instruction they were receiving and provided suggestions to make it more effective. Some students asked about the pace of the lecture, such as "Professor, can you slow down the lecture as a whole...especially when you talk about concepts/new things" (Anonymous, Experimental group, Week 2). One student was concerned about the terms the instructor used, "Professor…you constantly change the terms, which even confused yourself, and it is easy for students to get confused. Maybe this is the drawback of switching between Chinese and English ba[3]" (Anonymous, Experimental group, Week 2). Some students provided suggestions regarding specific instructional strategies, such as "At the end of a class, could you organize the content frame of this lesson and provide a mind map" (Anonymous, E-comparative group, Week 5) and "Could you read the title before you talk about PPT? QAQ" (Anonymous, E-comparative group, Week 6). Those questions were not asking specific knowledge points but requested or suggested ways for the instructor to modify the instruction to better fit students' needs.

Similarly, students asked questions regarding instructional materials. Most questions were requesting the courseware, i.e., PPT, such as "Professor, can you send us PPT before each class" (Pseudonym, Experimental group, Week 2), and "The PPT sent in WeChat is too brief…I want the detailed English version" (Anonymous, E-comparative group, Week 6). Some questions suggested modifications of the courseware, such as, "Professor, can you mark important concepts in Chinese in the future? Sometimes it does not correspond... There is not enough time to write down both Chinese and English when taking notes" (Anonymous, Experimental group, Week 2), and "I beg you to send Chinese PPT, English-Zha[4] is going to die 😇" (Anonymous, E-comparative group, Week 4).

Although requesting instructional materials might not seem directly relevant to the lecture, it might influence students' learning strategies in class as one student mentioned that s/he did not have enough time to take notes. S/he thought if the instructor ensured students that he would provide them with the PPT in advance next time, students might be more comfortable listening to the lecture instead of being busy taking notes. The question about an unclear PPT

[3] "ba" is a word that indicates an interrogative tone in this sentence.
[4] Here "English-Zha" means a person/student whose English proficiency is low.

slide also contributed to students' learning, as the instructor could easily solve this problem promptly so that the student could then continue learning rather than being lost.

There were also many questions about the examination, especially near the end of the semester. Most were about the scope of the exam, i.e., what will be assessed in the exam. For instance: "Chapters without homework will not be included in the exam, am I right (^-^)" (Anonymous, Experimental group, Week 4), "What is the content scope of the mid-term exam? ❤️❤️❤️" (Anonymous, E-comparative group, Week 4), "Is there an overlap between the mid-term exam and final exam?" (Student XW, E-comparative group, Week 4). There were also questions about the format of the test and the types of questions it included, "Are there all multiple-choice questions? No open-ended questions?" (Anonymous, E-comparative group, Week 4); "Could you please explain the numbers and types of questions in the final exam?" (Anonymous, E-comparative group, Week 4). Besides, some students also asked about the procedure or arrangement issues, such as the time and location of the final exam, what would happen if somebody failed the exam and what percentage did the final exam account for the total grades. Moreover, there was also an increasing number of questions requesting instructional materials used for the exam in the final week (the week after the 6-week experiment). Some students requested a mock-test or item banks before the final exam. Other students asked for a Chinese version of the instructional materials so that they could prepare the final exam better.

Exam questions were not directly related to the content covered in class; however, they indicated that students cared about their performances and were willing to prepare for the exam. Those questions also helped some grade-oriented students to set up appropriate learning objectives. Thus, those questions also indicated their cognitive engagement.

In summary, peripheral questions rarely occurred in face-to-face conditions when the instructor was lecturing. With the DQB, students were able to provide the instructor with immediate feedback about the teaching and learning process so that the instructor could modify accordingly. Therefore, although peripheral questions were not regarded as "on-task," they suggested that students reflected on the "what" and "how" they learned. In this way, peripheral questions indicated students' effortful and purposeful learning; in other words, it indicated cognitive engagement.

Irrelevant Questions

There were altogether 14 irrelevant questions, which occupied only 4.76% of all valid questions. It could be considered quite a small portion, as some researchers found off-task questions sufficiently prominent (Bergstrom et al., 2011). Unlike peripheral questions that were closely related to the instruction, irrelevant questions were considered more suitable to be dealt with after class. That delayed reply would not likely influence the learning experience in class. For instance, some questions were about the class arrangement, such as:

> How many classes do we have this semester (Anonymous, Experimental group, Week 1)?
>
> Professor, could we take more breaks? It is so easy to be sleepy at eight in the morning (Pseudonym, Experimental group, Week 2).
>
> What time is the first-class break (Anonymous question, Comparative group, Week 4)?

Some questions asked about technical problems such as requesting a link to download the app and how to change color. Those questions were not considered peripheral questions because they did not deal with time-sensitive technical issues that would hinder students from learning in lecture classes. Otherwise, technical questions could also be classified as peripheral questions if they targeted urgent issues that might influence the lecture and learning in class. For instance, a question asked about a typo in the instructor's PowerPoint in the pilot study. The student uploaded a screenshot of that slide as an attachment. This question could be considered a peripheral question rather than an irrelevant question as it provided immediate feedback about the instruction to the instructor.

Besides, there were also unrelated questions where the purpose was to initiate discussions. However, those questions were not related to the lecture content, such as, "Professor, what opinions do you have regarding the 5G technology" (Anonymous, E-comparative group, Week 5), or "Professor, what is your opinion about the Sino-US trade war" (Anonymous, E-comparative group, Week 5). Those horizontal questions were considered irrelevant as they might distract the instructor or students from the content that was being covered. To sum up, unlike peripheral questions that were time-sensitive and closely related to the way students learned, irrelevant questions did not require a timely response. In other words, to solve those irrelevant questions after class might not influence students' learning in lecture classes.

In short, results from the content analysis of DQB questions answered the RQ1.3 and suggested that the presence of the DQB enriched the types of questions students asked during large lecture classes, and most of them were on-task questions that facilitated learning.

Summary to RQ1

This section presents results to the research question RQ1 and one sub-hypothesis and two sub-questions. Results showed that, when the instructor discussed student questions at intervals in large lecture classes, students demonstrated different questioning behaviors when provided access to a DQB from those who were not provided with access to a DQB. The presence of a DQB improved student questioning.

RQ2: Student Engagement

Below three sections present results toward answering the research question RQ2: "*How does having access to a DQB during large lecture classes influence students' level of engagement?*" This research question is further broken into three sub-questions:

- RQ2.1. How does having DQB access influence behavioral engagement?
- RQ2.2. How does having DQB access influence cognitive engagement?
- RQ2.3. How does having DQB access influence emotional engagement?

RQ2.1: Having DQB Access Improved Behavioral Engagement

This section presents results from the quantitative analysis of students' DQB posts and self-reported surveys in response to RQ2.1: "How does having DQB access influence behavioral engagement?" This research has four sub-hypotheses.

- RH2.1.1. There is a difference in the frequency of responses between groups with or without DQB access.
- RH2.1.2. There is a difference in the frequency of interaction between groups with or without DQB access.
- RH2.1.3. There is a difference in the number of students who voluntarily browse, question, and answer questions between Week 4-6 and Week 1-3.
- RH2.1.4. There is a difference in the assignment completion rate between students with or without the DQB.

RH2.1.1. Higher Frequency of Responses in the Group with DQB Access. The previous section shows that students asked significantly more questions with DQB access. As for DQB responses, 10 were in the week after the experiment. Table 12 shows the frequency of responses between groups in two phases, including both oral responses and responses recorded in the DQB. A Mann-Whitney test indicated that across three weeks, the number of responses in the experimental group was greater than that in the comparative group (*U* = 0, $p < .05$), with a moderate effect size (*r* = .42), suggesting the group with DQB access had a significantly higher frequency of responses than the group without DQB access.

When students in the E-comparative group had DQB access in Phase 2, they posted significantly more responses than students in the experimental group (*U* = 36, $p < .01$), with a large effect size (*r* = .72). Responses in the E-comparative group in Phase 2 also overweighed the comparative group in Phase 1 (*U* = 2.0, $p < .01$), with a moderate effect size (*r* = .32), suggesting the group with 3-week DQB access had a higher frequency of responses than they did before.

Table 12

Frequency of Responses between Groups in Two Phases

Phase	Group	Week			Total	Mean Rank	*U*	*Z*	*r*
		W1	W2	W3					
1	Experimental (DQB)	19	6	11	36	20.5	0*	-2.56*	.42
	Comparative (No DQB)	0	0	2	2	1.5			
		W4	W5	W6					
2	Experimental (DQB)	10	1	8	19	11.59	36**	-6.63**	.72
	E-comparative (DQB)	37	27	2	66	51.95			

** $p < .01$; * $p < .05$.

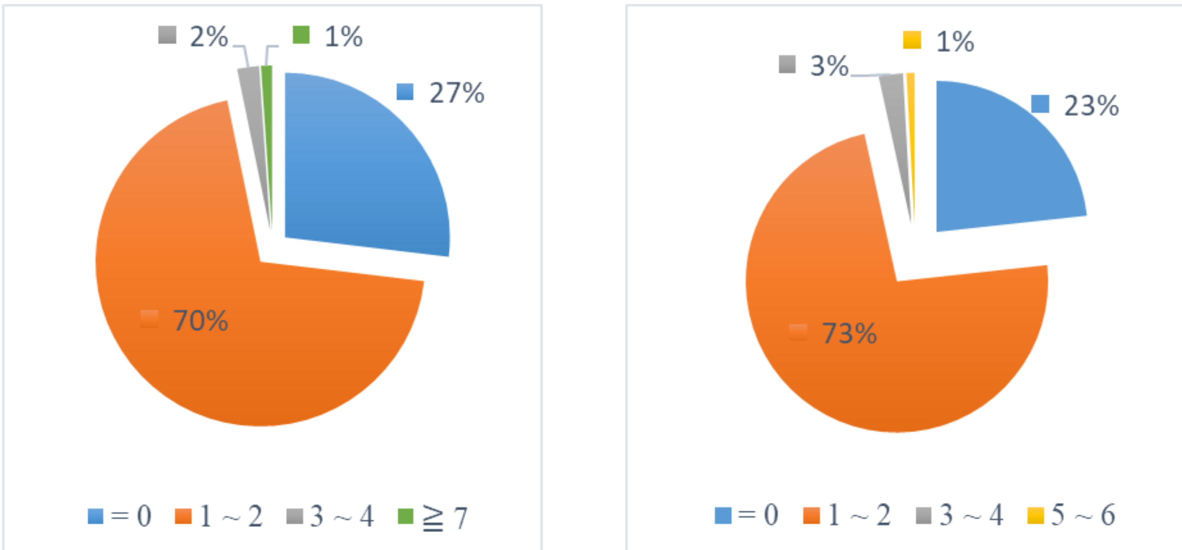
The RH2.1.1 was confirmed that within three weeks, there was a higher frequency of responses in the group with DQB access than the group without DQB access.

RH2.1.2. Higher Frequency of Interaction in the Group with DQB Access. As Figure 13 shows, in the pre-test survey, a five-point Likert question collected students' self-reported frequency of interaction in other classes (1 = 0 time, 2 = 1 ~ 2 times, 3 = 3 ~ 4 times, 4 = 5 ~ 6 times, 5 = 7 times and above). A Kruskal-Wallis H test suggested there was no significant difference in the interaction frequency between groups in the pre-test ($\chi^2(1) = .331$, $p = .565$);

students in the experimental group interacted slightly less frequently than students in the comparative group.

Figure 13

Students' Self-reported Frequency of Weekly Interactions in Other Classes



Experimental Group **Comparative Group**

To test RH2.1.2 regarding the difference of interaction between students with or without the DQB, questions, and answers were summed to form a new variable, "interaction." Table 13 illustrates the observed number of questions asked and answered by students between groups. Altogether there were 174 interactions in Phase 1. According to a Mann-Whitney test, across three weeks, students in the experimental group had significantly higher instances of questioning and answering than students in the comparative group ($U = 0$, $p < .01$), with a large effect size ($r = .7$), suggesting within three weeks, there was a higher frequency of interaction in the group with DQB access than the group without DQB access.

Table 13

Frequency of Interactions between Groups in Two Phases

Phase	Group	Week			Total	Mean Rank	*U*	*Z*	*r*
		W1	W2	W3					
1	Experimental (DQB)	57	46	37	140	104.5	0**	-9.34	.70
	Comparative (No DQB)	11	15	8	34	17.5			
		W4	W5	W6					
2	Experimental (DQB)	34	9	20	63	46.03	884**	-10.78	.68
	E-comparative (DQB)	120	44	26	190	153.85			

** $p < .01$; * $p < .05$.

When students in the E-comparative group had DQB access in Phase 2, they interacted significantly more than students in the Experimental group ($U = 884$, $P < .01$, $r = .68$), and more than themselves in Phase 1 with a large effect size ($U = 0$, $p < .01$, $r = .68$).

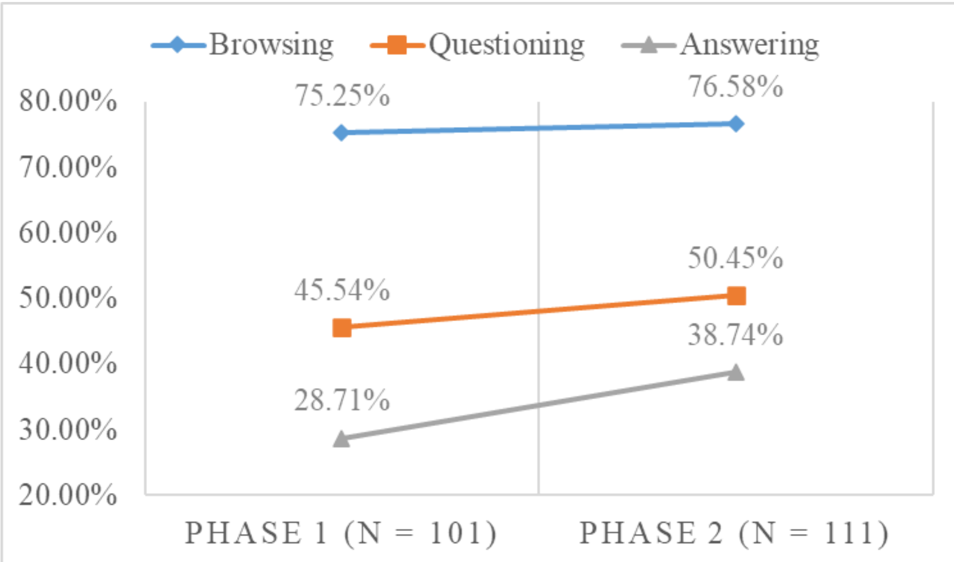
Results confirmed the RH2.1.3. that within three weeks, there was a higher frequency of interaction in the group with DQB access than the group without DQB access.

RH2.1.3. More Students Voluntarily Questioned and Answered in Week 4-6. The Wilcoxon signed-rank test partly confirmed the RH2.1.3 that there was a difference in the number of students who voluntarily questioned and answered in the DQB in Week 4-6 than in Week 1-3. The hypothesis that DQB access encouraged more students to browse the DQB was not significant.

In Week 3 (post-test of Phase 1) and Week 6 (post-test of Phase 2), students in the experimental group were asked about whether they had voluntarily browsed, asked, or answered questions in the DQB in the past three weeks. The comparison was made between two experimental phases, suggesting the difference was due to the continued presence of the DQB.

Figure 14

Students' Self-reported Behaviors in the DQB in the Experimental Group between Phases



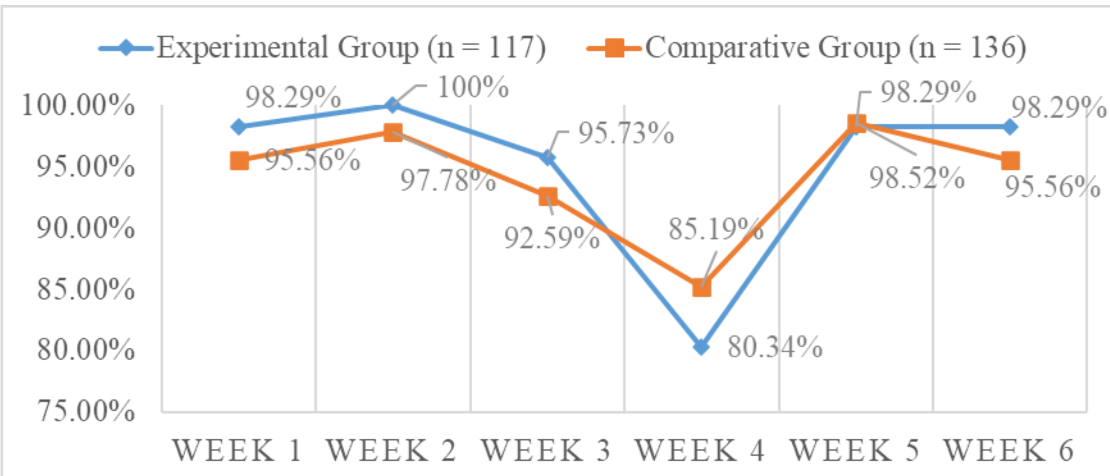
As Figure 14 shows, in the experimental group, among students who finished the surveys, most of the students voluntarily browsed the DQB throughout the semester, with a slightly insignificant increase ($Z = -.82$, $p = .41$) from Week 1-3 to Week 4-6. There was a significant increase in the number of students who posted questions in the DQB ($Z = -3.15$, $p < .01$). This finding was consistent with Baron et al. (2016), who also found a broader range of students participating in interactions after the backchannel's intervention. The number of students who answered others' questions also significantly increased ($Z = -4.08$, $p < .01$).

To conclude, the Wilcoxon signed-rank tests confirmed RH2.1.3 that, in the experimental group, there was a difference in the number of students who voluntarily questioned and answered in the DQB in Week 4-6 than in Week 1-3. More students in the experimental group voluntarily asked and answered questions in Week 4-6 than in Week 1-3. The increase of students who voluntarily browsed the DQB was not significant. This finding suggested that the continued presence of the DQB encouraged more students to participate with the DQB voluntarily.

RH2.1.4. Insignificant Influence on Assignment Completion Rates. Figure 15 illustrates the weekly assignment completion rates between groups throughout the semester. It should be noted that, in Week 4, the instructor did not explain the assignment in detail in class, which might lead to the unusual low completion rates in both groups.

Figure 15

Weekly Assignment Completion Rates between Groups



As Table 14 shows, Mann-Whitney tests suggested that, in Phase 1, although students in the experimental group had a higher assignment completion rate than students in the comparative group, the difference was not significant (U = 7478.5; p = ns). By the end of the semester, when students in the E-comparative group also had DQB access, their assignment completion rate increased, and they even had a slightly higher assignment completion rate than students in the experimental group, but the difference was not significant (U = 7664; p = ns).

Table 14

Class Weekly Assignment Completion Rates between Groups in Two Phases

Phase	Group	n	Mean Rank	*U*	*Z*	*p*
1	**Experimental (DQB)**	117	130.08	7478.5	-1.48	.14
	Comparative (No DQB)	135	123.40			
2	**Experimental (DQB)**	117	124.50	7664.0	-.58	.56
	E-comparative (DQB)	135	128.23			

In summary, results did not support the RH2.1.4, and there was no difference in the assignment completion rate between students with DQB access and ones without DQB access.

Summary to RQ2.1. This section presents results to the research question RQ2.1: *"How does having DQB access influence behavioral engagement?"* and its four sub-hypotheses. Results from the quantitative analysis of DQB posts and self-reported surveys showed:

- RH2.1.1. Within three weeks, there was a higher frequency of responses in the group with DQB access than the group without DQB access.
- RH2.1.2. Within three weeks, there was a higher frequency of interaction in the group with DQB access than the group without DQB access.
- RH2.1.3. More students in the experimental group voluntarily asked and answered questions in Week 4-6 than in Week 1-3. The increase of students who voluntarily browsed the DQB was not significant.
- RH2.14. There was no difference in the assignment completion rate between students with DQB access and those without DQB access.

To conclude RQ2.1, having access to a DQB during large lecture classes improved students' behavioral engagement.

RQ2.2: Having the DQB Access Improved Cognitive Engagement

This section presents results from the (1) the quantitative analysis of students' self-reported surveys, (2) the content analysis of students' DQB posts, and (3) the qualitative analysis of semi-structured interviews and open-ended survey responses. The data and subsequent analysis were directed toward answering the research question RQ2.2.: *"How does having DQB access influence cognitive engagement?"* This research question includes two sub-hypotheses and two sub-questions:

- *RH2.2.1. If students have DQB access, there is a higher level of self-regulation after six weeks, controlling for self-esteem, self-efficacy, and pre-test self-regulation.*
- *RH2.2.2. There is a difference in the frequency and proportion of on-task questions between students with DQB access and ones without DQB access.*
- *RQ2.2.3. What types of responses do students post with DQB access, and do they facilitate interaction?*
- *RQ2.2.4. How does DQB access influence cognitive engagement, as reflected in students' interviews and surveys?*

RH2.2.1. Higher Level of Self-regulation after Six Weeks. To test the RH2.2.1, the quantitative analysis was done to examine whether, statistically, the presence of the DQB in large lecture classes improved individual students' levels of self-regulation. The alpha coefficient obtained for the self-regulation scale was .775, which was considered reliable.

As shown in Table 15, the independent samples t-test suggested no significant difference in pre-test self-regulation between groups (t (244) = .87, p = .39). At the end of Phase 1, students in the comparative group had a higher level of self-regulation than students in the experimental group. However, the difference was not significant, suggesting the 3-week intervention did not statistically influence students' level of self-regulation. At the end of Phase 2, students in the experimental group had a significantly higher level of self-regulation than students in the E-comparative group (t (240) = 2.46, $p < .05$). Thus, students who had DQB access for six weeks had a higher self-regulation level than students who had DQB access for three weeks. However, the paired-samples t-tests suggested that, as compared to the pre-test self-regulation, both the increase in the experimental group and the decrease in the E-comparative group were not significant. This indicated that only the presence of the DQB could not statistically influence students' self-regulation.

Table 15

Students' Self-reported Self-regulation between Groups

Phase	Group	n	*M*	*SD*	*Skewness*	*Kurtosis*	*t*	*df*	*p*
Pre-test	**Experimental (DQB)**	113	43.84	7.70	.55	.24	.87	244	.39
	Comparative (No DQB)	133	43.05	6.64	-.01	1.45			
1	**Experimental (DQB)**	101	43.88	9.12	.02	.23	-.16	225	.87
	Comparative (No DQB)	126	44.06	8.13	-.09	-.40			
2	**Experimental (DQB)**	111	44.75	8.47	-.19	.29	2.46	240	.015
	E-comparative (DQB)	131	42.10	8.24	-.14	-.06			

In the meantime, as literature review suggested, students' self-regulation was significantly related to their levels of self-esteem (r (244) = .38, $p < .01$) and self-efficacy (r (246) = .60, $p < .01$). Cronbach's alphas for the ten Self-esteem and eight Self-efficacy items were .85 and .93, respectively. Students' self-regulation was also significantly related to whether they voluntarily browsed the DQB in Phase 2 (r (235) = .25, $p < .01$). Therefore, those variables were included to predict students' post-test self-regulation.

The hierarchical linear regression was computed to investigate how well the presence of the DQB influenced students' self-regulation in large lecture classes, after controlling for self-esteem, self-efficacy, and pre-test self-regulation (see Table 16). The assumptions of linearity, normally distributed errors, and uncorrelated errors were checked and met. When the first three variables were entered, their combination significantly predicted the post-test self-regulation, F (3,231) = 78.91, $p < .01$, adjusted $R^2 = .5$. Pre-test self-regulation significantly contributed to students' post-test self-regulation. The influences of self-esteem and self-efficacy were insignificant. It suggested that 50% of the post-test self-regulation variance could be predicted by knowing the student's self-esteem, self-efficacy, and pre-test self-regulation.

Table 16

Hierarchical Multiple Regression Analysis Summary Predicting Post-test Self-regulation from the Group and Whether Students Voluntarily Browsed the DQB When Controlling for Self-esteem, Self-Efficacy, and Pre-test Self-regulation, N = 231

Variable	***B***	***SEB***	***β***	R^2	ΔR^2
Step 1				.506	.500
Self-esteem	.096	.052	.094		
Self-efficacy	.095	.066	.085		
Pretest self-regulation	.715	.069	.613**		
Step 2				.542	.532
Self-esteem	.091	.051	.089		
Self-efficacy	.110	.064	.098		
Pretest self-regulation	.676	.068	.579**		
Group	1.947	.760	.115*		
Whether students voluntarily browsed the DQB	2.791	.859	.147**		

*$p < .05$; **$p < .01$.

Note. ΔR^2 = adjusted R^2.

When the "group" and "whether students browsed the DQB" were added, they significantly improved the prediction (R^2 change = .036, F (2, 229) = 9.07, p < .01). The combination significantly predicted students' post-test self-regulation, F (5, 229) = 54.28, p < .01, adjusted $R^2 = .53$, which was a large effect, according to Cohen (1988). With this combination of predictors, pre-test self-regulation had the highest beta (.58). "Group" and “whether a student voluntarily browsed the DQB” also had high betas (.115; .147), so they all contributed significantly to predicting post-test self-regulation.

To sum up, the 3-week long intervention did not significantly improve students’ self-regulation. When students had DQB access for six weeks, and if they voluntarily browsed the DQB, they had a higher level of self-regulation, controlling for self-esteem, and self-efficacy, and pre-test self-regulation.

RH2.2.2. Increased On-task Questions after Six Weeks. This section presents results to the sub-hypothesis RH2.2.2: “There is a difference in the frequency and proportion of on-task questions between students with DQB access and ones without DQB access.” Results in the previous section (RQ1.4) suggested that on-task questions dominated in the DQB. Among the on-task questions, students mostly used the DQB to resolve their perplexity in understanding the new knowledge covered in the lectures, which indicated their cognitive engagement. Meanwhile, peripheral questions about lectures and instructional strategies showed that students actively reflected on how they learned, which indicated their effortful learning. Exam questions also suggested students’ purposeful learning, which all contributed to their cognitive engagement.

Table 17

Types of Questions between Groups in Two Phases

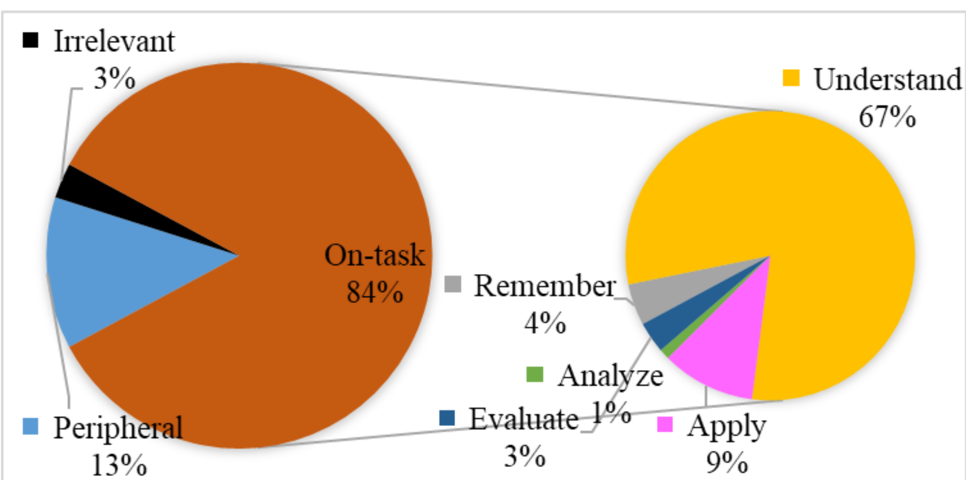
Phase	**Groups**	**On-task**					**Peripheral**	**Irrelevant**	**Total**
		Lower level			**Higher-level**				
		Remember	Understand	Apply	Analyze	Evaluate			
1	**Experimental (DQB)**	4	69	9	1	3	13	3	102
		3.92%	67.65%	8.82%	0.98%	2.94%	12.75%	2.94%	
	Comparative (No DQB)	2	23	1	4		1	1	32
		6.25%	71.88%	3.13%	12.50%		3.13%	3.13%	
2	**Experimental (DQB)**	2	27		8	1	1		39
		5.13%	69.23%		20.51%	2.56%	2.56%		
	E-comparative (DQB)	5	63		2		23	9	102
		4.90%	61.76%		1.96%		22.55%	8.82%	

Comparisons were further made to examine whether the distributions of questions differed between groups and phases. As Table 17 above shows, "understand" questions dominated in both groups and phases. Only students in the experimental group had asked "evaluate" questions. "Apply" questions were only observed in Phase 1. In general, students asked mostly low-level thinking questions in both groups.

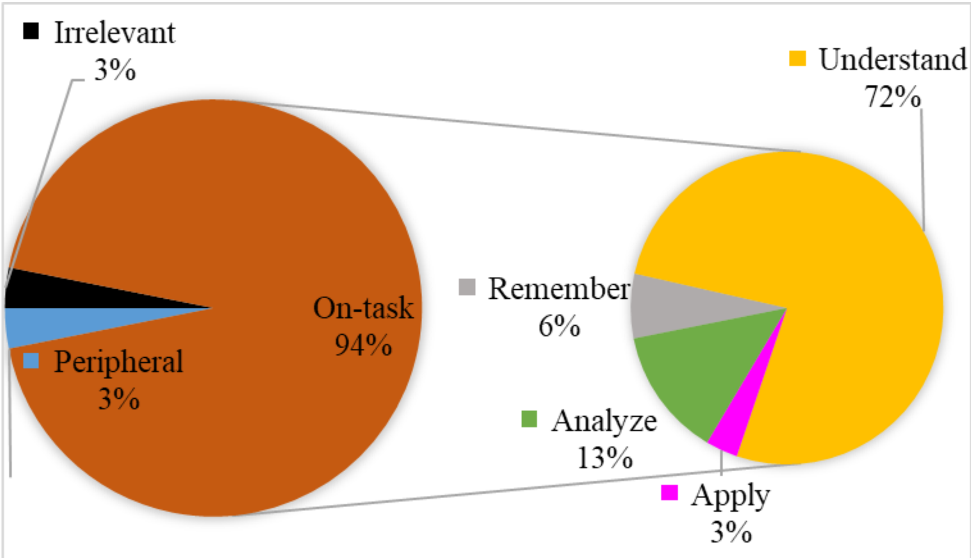
Figure 16 illustrates the distributions of questions between groups in Phase 1. Comparing groups in Phase 1, The chi-square test indicated that there was no statistically significant relationship between the type of questions and group ($\chi^2(2, N = 134) = 2.41, p = .3$). It suggested that although students in the experimental group asked a larger portion of peripheral questions and a smaller portion of on-task questions than students in the comparative group, the difference was not significant. Thus, the types of students' questions did not differ proportionally with or without the 3-week presence of the DQB.

Figure 16

Distributions of Questions between Groups in Phase 1



Experimental Group (DQB)



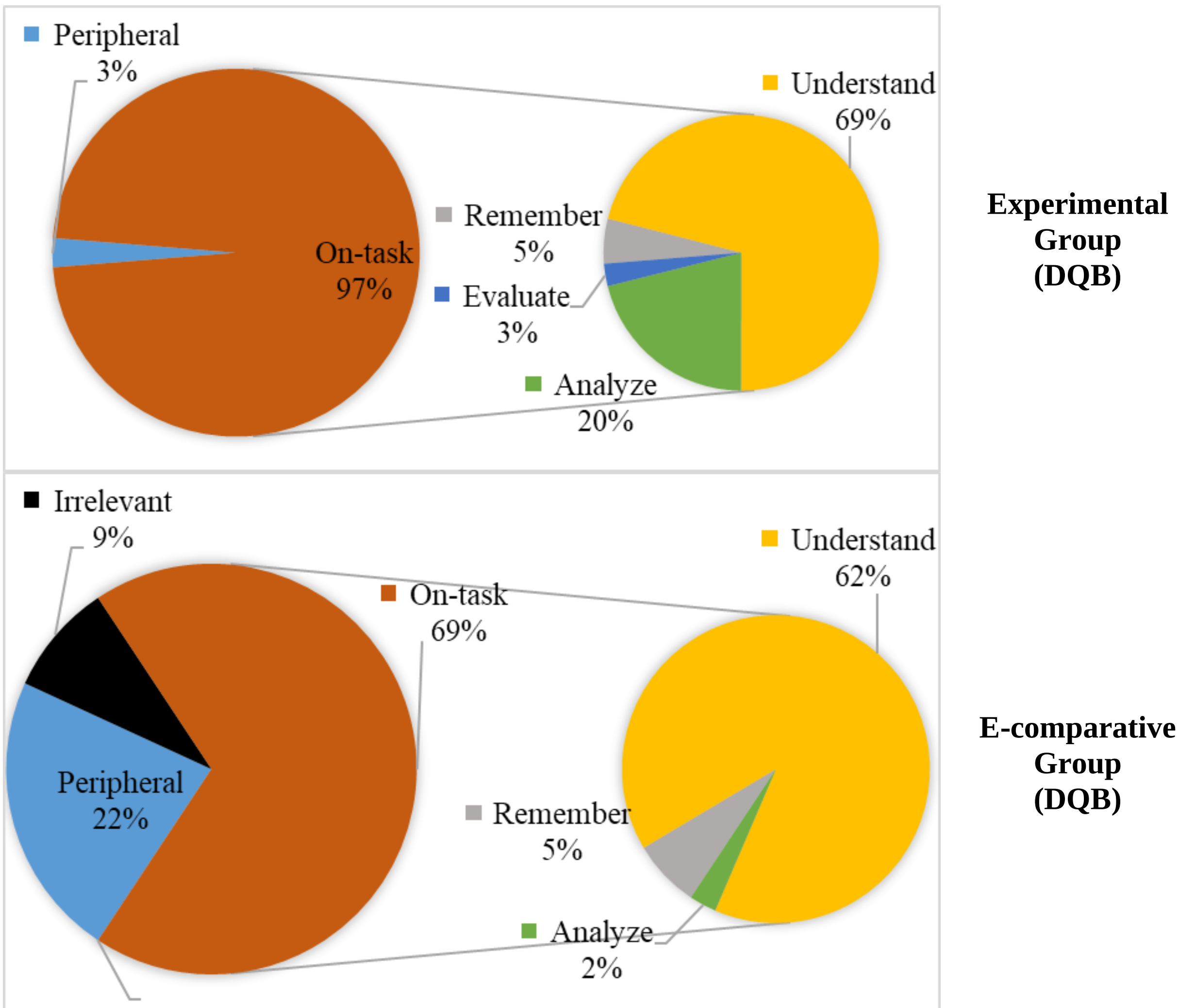
Comparative Group (No DQB)

Figure 17 illustrates the distributions of questions between groups in Phase 2. Comparing groups in Phase 2, the chi-square test indicated that there was a statistically significant relationship between the type of questions and group ($\chi^2(2, N = 141) = 13.12, p < .01$). After six weeks, students in the experimental group asked a significantly larger percentage of on-task questions, and students in the E-comparative group asked a significantly larger percentage of peripheral questions.

Together it suggests that the percentage of students' on-task questions did not significantly differ with the presence of the DQB for three weeks. When students had DQB access for six weeks, they asked a significantly larger portion of on-task questions and a smaller portion of peripheral questions than students who had DQB access for three weeks.

Figure 17

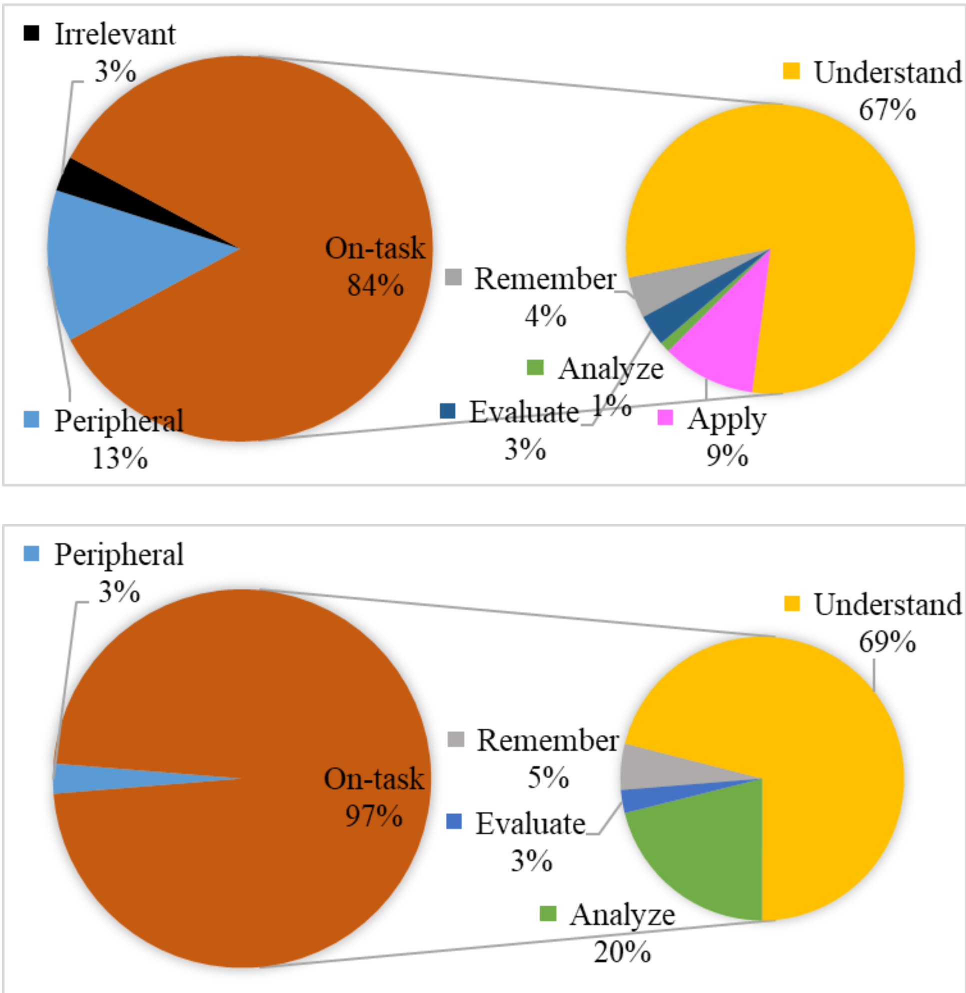
Distributions of Questions between Groups in Phase 2



Comparisons were further made between phases in each group. As Figure 18 shows, for students in the experimental group, although the overall frequency of on-task questions decreased from Phase 1 to Phase 2, the proportion of higher-level questions increased, such as "analyze," which showed their improved cognitive engagement. In Phase 2, students in the experimental group did not ask any irrelevant questions. Even the peripheral questions decreased.

Figure 18

Distributions of Questions in the Experimental Group between Phases



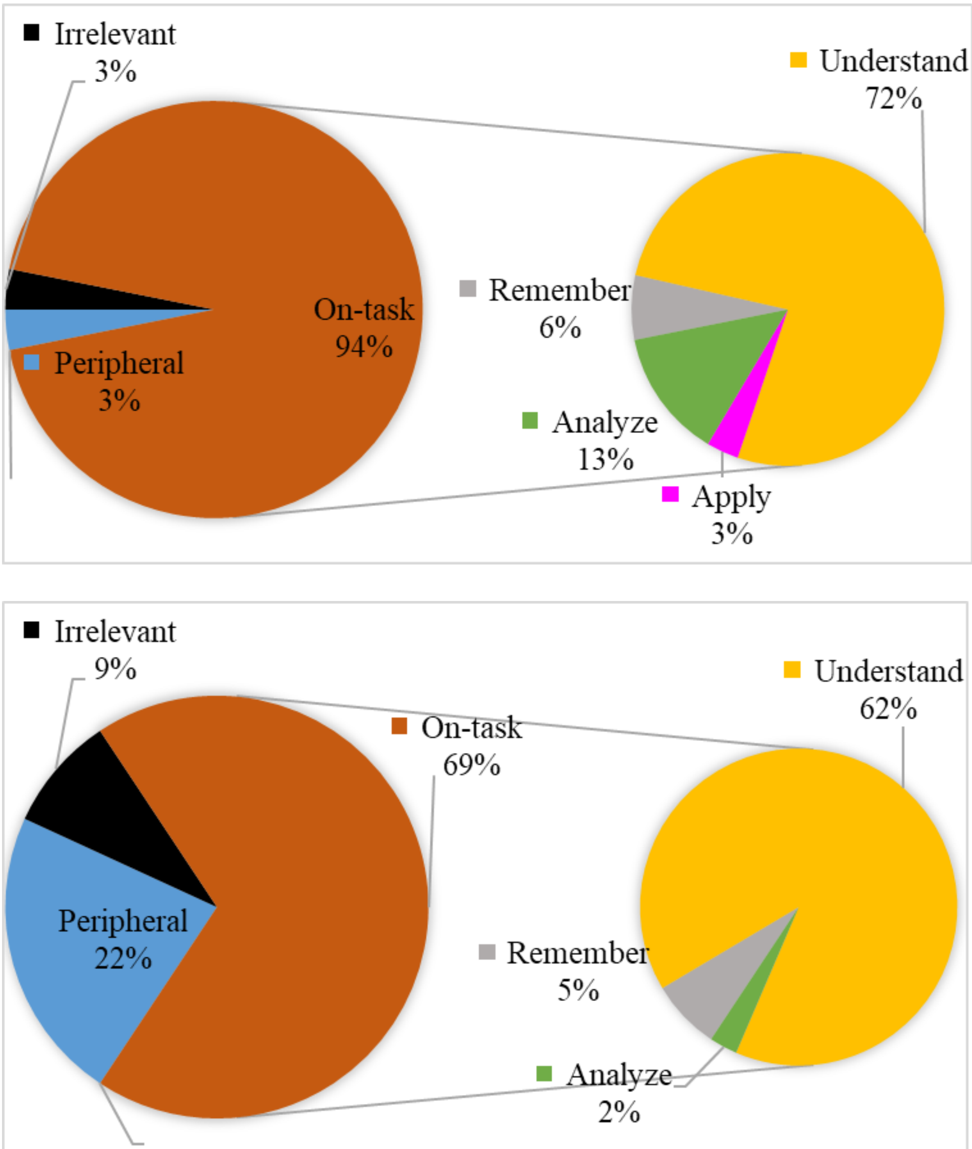
Phase 1

Phase 2

Students in the E-comparative group asked a larger percentage of lower-level questions in Phase 2 than in Phase 1 (Figure 19). The peripheral questions also occupied a larger portion when a DQB was provided in Phase 2. Given that the overall frequency of questions significantly increased in Phase 2, even though proportionally, there were more peripheral and low-level on-task questions, taken altogether, DQB access encouraged both on-task questions and peripheral questions.

Figure 19

Distributions of Questions in the Comparative Group between Phases



Phase 1

Phase 2

It should be noted that although students asked mostly low-level thinking questions with the presence of the DQB, this also indicated their cognitive engagement as they used the DQB to resolve their perplexity in understanding the lecture content to continue cognitive processing. As researchers suggest, it is essential to encourage lower-level questions, as students might feel disengaged if they think that they do not understand the basic concepts on which the rest of the lecture will be built (Sawang et al., 2017). This opinion was supported by many students in the current study, which will be presented in the following sections.

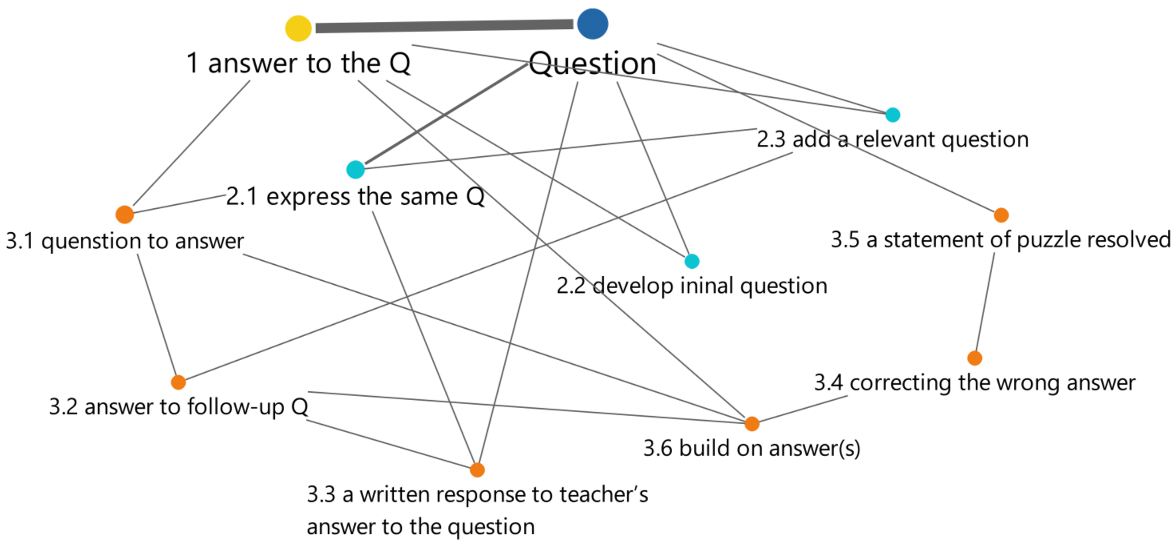
To conclude, when students had DQB access, most of the questions they asked were on-task learning questions. The presence of the DQB for three weeks encouraged a significantly larger portion of the peripheral questions, while the presence of the DQB for six weeks significantly prompted a larger portion of on-task questions.

RQ2.2.3. Enriched Student Responses and Enhanced Student Interactions. This section presents results from the qualitative analysis of DQB posts to answer RQ2.2.3: “What types of responses do students with the DQB post, and do they facilitate interaction?”

Students posted a variety of responses to the initial questions. The types of responses were enriched because of the presence of technology. They were first classified into three categories: (1) answers, (2) non-answer responses, and (3) follow-ups. The answers and non-answer responses directly followed the initial questions, so they were parallel. Follow-ups followed the answers or non-answer responses. Within each category, several themes of how the use of the DQB influenced students’ cognitive engagement were identified. Figure 20 illustrates the relationships between student responses and initial questions. The size of a dot indicates the frequency of this type of response. The thickness of the line indicates the number of connections between the two posts. Among all responses, the number of the answers to questions was the largest (n = 53), then followed by posts that expressed the same questions (n = 20) and questions to answers (n = 13).

Figure 20

Relationships of Student Responses and Questions



Note. The size of the dot indicates the frequency of the type of response. The thickness of the line indicates the number of connections between the two posts.

An initial question might trigger either an answer, a response expressing the same question, a response that develops upon the question, or a new question. Sometimes a question triggered multiple types of responses. Then the responses encouraged follow-ups. For instance, an answer to the initial question inspired students to post follow-up questions, developed the initial question, or built on the answer. Students also corrected the wrong answer. Table 18 gives detailed examples of each type of responses based on the cognitive coding scheme.

RQ2.2.3a. Answers to Questions. Answers to questions were the primary type of responses observed in the DQB. Compared to oral answers, DQB answers had advantages that were attributed to their written format and multi-media options, making it possible for students to post very long, detailed, multi-media answers. For instance, when a student asked if somebody could explain the "Grounded Theory," another student responded with 78 words (Anonymous, Experimental group, Final Week). Although the student did not specify the source of the answer, its tongue and wording indicated that it was a summary from the student's notes, as it involved many phrases rather than entire sentences. Regardless of the source of the answer, it was evident that DQB access made it convenient for students to provide a long and detailed answer. Interestingly, the student ended the answer with "That is all la[5]. Finished la," which showed that the student also thought this might be a long response. The "la" is a Chinese modal particle which shows an emphasis or emotion.

Table 18

Cognitive Coding Scheme for Student Responses in the DQB

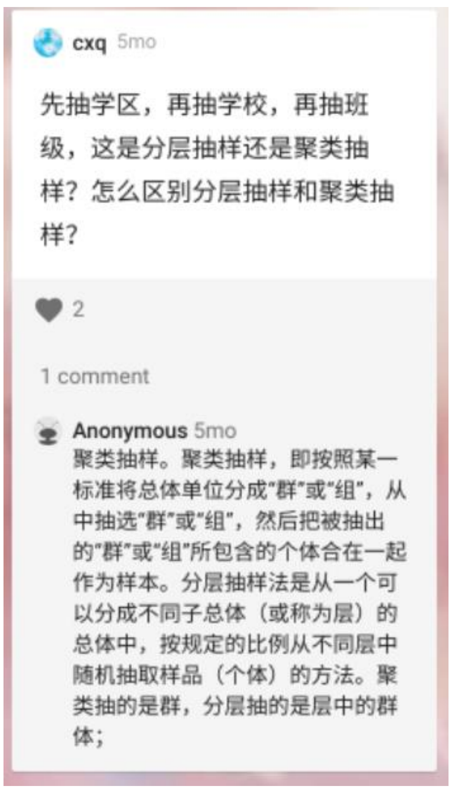
Categories	Descriptions & Examples
1 Answers	
-Answer to question(s)	Answer to the initial question(s)
2 Non-answer responses	
-Express the same question(s)	A response that expresses the same confusion, repeats the initial question, or requests examples, e.g., "I want to ask the same question." "Yes, why…."
-Develop an initial question	A response that revises, corrects, or modifies the initial questions, e.g., "Sorry, it should be …"
-Add a relevant question	A response to a question that contains a new question related to the initial question
-Ask for an explanation	A response to a question requests explanation, e.g., "Can you explain… (with more examples) …again?"
3 Follow-up	
- Question to answer	A follow-up question to an answer
- Answer to a follow-up question	A response to a follow-up question
-Response to the teacher's oral response	A written response to the teacher's oral answer to a question
-Correct the wrong answer	A response that corrects a previous answer to a question
-Statement of puzzle resolved	A response to a question that expresses a confusion resolved, e.g., "I get it."
-Build on the answer(s)	A response that adds a new perspective to previous answers to a question

[5] "la" is a modal particle in Chinese.

In another case from the pilot study, a student cited a long paragraph from web resources and explained that “I read a book related to this topic recently, so I excerpt the part about *what knowledge is* and post it here” (Anonymous, Experimental group, Final Week). Unless in a digital canvas, it was impractical for students to answer with a long response orally in traditional large lecture classes. A similar case could also be seen in the conversation below (Figure 21), between a questioner using a pseudonym and an anonymous responder in the Experimental group, Week 1.

Figure 21

An Example of Students' Long Response in the DQB



In this case above, the questioner described a sampling procedure and asked about its name and how to distinguish stratified sampling from cluster sampling. The responder answered that it was “cluster sampling” and gave a very long and detailed explanation, with 84 words. The students also used parentheses to present alternative terms, which was rarely seen in oral communication. Punctuation marks were easily read in a written format. Similarly, it was also only possible in the DQB that students could respond with formula or other mathematical notations, such as the below case in the first week in the experimental group shows (Figure 22).

Figure 22

An Example of Responses with Mathematical Notations

Translation
Anonymous

What is the 95% confidence interval?

Pseudonym 1
1.96

Pseudonym 2
【M±1.96*SE】

In short, the presence of the DQB not only encouraged more answers quantitatively but also allowed students to provide multi-media responses with detailed explanations, necessary punctuation marks, and mathematical notations. The variety of responses made their expression thorough and convenient, and thus contributed to their cognitive engagement.

RQ2.2.3b. Non-answer Responses. Within the first level of initial question-answer, rather than solely answers, students posted a variety of non-answer responses in the DQB that facilitated learning, which barely happened in regular large lecture classes.

First, students actively expressed that they had the same questions, such as, “Want to know +1” (Anonymous, E-comparative group, Week 5), “Plus 1” (Pseudonym, E-comparative group, Week 4) and “+1” (Anonymous, E-comparative group, Week 6). Indeed, “+1” or “1” were social media buzz words in China, which generally meant “me too.” Using such buzz words showed that students tended to express the same puzzles in convenient, simple ways. Interestingly, one student just said, “I do not know” (Anonymous, Experimental group, Week 4) with a sad emoji to indicate s/he also wanted to know the answer. Such expression was rarely seen in regular lecture classes. The expression of the same questions indicated students’ cognitive engagement as it suggested that the student had a question and wanted to know the answer. Although it was unknown whether students’ awareness of the question generated from browsing peers’ questions. Whereas such expression aided students’ cognitive engagement because (1) it revealed students’ learning deficiencies; and (2) it helped other students and the instructor realize the common problems, so they were more likely to be resolved. In this way, the expression of the same questions contributed to the conversation.

Moving beyond expressing the same puzzle, some students asked for further explanation or examples, such as: “I hope [somebody] could explain the 17th slide of PPT again” (Anonymous, E-comparative group, Week 4), and “Hope there is a detailed example” (Anonymous, Experimental group, Week 4). Asking for further explanation or examples might not be frequently seen in a lecture class. It might interrupt the lecture or make the student feel embarrassed, especially when other students already understood. In most cases, the instructor could only notice students’ perplexity from their confused facial expressions, shaking heads, or frown eyebrows. Ideally, the instructor could frequently ask, “Am I clear?” “Are you with me?” or “Any questions?” However, there must be some cases when most students get it, but a few are still struggling. DQB access enabled them to seek help in a timely and comfortable way.

It should be noted that, in two cases, the subjects of the sentences were omitted. The questioners did not specify the instructor to answer the questions. There was also a case where a student particularly asked peers for help, “I still did not get it, can any classmates explain it” (Anonymous, Experimental group, Week 4). In the case above, it could be inferred from the wording “still” that the original question had been answered by the instructor orally, but the student did not understand the response, so s/he sought help from peers. Researchers suggest that students felt they were better able to discuss and calibrate their understanding of specific concepts when peer instruction was employed (Draper & Brown, 2004). Some students preferred hearing explanations from their peers who had a similar language and therefore, can explain problems and solutions more effectively than the instructor (Caldwell, 2007). Thus, DQB access made it possible for students to seek peer help with ease.

In the meantime, students developed the initial questions in multiple ways. Some students rephrased a question when it was not clear or corrected a question when its expression was confusing or wrongly worded. For instance, a student asked, “What is the difference and relationship between accuracy and reliability” (Pseudonym, Experimental group, Week 2). Then s/he responded, “Wuwu, it is reliability and accuracy.[6]” In this case, “Wuwu” is an onomatopoeic word for crying in Chinese. It could be inferred that the original question was answered already by the instructor orally. However, as it was termed wrongly, the student’s confusion was not resolved, so s/he “cried.” Then, rather than giving up, the student continued to modify the original question to further his/her question.

A similar example is shown in the below case. A student asked, “What are the double questions to avoid in the questionnaire? Can you give me an example” (Pseudonym, Experimental group, Week 3). Then another student modified this question, “It should be to avoid double negative expressions in the question” (Pseudonym, Experimental group, Week 3).

[6] Here this student wrongly termed his/her question again.

Although the questioner and responder used different pseudonyms, we could not confirm from the response's content whether this response was from the original questioner or another student. Class observations and later interview suggested that as the initial question was not termed and appropriately formulated, the instructor did not understand the question. Then he asked if any students could explain the question so he could answer. Thus, another student revised the questions.

Rather than revising, some students expanded a question. In Week 4, a student in the experimental group asked about how to determine the cause of the change among multiple, simultaneous interventions. Then another student responded by expanding the initial question: "If multiple interventions are carried out in one day, then the influence of previous interventions cannot be ruled out. So, what are we testing...?" (Anonymous, Experimental group, Week 4). Developing the initial questions benefited the Q&A, as such responses helped the initial questions be more specific, concrete, and comprehendible. On the other hand, such types of responses could hardly be achieved in regular large lecture classes. At the same time, students also added relevant questions to an initial question. Existing DQB questions inspired students to be aware of new questions. It might also suggest that when students had a question, they related it to existing DQB questions, which all indicated their minds-on learning and cognitive engagement. For example, a student asked about the ethnology, another student followed with "+1 and the multiple-choice question just now, [I] still do not understand very well" (Anonymous, E-comparative group, Week 6).

In another case, one question even triggered multiple students' related questions. The initial question was "I do not quite understand the formula just now. Can [you] talk about it again" (Pseudonym, Experimental group, Week 1). Next, three anonymous responses were proposed:

- I do not know how to calculate 1.96 and 2.08 (Anonymous, Experimental group, Week 1).
- Same question, and why it is for sure that its reliability is 95% or 99% (Anonymous, Experimental group, Week 1)?
- The percentage is the degree of confidence, so what are 1.96 and 2.08 (Anonymous, Experimental group, Week 1)?

In sum, with DQB access, students developed a variety of non-answer responses, such as expressing the same questions, developing initial questions, and adding related questions. Although they did not directly respond to initial questions, they mapped out students' cognitive endeavors that reflected their mindful learning, which indicated cognitive engagement.

RQ2.2.3c. Follow-ups. Many interactions in the DQB moved beyond the initial question-answer level. Students posted various follow-up questions or answers to the initial questions, which might not be practical in regular large lecture classes, as it might take more lecture time. Usually, in a face-to-face class when a student asks a question, the instructor gives an answer. Unless the instructor invites other students to share their opinions, students rarely interrupt their conversion and speak out follow-up questions or responses. Below are three examples of Q&A between students that involved multiple levels.

In the case below (Figure 23), in the experimental group in Week 6, multiple students responded to the initial question. One response made another student realize that his/her response was wrong, so s/he learned from others' responses. It suggested that not only the questioner but other students who joined this conversation or simply observed this conversation could benefit from peers' Q&A.

Figure 23

An Example of a Question with Multiple Follow-ups in the Experimental Group

Translation

Pseudonym 1
It has been talked before, a paradigm that is not explanative but descriptive, which category does it belong to

Pseudonym 2
Anthropology?

Anonymous
Ethnography

Anonymous
Ethnography, anthropology does not need explanations; it mainly [involves] detailed and accurate description

Anonymous
[I] Misread, it is indeed anthropology

Pseudonym 1
I get it, thank you all

In the following conversation (Figure 24) in the E-comparative group in Week 4, obtaining an answer, the student then asked a follow-up question that moved beyond the initial question. The responder also provided a detailed explanation to help the questioner.

Figure 24

An Example of a Question with Multiple Follow-ups in the E-comparative Group (1)

Translation
Anonymous
Is ABAB alternative treatments design

Pseudonym 1
No, it is not

Anonymous
So how to distinguish ABAB and alternative treatment design

Anonymous
ABAB involves only one treatment, but there are different types of treatments in the alternative treatment design

Anonymous
If there are other treatments: C\D

Anonymous
Is ABACABADAC an alternative treatment design

Anonymous
Perhaps ba

In another case in the same week and the same group (Figure 25), a student gave a concise answer. Then the questioner expanded the original question and made his/her question more precise. Therefore, the responder gave a more detailed response.

Figure 25

An Example of a Question with Multiple Follow-ups in the E-comparative Group (2)

Translation

Anonymous
The relationship between “unclear causal relationship” and “time relationship” is not very clear [to me]

Pseudonym 1
It is just an analogy

Anonymous
An analogy also needs the similarity between the two, that is, the similarity is not very clear [to me]

Pseudonym 1
There is a cause; there is a result. There is a certain order of sequence

Pseudonym 1
The time relationship should be the alternating order between baseline and intervention in the single-subject design

In short, the presence of the DQB enriched the types of responses and enhanced interactions and eventually improved students’ cognitive engagement. Students posed answers, non-answer responses and follow-ups to facilitate the interaction, which led to the co-construction of knowledge.

RQ2.2.4. Five Themes of Cognitive Engagement from Qualitative Analyses. The qualitative analysis also helped us better understand how students used the DQB and whether their learning experience reflected cognitive engagement. Altogether 12 students were interviewed, and 117 of all students left feedback regarding their experience of using the DQB in the post-test surveys. Table 19 shows the demographics of the interviewees. For clarity throughout the paper, all pseudonyms for the experimental group's interviewees begin with the letter *E*. All interviewees' pseudonyms in the compared group begin with the letter *C*. The pseudonyms were generated with an online random name generator. The generator was set to construct a random list of the common names for each letter. Only gender was considered when selecting pseudonyms for the participants.

Table 19

Demographics of Interviewees

Pseudonyms	Gender	Year of School	Major	Group
Emmy	Female	First-year	Education	Experimental
Elsie	Female	First-year	Education	Experimental
Ellen	Female	First-year	Education	Experimental
Eliza	Female	First-year	Education	Experimental
Ella	Female	First-year	Education	Experimental
Erin	Female	First-year	Education	Experimental
Edith	Female	First-year	Education	Experimental
Elizabeth	Female	First-year	Education	Experimental
Eve	Female	First-year	Education	Experimental
Casey	Female	First-year	Education	Comparative
Cheryl	Female	First-year	Education	Comparative
Colin	Male	First-year	Education	Comparative

Results revealed that most students regarded the DQB as useful in facilitating learning in many ways. *Five* major themes emerged to illustrate how the use of the DQB indicated and improved students' cognitive engagement.

RQ2.2.4a. DQB Access Improved the Efficiency of Solving Learning Perplexity. Evidence from interviews and surveys suggested that students actively used the DQB to enhance the efficiency of solving learning perplexity in large lecture classes and reflected upon its effectiveness, which all indicated and improved their cognitive engagement.

To capture the change in students' questioning and learning behavior, knowing their previous learning behaviors was a must. In general, students all employed various strategies to solve their learning perplexity, such as asking peers or the instructor after class or figuring it out themselves. Quantitative analysis has shown that, among 253 students surveyed, when asked about their preferences for seeking help, more than half of them asked classmates in and after class, few preferred to ask the instructor orally in class, which were consistent with students' reflection in interviews. As the following case of Elizabeth shows, some students employed various ways to resolve their questions.

> If I have questions in other classes, most of the time, I digest them myself. I never interrupt the teacher in class. [shaking head, laughing] No. I often ask my classmates. If we sit together, I often ask the people next to me. If I do not understand, I will ask someone who knows better than me. In STEM courses, if I encounter confusion, my strategy is to listen carefully in class. I must understand. If I cannot, ask the teacher and ask after class (Elizabeth, Interview).

As discussed in Chapter 1, many Chinese students were reluctant to ask questions directly in large lecture classes. This phenomenon was also captured in interviews and surveys. Although students acknowledged that it was better to get questions solved in class, most of them tended to just "save it" or what they called "pile-up" rather than asking the instructor orally right in the class. To explain, shyness or introverted personalities received most credentials as a primary reason. Some students preferred to solve the questions themselves just to avoid interrupting the lecture. Some attributed the reluctance to large lecture classes' contextual limitations, as they preferred to ask questions orally in small classes. Besides personality and motivational factors, some students explained that they were used to a passive learning style and were not inclined to raise their hands to ask a question in class. When the instructor was lecturing, they preferred just to listen. Despite the difference, most participants actively used the DQB to solve questions and analyzed its effectiveness.

Firstly, findings around student questioning and behavioral engagement confirmed that many students used the DQB to resolve their confusion by posing a question or browsing others' Q&A to enhance their learning. Many students interviewed had asked questions in the DQB, although some deemed their questions were "not many," and some described them as "one or two a semester." Erin and Ellen suggested that they asked and answered questions in the DQB quite often. Meanwhile, although students were not required to use DBQ after class, Eliza still used it to solve after-class questions as she said, "Sometimes when I encountered questions while I was reviewing the lesson after class, I posted questions on the DQB again and hoped the professor could answer it" (Eliza, Interview).

As Figure 8 shows, survey results suggested that for all the students, using the DQB was students' third preferred way of seeking help. Students also depicted in interviews how they changed or enriched the ways they usually asked questions with DQB access. For instance, both Eve, Emmy, and Ella used to ask questions after class. They appreciated that the DQB enabled them to ask questions easily and timely in class. Many students (e.g., Eve, Edith, Elizabeth, and Eliza) preferred to ask classmates for help when they encountered questions, mostly limited to students who sat next to them or lived in the same dormitory. Using the DQB, they asked a broader range of students for help. Students who used to digesting by themselves (e.g., Elizabeth) also expanded their ways of resolving questions.

Moreover, students made appropriate use of the DQB and actively reflected upon its usage and usefulness. Some claimed that DQB access facilitated their questioning because it broke through time and space limitations in large lecture classes. Some students attributed the effectiveness to the synchrony (e.g., Eve) associated with the DQB that allowed timely Q&A. With the DQB and periodical Q&A sessions, students' questions could be solved "directly" and "timely" in class (e.g., Emmy, Eve), rather than "piling up questions" without interrupting the lecture. As Cheryl described, students did not need to "spend more time and effort after class," solving their in-class confusion. Eve also recognized that students could comment on questions in a timely way.

In addition to timeliness, students commented about ease of use, for example, Eliza emphasized that using the DQB, it was "easier," "simpler," but not "interruptive" for students to ask questions. Also, Erin appreciated how DQB access enabled a written format, which she certainly preferred over oral expressions, as she said, "you could think about what to say before you ask" (Erin, Interview). She also pointed out that "[DQB] combines students' different needs; you may have many things to express; you can tell the teacher this way and then tell other students" (Erin, Interview). It can be implied from Erin's conclusion, using the DQB, that students personalized the way they asked questions and sought help, thus contributing to the improved efficiency of resolving perplexity.

To summarize, although students were reluctant to ask questions in large lecture classes because of various reasons, most of them voluntarily used the DQB to seek help from both peers and the instructor. They changed or enriched their ways of seeking help. They also thoroughly reflected upon the effectiveness of asking questions using the DQB. The voluntary, timely, and strategical uses and in-depth analysis all indicated their cognitive engagement.

RQ2.2.4b. Browsing the DQB to Regulate Own Understanding. As the previous section showed, students used the DQB in individualized ways because the autonomy of using the DQB was ensured. Some used it frequently to answer or ask questions. Some used it less often or even rarely. Some used the DQB after class. The survey and interviews also suggested that students tactically browsed the DQB not only during the Q&A sessions but also during lectures, even if they did not have questions in mind. Thus, as the analytical framework (Figure 5) shows, the autonomy and individualization provided by the design of the DQB-based Q&A made it possible for student-centered learning and helped students to challenge themselves.

Qualitative analysis of interviews confirmed that browsing others' questions or asking questions in the DQB did not distract most of them from being concentrated in the lecture; on the contrary, they were add-ons to their learning experiences. Many students reflected upon how they browsed the DQB, which was challenging to observe using other analysis methods. For instance, both Eliza and Edith browsed the DQB mainly during Q&A sessions, but Eliza left it open throughout the whole class most of the time while Edith checked the DQB whenever she was free. Meanwhile, the uses of the DQB were even more flexible for Ella and Erin. Ella did not keep it open all the time. There was no fixed time for her to browse it. However, every so often, she browsed it when available. As for Erin, she also browsed the DQB now and then, after she noted down key points of the lecture. Among students interviewed, Ellen's expression suggested that she browsed the DQB the most frequently.

> I browsed the DQB six to eight times a morning. When the professor displayed the DQB the first time, I looked. When I had questions during the lecture, I also looked. Then I checked the DQB to see what questions other students had. Did they have the same questions as mine? I looked as well (Ellen, Interview).

Ellen's description also unfolded a significant similarity between the interviewed students: they all browsed the DQB to review questions their classmates posted, even if they did not have questions to ask, which was consistent with the survey results. For example, Eve did not frequently ask questions but mainly looked at the instructor's responses to other students. The further qualitative analysis explained that such browsing behavior benefited students' cognitive processing as they observed peers' questions and responses to monitor and regulate their own levels of understanding. As the analytical framework reveals, the autonomy associated with the DQB and other m-technologies made student questioning individualized and their learning personalized. Students could actively use peers' discourses to reinforce their learning whenever they felt available. Specifically, As Ellen's case above suggested, she checked the DQB to see if other students had the same questions as she did. Students who did not browse the DQB with an existing question in mind still were "curious" about others' questions. In Cheryl's own words, "we can see others' questions so that we could think about them" (Cheryl, Interview). In Edith's words, "when I browsed others' questions, what they asked may also be something I did not know clearly" (Edith, Interview). Thus, by browsing questions posted by others, Cheryl and Edith, and other students, were able to assess if they understood those pieces of knowledge. Even more, Erin regarded the use of the DQB helped her to concentrate in class: "I think without a DQB, you may not know what you are doing, right? It is easy to get lost in the lecture" (Erin, Interview). Like Erin's opinion, according to Emmy, she was sometimes not aware of her perplexity, but the questions in the DQB helped her to notice learning gaps.

> Usually, I did not know my classmates' questions, so this was a very good thing about the DQB because it let me know what else I did not know through other people's questions. There was something others knew, and I did not know that I did not know. However, as soon as their questions came out, I said to myself, "Oh, I did not know this question either!" (Emmy, Interview).

Moreover, Ella and Elsie also suggested that they all got inspiration from peers' questions. It showed the critical role of the peer in Vygotsky's (1978) concept of the zone of proximal development. In addition to appreciating that peers' questions inspired them, Ella and Elsie also depicted how they reacted, or in other words, how they challenged themselves:

> I seemed to be influenced by other students' questions……s/he raised a knowledge point, which happened to be something I did not even notice. I thought, "Ah, I missed this!" so I would go through my notes to see if I wrote it down, or look at the PPT. I was inspired most by the relationship between some knowledge points revealed by other students' questions in the DQB, especially the knowledge points that I had not noticed myself (Ella, Interview).
>
> Other students' questions inspired me. If you see something you did not know, then you would think about it. Did the teacher just talk about this knowledge point? Did I not hear clearly? Then I would see if anyone answered the question (Elsie).

Their cases showed that students actively used the DQB to seek unaware questions, challenge themselves with emerging questions.

To summarize, as one student pointed out, "seeing other students' questions is also very helpful for my learning" (Student, Post-test Survey). The autonomy, individualization, and collaboration associated with the DQB allowed students to use the DQB in a personalized way to either resolve confusion or get inspiration. As students purposefully explored questions that they did not foresee, they actively faced challenges and expended effort to deal with the new challenges. As students kept assessing their understanding through others' questions, they became more self-regulated. Such effortful, purposeful learning all indicated students' cognitive engagement.

RQ2.2.4c. Contributing to the Co-construction of Knowledge. As the previous content analysis of DQB posts showed, students created various questions and responses to either seek help to resolve perplexity or help others. Qualitative analyses of interviews and surveys also confirmed that many students' interactions in the DQB were active, which indicated their cognitive engagement as they were co-constructing knowledge. On the one hand, using the DQB, students actively raised their common questions; on the other hand, they actively provided help to each other. With common questions, the instructor was able to modify instruction to address the commonality of questions most students encountered. In this way, although students did not contribute "new messages," they still contributed to the co-construction of knowledge. Providing support to each other helped students resolve their questions and inspire students who did not expect questions. In this way, students actively built supportive learning communities and co-constructed knowledge together.

Firstly, consistent with content analysis of DQB posts, students in interviews and surveys appreciated that other students had asked the same questions in the DQB (e.g., Cheryl, Elsie, Eliza), so they did not need to ask themselves, which also greatly improved the efficiency of resolving perplexity, such as Eve's reflection, below:

> I think around 30% to 40% of students had asked questions. They asked many questions that were *common* to everyone. Therefore, maybe students did not use the DQB to ask questions because their questions were similar, other students had asked, so they did not need to ask themselves (Eve, Interview).

Consistent with Eve's observation and assumption, Cheryl, Emmy, Ellen, and Elsie had the same experience: that other students in the DQB had asked their questions, so they just "liked" them rather than initiating new questions. As Ellen pointed out, it was "convenient" and "time-saving" to "like" other students' questions, as they reflected "students' common, concentrated questions" and "questions that most people wanted to ask" (Ellen, Interview). In

Emmy's words, students' questions in the DQB were "similar and interlinked" (Emmy, Interview). As for Elsie, consulting DQB questions became her routine when she encountered questions of her own. According to Eve, the number of "likes" revealed the "importance" of the question (Eve, Interview). As Erin put forward, students appreciated that the DQB allowed *common questions* to emerge so that they did not need to ask for themselves, which made it possible for students to ask and resolve their questions efficiently. They could either "like" others' questions, comment on those similar questions, or just wait for a response. In Eliza's words, the instructor could, therefore, resolve students' questions in a unified way.

> When the instructor saw those common questions, he could solve them in a unified way. It was like, one (answered) question resolved many people's doubts. This was very good. When those questions were shared, it could be regarded as a kind of resource-sharing (Eliza, Interview).

Emmy, Ellen, and Elsie's cases showed that, rather than passively waiting for an answer, students actively expressed that they had the same questions, through "liking." They reckoned that a question with many "likes" might be more likely to receive the instructor's answers. Indeed, some students especially pointed out in interviews that the instructor would prioritize questions with the most likes to respond (e.g., Eve, Erin, and Eliza). As Eliza concluded, the use of the DQB helped students solve their common, closely related perplexity more easily and efficiently, especially when the instructor prioritized questions that most students faced. The shared questions became learning resources that benefited all the students. T like, to express the same questions, also indicated students' cognitive engagement and contributed to the co-construction of knowledge. It flagged the commonality of questions, which made the instructor's responses more tactical in pinpointing students' real needs.

Secondly, some students actively contributed responses, such as Eliza, Ellen, and Erin. Although Eliza pointed out that she could answer few questions, she tried her best to answer. Ellen responded to others' questions whenever she had the time and knew the answer. Also, many students, such as Erin, Ella, Eliza, and Ellen, appreciated that they could obtain answers from peers. They also elaborated in interviews why responses from classmates better helped resolve their questions. In general, students, such as Ella and Ellen, reckoned that classmates were more approachable than the college instructor, and they had the same language. For example, both Emmy and Ellen recalled incidents when they did not receive a satisfactory response from the instructor because they interpreted the question differently. Ellen thought sometimes the instructor's answer did not perfectly resolve her questions.

> The responses were sometimes pretty good, and sometimes comparatively unclear. Maybe it was because of the way I asked…he answered the question vaguely, and did not achieve what I wanted to know, did not completely resolve my question (Ellen, Interview).

Ellen noted that the instructor failed to resolve her questions because they comprehended the question differently. Emmy's conversation with her classmate also suggested that the instructor interpreted the question differently from students, which led to a gap in their communication.

> It was quite often that the instructor said, "What do you mean by this question? I do not understand." However, in fact, we all understood the question. My classmate once asked me very curiously, "Why sometimes the questions we asked he did not think it could become a question?" The professor was a bit confused about what we were asking. However, our classmates could all understand. Thus, sometimes when those kinds of

questions came out, he would say, “You guys discuss the questions first, please.” He did not understand what we were asking, and there was a little gap in our communication (Emmy, Interview).

To explain such a phenomenon, Ellen suggested that the instructor’s understanding of the questions might differ from the students. Expanding upon Ellen’s assertion, Emmy gave an even more thoughtful explanation:

> Maybe he saw the questions as a person who already knew that knowledge, so he knew it. However, we knew nothing, so we did not understand…Besides, when he talked about concepts and theories, his lectures were comparatively obscure…Sometimes he gave an example. Although the example was very vivid, it was still a little bit far away from me, so I still did not understand (Emmy, Interview).

From Emmy and Ellen’s statements, we can see that although the professor was more knowledgeable and capable of explaining the question, as he perceived it differently, sometimes he could not give the student a pertinent answer. The professor’s inadequate answer explained previous findings where students posted various non-answer responses in the DQB to facilitate the Q&A, such as expressing the same puzzle, asking for explanations, and developing the initial questions. Eliza encountered a similar situation where the instructor’s response was not satisfactory. Fortunately, she obtained helpful responses from classmates, who provided her with detailed, understandable explanations:

> For some questions, I did not understand very well the way he explained it…. Other students had also answered my questions. The other students were helpful because they gave some detailed explanations. For example, once, Professor gave an example, but I missed the small piece and did not listen to it. Then the small piece was not very clear to

me. I asked. A classmate gave me a more detailed answer. I got a satisfactory answer (Eliza, Interview).

With the presence of the DQB, students actively raised their common questions and provided help to each other, contributing to the co-construction of knowledge. The use of the DQB transformed students' questions and responses to shared learning resources and allowed them to solve common perplexity effectively. Using the same language, interactions between students became effective in understanding new concepts together. Speaking to this, according to Reeve and Tseng (2011), students' constructive contribution to the instruction flow is considered agentic engagement (p. 258), which could also be seen in the following theme.

RQ2.2.4d. Analyzing, Evaluating, and Reflecting on Questions and Responses. Although content analysis found that students asked mostly on-task or peripheral questions that all facilitated learning, how did students think about the quality of DQB questions? Indeed, because students valued the questions as learning resources, they were concerned about their quality. Thus, they critically analyzed and evaluated the quality of questions, as if they were evaluating online learning resources.

Some students found that the quality of questions varied. Although most described questions as either "helpful" or "unhelpful," qualitative analysis suggested they evaluated questions from three dimensions: the relatedness to the lecture content, the cognitive difficulty of the questions, and the commonality of the questions.

For instance, some students claimed that there were "irrelevant questions" or questions that were "not related to the content" (Students, Post-test Survey). Given that only a small portion of questions was coded as "irrelevant," complaints about this issue were also limited. It was interesting that rather than complaining about how irrelevant questions hindered or distracted their learning, a student imagined and empathized with the professor, writing, “[irrelevant questions] make me feel embarrassed for the teacher” (Student, Post-test survey). It could be inferred from his/her opinion that s/he thought the instructor expected students to pose questions related to the content. However, the instructor did not specify that only questions related to the content could be posted in the DQB. Thus, it demonstrated that the student was very self-regulated and expected all fellow students to use the DQB for learning purposes.

At the same time, Colin listed various types of questions he observed in the DQB. He spoke highly of the meaningful questions and relevant questions. He clearly expressed his dislike of irrelevant questions. He also had vague attitudes toward exam-related questions or questions that requested the lecture PPT, which were all coded as peripheral questions based on the coding scheme. He even called irrelevant questions “garbage” (Colin, Interview). He reckoned that those peripheral questions “violated the original intention of the DQB” however, he followed this with, “but you could also say it was not violated” (Colin, Interview). It can be said that Colin was very cognitively engaged in the learning process as he observed and analyzed the trend of student questioning in the DQB. He mapped out that related questions decreased, and exam questions increased as the final exam approached. He also recognized the positive influence of those relevant questions. His concerns were mostly about the peripheral questions, especially ones regarding the final exam. He was not sure about their usefulness. It seems that Colin was not a grade-orientated student, as he had a moderate expected score from this course (79). Therefore, he cared more about the learning itself rather than how to obtain a high score. However, for other grade-oriented students, the exam questions were regarded as necessary and useful, as most of them received many “likes.” As for other types of peripheral questions, as Holzer et al. (2014) found in their study, organizational messages, such as requesting lecture slides, were ‘liked’ the most out of any other posting types. Thus, it seems that whether students regarded peripheral questions as helpful or not partly depended on their goal orientations. For most of the students, peripheral questions were regarded as useful in general.

Besides the relatedness of questions to the lecture content, students held different preferences regarding the cognitive difficulty of the questions. Some students regarded only difficult questions as useful for their learning and suggested the instructor spend less time on simple ones. A student commented that “I suggest that the professor can post on a problem that is comparatively difficult to understand in the DQB so that students can comment on their confusion below” (Student, Post-test survey). Cheryl supported the idea of focusing on difficult questions because she thought it was “time-consuming” to deal with simple questions (Cheryl, Interview). She called those simple questions “funny” and “hindered the instructor from solving more difficult ones” (Cheryl, Interview). Instead, she wished questions that were difficult and common for many students could be prioritized. In her words, “I hope that the questions in the DQB are all questions that can trigger most students to think deeply, questions that can solve the perplexity/doubts of most people” (Cheryl, Interview). For simple questions, Cheryl firstly suggested that the instructor should guide students to figure them out by reading the lecture PPT slides. However, when asked, “How would you help the student to resolve simple questions?” Cheryl further acknowledged the necessity of spending time explaining simple questions:

> I might not just tell the student to find it on the PPT. Because sometimes, if s/he does not understand the content, even if he reads the PPT, he still could not understand. Alternatively, he might be too lazy to find it on the PPT (Cheryl, Interview).

Despite Cheryl’s contradictory opinions, many other students regarded simple**,** easy, or conceptual questions as necessary and important. As one student mentioned in the survey that s/he wished the instructor answered both questions with most “likes” and ones without many “likes,” especially questions about conceptual knowledge. To further explain, both Elizabeth and Emmy pointed out that conceptual questions were necessary as they laid the foundation for higher-level learning. In Elizabeth’s words, “the simple ones are the foundation. If we do not understand the simple questions, how can we go deeper?” (Elizabeth, Interview).

Emmy observed various types of questions in the DQB and identified how a simple lecture could lead to difficult, higher-order thinking questions. According to Emmy, the difficulty of questions depended on the difficulty of lecture content; the lecture topics also influenced the types and distributions of questions. Emmy also suggested that “only till you knew the basic concept first, then could you comprehend” (Emmy, Interview). Therefore, whenever she saw a simple or conceptual question that she did not know, she “liked” it. Besides, Elizbeth pointed out, it was fair for everyone to ask questions, no matter how simple or difficult, so she did not want everyone to ask high-quality questions in the DQB.

Regardless of how students perceived the usefulness of DQB questions, what they had in common was they actively analyzed, evaluated, and reflected on DQB questions and what role they played in facilitating (or hindering) their learning. It vividly showed their cognitive engagement, as they did not just browse the DQB aimlessly or only use it for asking questions. In general, students would like to see more relevant questions that were both closely related to the content and common for most students. Both difficult and simple questions were useful in benefiting students’ comprehension, as the lower-level questions laid the foundation for higher-level learning.

RQ2.2.4e. Employing Strategies to Cope with Challenges. Purposeful learning and preference for challenges are all indicators of cognitive engagement (Fredricks et al., 2004). On the one hand, raising questions is considered facing challenges. On the other hand, rather than using the DQB aimlessly, students used the DQB strategically to cope with challenges. They also brainstormed suggestions for further implementation to use the DQB better to facilitate learning.

Some students faced the challenge of balancing the use of the DQB and concentrating in lectures. They explained in the surveys that they were concentrated in class and had no time to browse (N = 12), such as “you may miss something when you post a question in the DQB while listening to the lecture.” Some students confirmed this statement in interviews also. Elizabeth suggested that she did not have enough time to browse through it during the lecture because her “brain was sometimes puzzled by the lecture” (Elizabeth, Interview). Emmy was afraid of missing the knowledge points if she browsed the DQB in class. She felt that if she typed, she could not listen to the lecture. Ellen shared similar experiences with Emmy. Ellen suggested that “no matter what you did in the DQB, it all took time…it took time for you to “like” others, browse questions, and ask questions” (Ellen, Interview). As students concluded, “the timing of using the DQB was challenging to decide” (Elizabeth, Interview); “it was a challenge to allocate time for the DQB from listening to the lecture” (Ellen, Interview).

To further investigate the reasons, both Ellen and Elizabeth pointed out that the difficulty of allocating time for Q&A in the DQB was associated with the lecture's pace, especially when it was too fast. As Ellen claimed, during a “tense” lecture, it was not likely for the instructor to pause and invite students to ask questions (Ellen, Interview). At the same time, Elizabeth suggested that sometimes the instructor spoke very fast and constantly switched between Chinese and English. Elizabeth and Elsie also attributed the difficulty to the challenging lecture content. For Elizabeth, whether she could handle both browsing the DQB and listening to the lecture depended on its easiness. She claimed that if she could easily follow the lecture, she could do both and regarded Q&A in the DQB as “definitely very useful” (Elizabeth, Interview).

It should be noted that, although both faced the problem of balancing the use of the DQB and listening to the lecture, they <u>did not</u> prioritize listening to the lecture over asking DQB questions or give up using the DQB to facilitate their learning. As a student called this situation “contradictory” (Ellen, Interview), she acknowledged the importance and necessity of concentrating on lectures and using the DQB to facilitate learning. As a result, students were instead actively seeking better timing or employ strategies to resolve questions.

Some students browsed the DQB only when they encountered questions or during the Q&A sessions. In Elsie’s case, she browsed the DQB several times in each class, mostly during Q&A sessions. When the professor was giving lectures, she would not take the initiative to browse questions. For Emmy, because she regarded the frequency of the instructor checking the DQB “quite enough,” she mostly used the DQB during Q&A sessions. In her words, “there was no need to browse it again before he displayed it unless I had questions, I needed to type” (Emmy, Interview). However, when necessary, she took the initiative to ask questions in the DQB while the instructor was lecturing. Emmy also emphasized that she might ask questions when everyone was looking at the DQB. Both Elise and Emmy’s experiences suggested that they purposefully prevented themselves from being distracted during lectures while effectively resolving their perplexity. Such a strategy had been employed by many other students who could not handle using the DQB alongside the lecture or “non-multi-taskers.” For those students, rather than a trade-off between using the DQB and listening to the lecture, they strategically balanced the two.

Additionally, some students encountered the challenge that the instructor did not resolve their questions. For instance, as was discussed in the previous section, some students (e.g., Emmy, Ellen, and Eliza) encountered situations when the instructor did not resolve their questions. Ellen also noticed that the instructor had ignored her follow-up questions. The qualitative analysis further showed that, rather than giving up, they employed multiple ways to resolve their questions, depending on specific situations. They used the DQB as an add-on to their help-seeking methods.

In Emmy's case, she usually tried to resolve questions by herself or sought help from her roommates and people around her. When she faced a question that her roommate did not understand and felt she could not resolve it at all without the instructor's help, she would ask the question in the DQB. If the instructor did not respond to her question, she then would ask him in person. For Elsie, she preferred to ask friends or the students next to her first if she had any questions. If she wrote them down, she would ask after class. If she could not obtain an answer from her classmates, she may ask the instructor in the DQB. Elsie further explained that whether she asked questions to the instructor in the DQB depended on how difficult this question was and whether the students around could answer it. As she recalled, 70% of her questions targeted students around her, while 30% targeted the instructor when students could not answer them. Eliza suggested that it was very effective to consult the instructor in person for some "individual" (Eliza, Interview) questions that students did not want to ask in the DQB. In another case, when the instructor's response did not answer Eliza's question, she asked the instructor again by initiating another question in the DQB. Next, she would ask and discuss with classmates around her to solve this problem. In the end, Eliza concluded that 80% of the remaining questions had been solved (in class). For the remaining 20%, she would check it later when she reviewed the lesson. As for Ellen, when the instructor ignored her questions in the DQB, she would pose follow-up questions. If the instructor overlooked the follow-up question, she would mark that question and ask him after class.

Despite the order in which students sought help, what they had in common was that they all employed multiple ways to solve their questions, such as asking friends orally, asking the instructor after class, using the DQB, and figuring it out by themselves. The DQB did not "dramatically" change the way students sought help but could be regarded as an enhancement to their help-seeking routines. Although some students might not use the DQB very frequently, they incorporated it into their help-seeking routine nicely, clearly knowing on which occasions to employ certain methods and their advantages or disadvantages.

Moreover, students contributed various ideas to improve the effectiveness of using the DQB to facilitate learning. For instance, responses in the post-test surveys showed that to deal with the difficulty of balancing time for questioning and listening, some students suggested leaving more time to post questions before Q&A sessions. Some students suggested adding extra face-to-face Q&A sessions every half an hour. Some also suggested technical improvements to increase the efficiency of browsing DQB posts, such as adding a new feature to notify the user about new responses, enabling subscriptions to question threads, and allowing filtering of questions. To increase the probability of obtaining pertinent answers to questions, some students suggested (the instructor) post brief answers in the DQB after class. Meanwhile, Ellen reckoned that if the professor answered a (follow-up) question, but students still could not understand, his answer was "in vain," and that would be a "pity" (Ellen, Interview). She then suggested making follow-up questions stand out so that they were obvious and stood out for the professor to notice more easily. Although students' suggestions focused on different aspects, such as instructor involvement or technical improvement, they all aimed at improving student questioning effectiveness and efficiency.

Summary to RQ2.2.4. When facing challenges, students actively employed appropriate strategies to overcome difficulties rather than giving up. They critically evaluated various choices and selected those that most fit their needs. They searched for perfect timing and occasions to browse the DQB without being distracted from the lectures. They employed multiple methods to resolve their questions. They also contributed suggestions to make the use of the DQB more effective.

Summary to RQ2.2. This section presents results to the research question RQ2.2: "How does having DQB access influence cognitive engagement?" and its two sub-hypotheses and two sub-questions. Results from the regression analysis of students' self-reported surveys, the content analysis of DQB posts and the qualitative analysis of interviews and open-ended survey questions, showed:

- RH2.2.1. When students had DQB access for six weeks, and if they voluntarily browsed the DQB, they had a higher level of self-regulation, controlling for self-esteem, and self-efficacy, and pre-test self-regulation.
- RH2.2.2. There was a difference in the frequency and proportion of on-task questions between students with DQB access and ones without DQB access. The presence of the DQB for six weeks significantly increased the percentage of on-task questions.
- RQ2.2.3. The presence of the DQB enriched the types of responses. Students posed answers, non-answer responses and follow-ups to facilitate the interaction.
- RQ2.2.4. Having DQB access facilitated students' cognitive engagement from five aspects:

a) DQB access improved the efficiency of solving learning perplexity.

b) Students browsed the DQB to regulate their understanding.

c) Students actively contributed to the co-construction of knowledge.

d) Students analyzed, evaluated, and reflected on DQB posts.

e) Students employed strategies to cope with challenges.

In a nutshell, results from all dimensions suggested that having DQB access improved students' cognitive engagement in large lecture classes.

RQ2.3: Having the DQB Access Facilitated Emotional Engagement

This section presents results from (1) the qualitative analysis of students' DQB posts, semi-structured interviews, and open-ended survey responses; (2) the quantitative analysis of the results from qualitative analysis of open-ended survey responses; and (3) the quantitative analysis of students' self-reported surveys. The data and subsequent analysis were directed toward answering the research question RQ2.3*:* "How does having DQB access influence emotional engagement?" This research question involves two sub-questions and one sub-hypothesis:

- RQ2.3.1. How does having DQB access influence emotional engagement as reflected in students' DQB posts, interviews, and surveys?
- RQ2.3.2. What is the level of emotional engagement for most students?
- RH2.3.2. Students with 6-week DQB access had more positive attitudes than students with 3-week DQB access.

RQ2.3.1. Five Themes of Emotional Engagement from Qualitative Analyses. The qualitative analysis of semi-structured interviews, open-ended survey responses, and DQB posts revealed that most students were emotionally engaged in learning with the DQB. Five major themes emerged to illustrate how DQB access influenced emotional engagement.

RQ2.3.1a. Students Enjoyed Learning with the DQB. Most of the students surveyed and interviewed expressed positive emotions, such as liking, favor, and interest. For instance, one student regarded the DQB as "the source of joy in the classroom" and ended the statement with multiple onomatopoeias "ha ha ha ha ha ha!!" to emphasize his/her emotion (Student, Post-test survey). Another student directly said, "I like the DQB the most" (Eve, interview). Some students expressed their gratefulness, such as "Thank you, Professor, for patiently answering our questions" (Students, Post-test interview). More students clearly expressed that they perceived the DQB as useful and effective in facilitating their learning or made it convenient to ask and answer questions in large lecture classes. Some students also appreciated its uniqueness, as it had not been used in other subjects yet (e.g., Ellen, Interview). Similarly, Colin also regarded the DQB as useful, particularly in large college classes as compared with small classes.

Further, many students specifically mentioned in the post-test survey that they wished to continue using the DQB, which was also considered an emotional engagement indicator. In short, most students enjoyed learning with the DQB. They expressed their appreciation or support of the DQB directly. They liked how the DQB helped them seek help and learn in large lecture classes.

RQ2.3.1b. DQB Access Increased Interactivity among Students. Previous content analyses of DQB posts revealed that students could post a variety of questions and responses. Some types of questions and responses were rarely seen in regular large lecture classes. Findings from interviews also confirmed that DQB access reduced the perceived pressure of asking questions in large lecture classes and enabled students to "say whatever you want" (Edith, Interview). Such convenience and variety benefited student interaction. Those various questions and responses enhanced student interaction, which showed their emotional engagement, as collaborative social interaction was considered an indicator of emotional engagement.

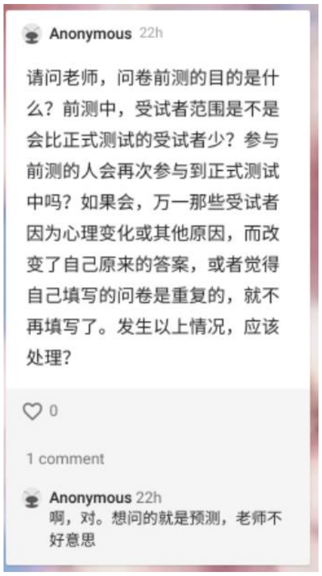
The DQB enabled students to post tentative answers, such as ending a narrative statement with a question mark, e.g., “So the sample size is 3?” (Anonymous, Experimental group, Week 1). “To classify the population into layers, determine the portion of each sample in the population and then conduct specific sampling?” (Anonymous, Experimental group, Week 1). There were some cases when students used the words “maybe” or “perhaps” to indicate their uncertainty, such as “Maybe bilingual” (Anonymous, Experimental group, Week 2), “I think maybe both” (Anonymous, Experimental group, Week 3), “Perhaps Likert” (Pseudonym, Experimental group, Week 3). Some students began a sentence with “I think” to imply that this answer was from his/her personal understanding, rather than a definite answer, such as “I think that sampling refers to the process and sampling unit refers to the sample” (Pseudonym, Experimental group, Week 1).

All the cases presented above showed that, although students were not sure about the correct answers, they actively shared their ideas and challenged themselves to propose an answer. Thus, tentative answers indicated students’ willingness to help others and their exploration of the topic. In this way, students interacted more with the presence of the DQB.

Similarly, the DQB enabled various responses rarely seen in regular large lecture classes to enhance student interaction. One special type of follow-up response was a good indicator of students’ emotional engagement: the anonymously written response to the instructor’s answer to the question. This type of response typically followed an unanswered question and specifically targeted the instructor. For instance, as the figure below shows (Figure 26), a student asked a question anonymously, then followed by a response correcting his/her original question.

Figure 26

An Example of Students' Written Response to the Instructor



Translation

Anonymous

Professor, may I ask, what is the purpose for a pre-test? During the pre-test, are there fewer participants than in the formal test? For people who have participated in the pre-test, will they be able to participate in the formal test? If so, what should we do if by any chance those participants change their initial responses because of psychological changes or other reasons; or if they refuse to fill the questionnaire because they find the questionnaire is duplicated.

Anonymous

Ah, yes. What I wanted to ask was Pilot test, Professor I am sorry

We could imply that this was a direct response to the instructor's verbal communication. It seemed that the instructor had corrected the student's wrong wording "pre-test" into "pilot test" so that the student confirmed with the instructor. Although it was anonymous, it still showed that the student wanted to interact with the instructor to further the conversation. S/he also had a *polite and positive tone.*

Another good example of how DQB access contributed to the increased interaction was the expression of the same questions. Some students responded to initial questions by expressing that they had the same confusion, such as "I want to know too" (Anonymous, E-comparative group, Week 5), and "+1!" (Anonymous, E-comparative group, Week 6). Although this type of response might neither answer the initial question nor move it further, it added to the conversation. It let students know that they shared the same confusion and were not alone in their eagerness to obtain an answer.

Many students gave credit to how using the DQB improved the interactivity between students and the instructor. For instance, in the survey, some students regarded the DQB as "very helpful for classroom interactive learning." In interviews, Casey claimed, "The interaction is pretty good," while Elsie claimed, "the DQB could improve our interactivity." Also, both Ellen and Colin regarded the improved interactivity as an advantage of learning with the DQB:

> Originally, it was difficult for large classes to interact. The advantage of the DQB is that it is an effective way of communication between teachers and students for large classes (Ellen, Interview).
>
> Compared to other large classes, this course has a DQB, so there are more interactions (Colin, Interview).

To further elaborate on why DQB access encouraged student interaction, its role as an alternative communication channel should be given due credit. This is especially so because it allowed questioning without interrupting the lecture.

When talking about students' broad experiences in large lecture classes, most of them reflected that they did not ask questions or interact, not because they did not see the value, but because they were afraid of interrupting the lecture (e.g., Erin). In Ella's words, if she stood up and asked the instructor a question, the instructor would be "more targeted" (Ella, Interview) to answer her question, which would better help her resolve this question. Similarly, as Erin described, if a student asked questions orally in class, s/he "made the question clear," then maybe the teacher "adjusted the instruction for her/them" (Erin, Interview). However, Erin recalled a case in her high school, where she was, to some extent, “annoyed” by another student’s questioning behavior.

> When I was in high school, a student in my class actively made his voices heard. He liked to raise his hands and ask the teacher questions in class. If he kept asking questions on and on, I would feel a little annoyed… when the teacher was lecturing, it was not good to constantly interrupt him/her (Erin, Interview).

Similarly, although Eliza preferred to ask classmates in class, she thought the Q&A with peers should be short, secret, and not interruptive.

> … If you would like to interact with people around you…there are several important points: first, do not affect the whole class's discipline. If you ask students questions in loud and noisy voices, that will not work at all. Secondly, some students may be concentrating on the lecture. When I have a question that I want to communicate secretly, I should be careful and try to solve it in one or two sentences. Do not spend too much time because it is also affecting other people's listening. It is disturbing others (Eliza).

Therefore, in surveys and interviews, because of the synchronous communication channel, Erin and many other students acknowledged that DQB access prompted interactions between students and the instructor as it allowed students to ask questions easily, in a timely way, without interrupting the class.

To summarize, students actively interacted with each other in the DQB with enriched types of responses and questions. The anonymity associated with the DQB enabled them to help each other, such as providing tentative answers confidently. They also expressed their willingness for more interactions with the DQB. Thus, such improved interactivity associated with the DQB-mediated learning proved that students were emotionally engaged.

RQ2.3.1c. Reduced Social Pressure of Questioning. As is introduced in Chapter 1, social pressure inhibited student questioning in large lecture classes for many Chinese college students. Such a barrier was confirmed in the current study. For instance, Eve, Elsie, Edith, and Emmy described themselves as “introverted” or “shy” and unlikely to ask questions orally in large classes. On the contrary, Eliza did not mind asking questions with real names, but she did suggest that her roommates were a little introverted and preferred not to post questions with real names. Eve preferred not to ask questions even in small classes. Edith pointed out that she did not want to be embarrassed about asking “silly” questions, which suggested that she was not opposed to questioning in class but cared about how others perceived her. Ella called herself “not the kind of student who tended to ask questions in the large class orally” (Ella, Interview), which also suggested she recognized that there were some students who did ask questions. According to Eliza, “very shy” students “may not be very comfortable or confident to raise their hands to ask the teacher directly in class or ask the teacher face-to-face after class” (Eliza, Interview), while Emmy suggested that [most] students were embarrassed of raising their hand in class.

> It was very unlikely that somebody would raise their hands in class. They would rather talk to the teachers after class or through virtual network technology. Raising hands in class is the last choice because if you raise your hands directly to ask the teacher in class, you will feel a little embarrassed (Emmy, Interview).

Similarly, according to Erin, even for extroverted students who were very lively and active after class, they were unlikely to interrupt the lecture and ask questions orally because they were used to that way of teaching and learning in college: “the teacher gives lectures, and you just listen. You write down what you hear, memorize it, then write it on the test papers” (Erin, Interview). Erin described it as a culture-norm of learning, where students tended to behave homogeneously because of social pressure. It is also worth noting that, rather than individualism, Erin preferred collectivism, so she prioritized other students' learning experience over solving her perplexity. She also based on what "everyone" was like when she analyzed the appropriateness of oral questioning in class.

> When most of the students had already understood it, then if you kept asking questions, it was not particularly valuable for the whole class's learning…. I think [oral questioning] may be more suitable in elementary schools, as everyone is very active (Erin, Interview).

Erin's assertions were mirrored in Elizabeth's personal experience:

> In class, raising hands to ask questions in class is rare for me. Because since middle school and junior high school, I am used to this kind of *indoctrination learning* (Elizabeth, Interview).

Some students also emphasized the contextual limitation, relationship with the instructor, or culture-norm of large lecture classes. In Ella's case, she usually asked questions after class because there were too many people in large classes. Instead, she might ask oral questions only in small classes. For her, whether she would ask the instructor questions depended on how she felt about the instructor. While for Ellen, she considered how other students behaved when she decided whether to ask the instructor.

> When I was in college, I was farther away from teachers. Secondly, I did not have the habit of asking the teacher. I felt as if there was no one asked the teacher in college. For example, if I want to ask the teacher, only if I see that many people ask the teacher, I will go to ask the teacher. I will instead ask classmates in class and after class also (Ellen, Interview).

Although slightly different, indeed, students were not against questioning, they acknowledged its necessity but were inhibited by social pressure. Using the DQB reduced their social pressure and brought them the confidence of questioning. Reflecting upon the learning experience with DQB access, students concluded that "it was good to use the DQB" because it could "relieve the embarrassment" (Emmy, Interview); so "there will be less pressure" (Edith, Interview). Similarly, many other students also deemed that using the DQB solved the problem of being embarrassed about raising their hands to ask questions because it allowed them to ask questions freely and confidently without worrying about how others perceived them. Even for students who did not suffer from the social pressure of questioning and preferred face-to-face communication, such as Colin, they appreciated the DQB-based communication and the advantage of the DQB in encouraging shy students to talk in a large lecture:

> I think the DQB has its advantages. It is suitable for large class teaching… many students are not willing to open their mouths to express themselves. DQB access at least makes them less shy, right? ...not so shy to ask questions. In a class of hundreds of people, there is an interactive opportunity. It is a very good way (Colin, Interview).

Elizabeth's experience in the last section suggested that she was afraid of interrupting her classmates' learning when she sought help from students around her during lectures. Using the DQB, she no longer needed to worry about whether her questions caused trouble or burdened others, as her questions in the DQB could target multiple people, thus helping to reduce social pressure.

Many students attributed the advantage of the DQB in reducing social pressure to its anonymous feature (e.g., Eliza, Elsie). Eliza suggested that by having the option to be anonymous, even shy, and introverted students might ask questions. According to Elsie, it was “less stressful” to ask questions anonymously, and “there was nothing to worry about” (Elsie, Interview). As Eliza learned from her introverted roommates, being anonymous also “relieved anxiety of asking questions” as students could “conceal their true identities” (Eliza, Interview). Another student pointed out that “to ask or answer questions anonymously could lead to a better discussion” (Student, Post-test survey). Although this student did not further explain why s/he considered anonymous discussion better than identified discussion, her/his positive attitude towards anonymity was evident. To summarize, the anonymity associated with the DQB freed students from social cues. They no longer needed to worry about the consequences of their questioning, which contributed to the reduced social pressure.

Being exposed to the expression of the same questions also contributed to reducing social pressure. When students expressed that they had the same confusion it reduced other students’ pressure about being left behind, as they realized that this was a common problem among them. They could feel that they were “less incompetent” than they might have originally thought.

In short, asking questions in a computer-mediated learning environment itself might reduce social pressure, especially for students who feel embarrassed or are reluctant to engage in verbal questioning in large lecture classes. On the other hand, being anonymous contributed to providing students with a comfortable, low-risk environment to ask questions in large lecture classes. Moreover, expressions of the same questions helped reduce other students’ pressure about being left behind or less competent.

RQ2.3.1d. Building a Social Learning Community. Qualitative analysis of DQB posts showed that students employed various expressions to voice their feelings and emotions. Such emotions not only indicated their emotional engagement but also helped build a social learning community. This social learning community contributed to a friendly environment for collaboration, where students could challenge themselves thanks to support from both their peers and the instructor. Table 20 presents the coding scheme for emotional engagement reflected in student questions and responses.

Table 20

Emotional Engagement Coding Scheme for Student Questions and Responses

Categories	Description and Examples
Tentative Answers	
-Question mark	An answer to the initial question that ends with a question mark, e.g., "the answer is 3?"
-Words of uncertainty	An answer to the initial questions that contain words to indicate uncertainty, such as "maybe" and "perhaps."
Same Questions	A response to the initial questions that express students' same confusion
Emotional Expressions	
-Buzz words	A question or response that contains buzz words, such as "+1"
-Exclamation marks	A response that ends with one or multiple exclamation marks "!"
-Emoji or emoticons	A question or response that contains emoji or emoticons, such as "^_^"
-Modal particles	A question or response that contains modal words, e.g., "ne" "ha"
Social Comments	
-Thanks, and appreciation	A question or response that expresses thanks or appreciations, e.g., "Thank you!"
-Written response to the instructor	A response not to the initial question, but the instructor's oral response(s)
-Other	Other social comments, such as greetings

Many posts in the DQB contained emoji or emoticons, such as "😊" (Anonymous, E-comparative group, Week 5), "XD" (Pseudonym, Experimental group, Week 3), ":(" (Anonymous, Experimental group, Week 4), and "(>̶̤́ ʷ <̶̤̀)" (Anonymous, Experimental group, Week 4). Emoji made up for the lack of emotion in text communication and sometimes made the text easier to understand. Take the following case as an example: "Professor, your response is very PC ^_^" (Pseudonym, E-comparative group, Week 5). Although we could infer that this statement responded to the instructor’s response (to a question), without the emoji, it was difficult to interpret the meaning and attitude of “PC.” Instead, a “smiling face” allowed us to assume “PC” was a positive adjective that expressed students’ appreciation or thanks. In another case, the student ended a sentence with sad emoji: “I do not know, ☹” (Anonymous, Experimental group, Week 4). We could infer from the sad expression that the student was not happy about not knowing the answer. Without the emoji, this declarative sentence might not reflect that this student was willing to know the answer. Similarly, in another case, the ending emoticon “/(/_ _)/” (Anonymous, Experimental group, Week 4), depicted the student’s confusion and eagerness to receive an answer. Similar cases could be seen in many other conversations. In short, the emoji conveyed emotions. The widespread use of emoji showed students' emotional engagement. They also helped contribute to positive interpersonal communication, where students could feel they were not interacting with the computer or written words, but with another person behind the screen.

Students shared various social comments in the DQB, most of which reflected positive emotions. Some social comments were greetings, such as “Good evening, Professor” (Anonymous, E-comparative group, Week 5) and “Good night, everybody” (Anonymous, E-comparative group, Week 4). Some social comments expressed appreciation and thanks, such as “I get it. Thank you all” (Pseudonym, Experimental group, Week 6). There was also a case where the student uploaded a picture that had a little bear saying, “Hello” (Anonymous, E-comparative group, Week 5). Although such social comments were as off-task or even irrelevant based on the cognitive engagement coding scheme, they, on the other hand, suggested students’ emotional engagement. It should also be noted that most social comments were anonymous. This suggests that students’ enthusiastic and polite expressions were sincere, rather than formalities or conventional greetings. Moreover, almost all the questions that had responses were on-task or peripheral questions; rarely did irrelevant questions trigger any responses, except one case:

Figure 27

An Example of an Irrelevant Question with Multiple Responses

Translation

Anonymous
I guess Professor thinks the trade war is just like kids fighting

Anonymous
How clever you are

Anonymous
Do not play petty tricks[7]; could you

Anonymous
Students should behave as students, study hard

Anonymous
It is none of your business

Anonymous
Nothing to do with you

Anonymous
You wasted my time, why it is not my business

This example (Figure 27) shows that students wanted to use the DQB as a learning resource. Thus, they deemed the irrelevant questions or topics "wasting time" and students were against irrelevant questions. As Carpenter (2015) found that irrelevant or unhelpful chatter sometimes distracted both students and teachers, caused inattention to the spoken discussion,

[7] Here the student used a buzz word "dou ji ling (抖机灵)."

students in the current study purposefully avoided such instances. This case, above, also shows how students used social comments to facilitate learning.

Students used a variety of ways to express their emotions. Many DQB posts ended with Chinese modal particles, or mood words, which were also ways to express students' emotions. Some of the modal particles showed students' politeness, such as "ne" in the following question: "What is the difference and relationship between accuracy and reliability ne" (Pseudonym, Experimental group, Week 2). At the same time, some modal particles showed students' uncertainty, such as "ba" in the sentence "Perhaps ba" (Anonymous, E-comparative group, Week 4). In general, using modal words could make Chinese sentences more expressive and emotive. They also convey the mood, which help better express people's feelings.

As the case below reveals, a student used an onomatopoeic word for crying, "Wuwu," to express his/her emotion when s/he corrected his/her wrongly expressed original question: "Wuwu, it is reliability and accuracy" (Pseudonym, Experimental group, Week 2). More interestingly, students even made unique use of regular punctuation to express their emotions. Take the following case for example, the ellipsis, "…" was a commonly used buzz word to show confusion or uncertainty, rather than omission in formal writing. Unlike a full stop that suggests an absolute ending of a sentence, an ellipsis suggests a thought is trailing off.

> If multiple interventions are carried out in one day, then the influence of earlier interventions cannot be ruled out. So, what are we testing...? (Anonymous, Experimental group, Week 4)

Similarly, some students used multiple exclamation marks or multiple "yes" to express their strong emotions and eager interests to obtain the answer to their questions. Moreover, the use of buzz words such as "+1" also showed that students regarded the DQB as an informal communication channel to express feelings conveniently and enthusiastically. Regardless of the variety of expressions, they all made communication in the DQB more emotionally authentic and livelier.

To summarize, students employed various means of expressing their emotions with DQB access, such as emoji, emoticons, mood words, and social comments. Those expressions showed that students were emotionally engaged in learning with the DQB. Those expressions also reflected a positive and active learning atmosphere. This, in turn, nurtured a social learning community.

RQ2.3.1e. Disaffection: Frustration, Disinterest, and Worry. Although most students displayed positive emotional engagement when they used the DQB, some students generated negative emotions or what Skinner and Pitzer (2012) called “disaffection,” such as disinterest, frustration, and worry. Qualitative analysis unfolded three major reasons.

Firstly, among students who expressed negative emotions about the DQB, it was obvious that technical problems contributed the most to students’ frustration. Some students claimed that the tool was “laggy, not flexible, not easy to use” (Students, Post-test survey). A student suggested not to use the software because his/her smartphone was “super-hot” (Student, Post-test survey). It was the first time that Padlet served as the DQB in the current experiment, and there were some unexpected technical problems. Although orientation and pilot tests were conducted before the experiment, some students still encountered different issues that influenced their feelings during learning. However, it is noteworthy that, in addition to expressing dissatisfaction with the software’s shortcomings, students also actively contributed ideas to improve the use of the DQB. For instance, a student suggested using another tool as the DQB for the same Q&A activity. Another student provided suggestions regarding the layout of the DQB so that new questions would not “squeeze out” earlier unanswered questions. Thus, although technical issues somehow hindered students from effectively using the DQB to facilitate learning, their negative emotions targeted mostly the inconvenience of the technology. Indeed, they were not against the alternative communication channel or Q&A sessions.

Secondly, disinterest was mostly seen among students who preferred face-to-face interactions in large lecture classes. To put it another way, they might not suffer from the high social pressure of asking questions orally in front of many people. They were reluctant toward computer-mediated communication, as they claimed it was less efficient to ask questions in the DQB than raising their hands, and they preferred to interact with the instructor face-to-face. Casey explained that she and her roommate preferred oral questioning in large lecture classes and considered it “comparatively better” than using the DQB (Casey, Interview). According to Casey, since everyone was sitting in the room, there was no need to use the DQB to talk. She also believed that there were few students in her class who were willing to ask questions, so “if you wanted to ask, you always had the opportunity to ask” (Casey, Interview). It seems for Casey, the best way to communicate with the instructor was face-to-face. She did not feel any pressure about asking questions in large lecture classes. It is also noteworthy that students like Casey and her roommates were not the targeted population of this study. The DQB was not designed for this type of student. They already had their venue to communicate and ask questions, even in large lecture classes. Therefore, their disinterests or criticisms were both predictable and reasonable. In the targeted group, for instance, Ella pointed out that “encouraging us to use the DQB will not affect our enthusiasm for oral questioning” (Ella, Interview). Thus, no matter the students preferred face-to-face or computer-mediated communication method, digital questioning did not dissuade them from engagement.

Thirdly, some students were frustrated by misunderstanding or miscommunication between students and the instructor. Elsie recalled an experience when her classmates wrote a long paragraph, but she did not get it. There were also other cases when she did not understand others' responses, which she rationalized as some answers were different from how the student(s) thought. To explain, Elsie further attributed the problem to the difficulty of formulating questions.

> Sometimes we expressed some of the questions differently from what we really thought…there was a formulation problem…asking [good] questions still require some experience and needs guidance (Elsie, Interview).

Casey shared a similar experience with Elsie. She saw three times when the instructor did not understand the questions that students asked in the DQB. The instructor then prompted students to ask again or explain the question, which sometimes left the question unsolved. To reflect on her observation, Casey said,

> Sometimes I did not know how to … express my questions in the formal written language. Maybe it is clearer to speak it out… [for the unsolved questions] if you ask him orally, he will ask "What do you mean?" Then you could tell him again. If you give him an example, he will know what you mean. I feel that would be more effective (Casey, Interview).

Obviously, for Casey, she preferred oral expression to written format. It was challenging for her to formulate written questions. She considered oral questioning more effective, especially for follow-ups. For Elsie, she was not against written formats but suggested that she could benefit from more guidance on formulating a good question. Thus, students like Elsie and Casey might be frustrated by the miscommunication caused by difficulties of formulating questions or constructing written questions. Early researchers had shown that some cognitive factors played important roles in producing or formulating useful questions, such as students' prior knowledge (van der Meij, 1990), skill level (Butler & Neuman, 1995), and verbal ability (van der Meij & Dillon, 1994). A questioner needs skills to overcome the knowledge gap and skills to communicate the intended message (van der Meij, 1990). Although college students had a higher level of cognitive ability than students in K-12, their prior knowledge and communicative skills might influence their formulation of questions. Additionally, even though students might formulate a "good question," the instructor might perceive it differently, which could lead to the miscommunication or misunderstanding.

In short, technical problems, preference for face-to-face interaction, and miscommunication were the three main reasons for some students' disaffection during learning with the DQB. However, these students were not against using technologies to facilitate questioning and learning but expected more efficient and effective uses. They also actively contributed suggestions for its improvement. Students who did not benefit much from digital questioning were indeed ones who did not suffer from social pressure when interacting orally. Therefore, despite the limited disaffection, students were emotionally engaged when learning with the DQB.

Summary to RQ2.3.1. To summarize, five themes from qualitative analysis of DQB posts, open-ended surveys and interviews emerged: (a) Most students displayed positive emotional engagement in their learning with the DQB; (b) DQB access increased interactivity among students; (c) DQB access, anonymity and expressions of the same questions reduced perceived social pressure of questioning. (d) Students employed various means of expressing their emotions with DQB access, building a social learning community. (e) Technical problems, preference for face-to-face interaction, and miscommunication explained some students' disaffection.

RQ2.3.2. Most Students were Emotionally Engaged. To further illustrate students' overall emotional engagement levels, themes that emerged from the qualitative analysis of open-ended survey questions were organized as either positive or negative. Although some students did not express obvious positive or negative emotions, they actively shared their ideas about making learning with the DQB better, including technical improvement, instructional design, and DQB strategies. Those incidences were classified as neutral. Each student's emotional engagement was further rated from very negative (-2) to very positive (2) by two coders, with a Kappa of 0.94. Table 21 shows the descriptions and examples of the coding scheme.

Table 21

Emotional Engagement Level Coding Scheme

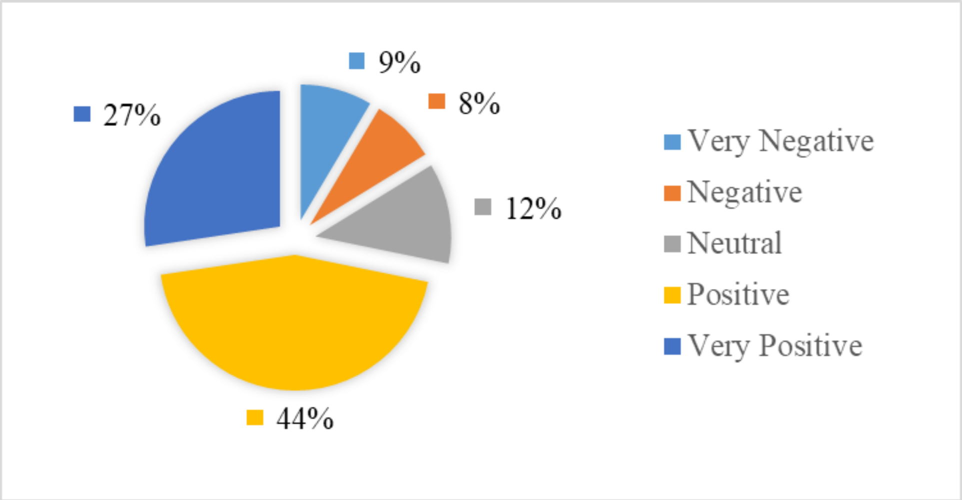
Levels	Descriptions	Examples
Very Negative (-2)	Expression of dislikes, not enjoying	- Do not use the DQB. - It is not easy to use the DQB. - The DQB is useless.
Negative (-1)	Concerns about quality questions, preference of other tools, or report a technical problem	- Some students will ask irrelevant questions. - The quality of questions varied; they were not very helpful. - I wish the layout of the DQB could be improved; whenever new questions appear; they squeeze out previous questions that have not been answered before.
Neutral (0)	No obvious positive or negative emotion, e.g., suggesting technical improvement, instructional design, and strategies of using the DQB	- Keep Professor's enthusiasm for answering questions. - I wish the interface of the DQB could be simpler. - I suggest interaction and group communication. - There could be more types of class interactions. - The professor could check the DQB after class to answer questions. - I still wish that Professor could post and answers in the DQB. - Access to the DQB could be optimized.

Levels	Descriptions	Examples
Positive (1)	Propose to keep the instructional design, Q&A interactions, and the DQB	- Keep the instructional design. - The Q&A session is very good; all can be retained. - Keep the interactions with APP. - Keep the DQB.
Very Positive (2)	Expression of fun, enjoyment, satisfaction, appreciation, and liking; feeling easy/comfortable to use; and perceived usefulness.	- I am very satisfied. I feel very comfortable using the DQB. - I think the DQB is very useful! - I think to ask, or answer questions anonymously could lead to better discussion. - The setting of Padlet the DQB is very good. - The DQB is very good. - Thank you, Professor, for patiently answering our questions.

As Figure 28 shows, more than two thirds (71%) of students were positively emotionally engaged in learning with the DQB, while 17% of students held negative emotions toward the use of the DQB.

Figure 28

Students' Emotional Engagement in Learning with the DQB Reported in the Open-ended Survey Questions (N = 117)



This finding was also consistent with students' self-reported attitudes toward the use of the DQB. As shown in the table below (Table 22), most students were satisfied with the use of the DQB (76.5%) and perceived the DQB as useful in facilitating their learning (80.2%). There was also 61.6% of students who regarded only browsing the DQB as beneficial for their learning.

Table 22

Students' Self-reported Attitudes Toward the Use of the DQB between Groups (N = 177)

Satisfaction	Very satisfied	Satisfied	Somewhat satisfied	Neutral	Somewhat dissatisfied	Dissatisfied	Very dissatisfied
	14.4%	28.2%	33.9%	20.3%	1.7%	1.7%	0%
Usefulness	Very useful	Useful	Somewhat useful	Neutral	Somewhat useless	Useless	Very useless
	15.3%	36.7%	28.2%	15.8%	3.4%	0%	0.6%
Browsing usefulness	Very useful	Useful	Somewhat useful	Neutral	Somewhat useless	Useless	Very useless
	8.5%	25.4%	27.7%	23.7%	13%	1.1%	0.6%

Together, results from qualitative analysis and quantitative analysis all suggested that for RQ2.3.2, Most students reported positive emotional engagement in their learning with the DQB. The next section will further discuss whether students' attitudes differed by groups.

RH2.3.3. More Positive Attitude after Six Weeks. This study also confirmed RH2.3.3 that students with 6-week DQB access had more positive attitudes than students with 3-week DQB access.

Independent samples tests compared students' attitudes between groups. As Table 23 shows, results suggested that students in the experimental group had significantly more positive attitudes than students in the comparative group in all three areas: Satisfaction, Usefulness, and Browsing Usefulness. It suggests that students with 6-week DQB access had more positive attitudes than students with 3-week DQB access.

Table 23

Students' Self-reported Attitudes Toward the Use of the DQB between Groups

	Group	n	M	SD	t	df
Satisfaction	**Experimental (6-week DQB)**	85	5.53	1.02	3.03**	174.97
	E-comparative (3-week DQB)	92	5.04	1.12		
Usefulness	**Experimental (6-week DQB)**	85	5.65	1.05	2.67**	174.59
	E-comparative (3-week DQB)	92	5.22	1.09		
Browsing usefulness	**Experimental (6-week DQB)**	85	5.16	1.18	3.12**	174.73
	E-comparative (3-week DQB)	92	4.60	1.23		

**$p < .01$

In summary, most students held a positive attitude toward using the DQB in class and regarded it as useful in facilitating their learning. Meanwhile, the hypothesis RH2.3.3 was confirmed that as students continued using the DQB to facilitate learning (for six weeks), they became more emotionally engaged than students with DQB access for three weeks. However, this difference could alternately be explained by students in the experimental group had more time to become familiar with the technology.

Summary to RQ2.3. To examine RQ2.3: "how does having access of the DQB in large lecture classes influenced students' emotional engagement," and its two sub-questions and one sub-hypothesis, in this section, the researcher presented results from (1) the qualitative analysis of students' DQB posts, semi-structured interviews, and open-ended survey responses; (2) the quantitative analysis of the results from qualitative analysis of open-ended survey responses; and (3) the quantitative analysis of students' self-reported surveys. Results showed:

- RQ2.3.1. Having DQB access, most students displayed positive emotional engagement from five aspects:
    a) Most students displayed positive emotional engagement in their learning with the DQB.
    b) DQB access increased interactivity among students.

c) DQB access, anonymity and expressions of the same questions reduced perceived social pressure of questioning.

d) Students employed various means of expressing their emotions with DQB access, building a social learning community.

e) Technical problems, preference for face-to-face interaction, and miscommunication explained some students' disaffection.

- RQ2.3.2. Most students reported positive emotional engagement in their learning with the DQB.
- RH2.3.3. Students with 6-week DQB access had more positive attitudes than students with 3-week DQB access.

To conclude, having DQB access facilitated students' emotional engagement. Most of the students displayed positive emotional engagement in their learning with the DQB.

Summary to RQ2

This section presents results to the research question RQ2 and three sub-questions. Results showed that having DQB access improved students' behavioral and cognitive engagement, facilitated emotional engagement. Most of the students displayed positive emotional engagement in their learning with the DQB.

List of Findings

Below is a summary of the major findings from the data analysis.

- RQ1. When the instructor discussed student questions at intervals in large lecture classes, students with DQB access demonstrated different questioning behaviors from those without DQB access.

    - RQ1.1. Within three weeks, there was a higher frequency of questions in the group with DQB access than the group without DQB access.
    - RQ1.2. Students asked most questions in anonymous conditions. Students used a variety of strategies to solve questions, among which using the DQB ranked the third. Most of the students voluntarily browsed the DQB 2 to 5 times in a weekly class. They browsed the DQB to see other students' questions even if they did not have questions in mind.
    - RQ1.3. The presence of the DQB enriched the types of questions students asked during large lecture classes, and most of them were on-task questions that facilitated learning.
- RQ2. Having access to a DQB during large lecture classes improved students' behavioral, cognitive, and facilitated emotional engagement.
    - RQ2.1. Having DQB access improved behavioral engagement.
        - RH2.1.1. Within three weeks, there was a higher frequency of responses in the group with DQB access than the group without DQB access.
        - RH2.1.2. Within three weeks, there was a higher frequency of interaction in the group with DQB access than the group without DQB access.
        - RH2.1.3. More students in the experimental group voluntarily asked and answered questions in Week 4-6 than in Week 1-3. The increase of students who voluntarily browsed the DQB was not significant.
        - RH2.14. There was no difference in the assignment completion rate between students with DQB access and those without DQB access.
    - RQ2.2. Having DQB access improved cognitive engagement.

    - RH2.2.1. When students had DQB access for six weeks, and if they voluntarily browsed the DQB, they had a higher level of self-regulation, controlling for self-esteem, and self-efficacy, and pre-test self-regulation.
    - RH2.2.2. There was a difference in the frequency and proportion of on-task questions between students with DQB access and ones without DQB access. The presence of the DQB for six weeks significantly increased the percentage of on-task questions.
    - RQ2.2.3. The presence of the DQB enriched the types of responses. Students posed answers, non-answer responses and follow-ups to facilitate the interaction.
    - RQ2.2.4. Having DQB access facilitated students' cognitive engagement from five aspects:
        a) DQB access improved the efficiency of solving learning perplexity.
        b) Students browsed the DQB to regulate their understanding.
        c) Students actively contributed to the co-construction of knowledge.
        d) Students analyzed, evaluated, and reflected on DQB posts.
        e) Students employed strategies to cope with challenges.
- RQ2.3. Having DQB access facilitated students' emotional engagement. Most of the students displayed positive emotional engagement in their learning with the DQB.
    - RQ2.3.1. Having DQB access, most students displayed positive emotional engagement from five aspects:
        a) Most students displayed positive emotional engagement in their learning with the DQB.

b) DQB access increased interactivity among students.

c) DQB access, anonymity and expressions of the same questions reduced perceived social pressure of questioning.

d) Students employed various means of expressing their emotions with DQB access, building a social learning community.

e) Technical problems, preference for face-to-face interaction, and miscommunication explained some students' disaffection.

- RQ2.3.2. Most students reported positive emotional engagement in their learning with the DQB.
- RH2.3.3. Students with 6-week DQB access had more positive attitudes than students with 3-week DQB access.

Overall results suggested that when the instructor discussed student questions after every 20-30 minutes in large lecture classes, the presence of the DQB significantly increased students' questioning and answering frequency after the 3-week intervention. The presence of the DQB enriched the types of questions and responses and encouraged mostly on-task learning questions. Having DQB access also greatly improved students' behavioral and cognitive engagement and facilitated emotional engagement. The next chapter presents the integrated findings. Contributions to theoretical understandings and implications for future research are discussed. The author also reflects on the limitation, unexpected findings, the experience of doing research at distance, and the conclusion of this study.

Chapter 5: Discussion

This chapter presents an overview of the study and integrated findings, contributions to theoretical understandings, implications for future research, limitations, and unexpected findings. The experience of doing research from a distance is also discussed. This chapter ends with the conclusion of the study and closing thoughts.

Overview of the Study

A QUAN+qual mixed-methods study with a quasi-experiment was conducted to answer two major research questions: (1) Do students demonstrate different questioning behaviors when provided access to a DQB from those students who are not provided with access to a DQB in large lecture classes? and (2) How does having access to a DQB during large lecture classes influence students' level of engagement? The study was conducted in two groups of an introductory research methodology course in a large comprehensive university in eastern China. The pre-post quasi-experiment lasted for six weeks. The instructor discussed questions after every 20–30 minutes in both groups. In Phase 1, only students in the experiment group had DQB access. In Phase 2, students in both groups had DQB access. There were 117 students in the experimental group and 136 students in the comparative group. The data from surveys, interviews, observations, and online posts (log data) were collected; quantitative analysis, content analysis, and qualitative analysis were conducted to answer the research questions and test the research hypotheses. The findings listed in the previous chapter are integrated and discussed in the following section.

Integrated Findings

This study revealed that when the instructor discussed student questions after every 20–30 minutes in large lecture classes, students with DQB access had a significantly higher frequency of questioning instances than those without DQB access. The presence of the DQB significantly increased students' questioning and answering in class after the three-week intervention. The DQB access enriched the types of questions and responses and encouraged mostly on-task learning questions. Having DQB access also greatly improved students' behavioral and cognitive engagement and facilitated emotional engagement.

Improved Student Questioning and Student Engagement with DQB Access

The evidence suggested that DQB access improved student questioning, behavioral engagement, and cognitive engagement. It created a constructivist learning component in a large lecture class and enabled students to take the initiative to solve learning perplexity timely. It was evident that the presence of the DQB and the systematic discussions around DQB questions improved the overall frequency of student questions observed. Most questions were on-task learning questions that aimed at resolving their learning perplexity in understanding the lecture content. Students also actively employed and contributed strategies for using the DQB to facilitate their learning efficiently and effectively. This positive influence might partly be attributed to advances in the technology-enhanced learning environment.

The technology-mediated learning environment improved the efficiency of asking questions in large lecture classes. Earlier research has suggested that students in classroom settings may not raise questions for fear of interrupting the class and feeling inadequate by sharing questions (Baron et al., 2016; Harunasari & Halim, 2019). Technology can break through the environmental limitation and help provide a safer and more easily accessible way to ask questions that does not make it uncomfortable (Koszalka & Ntloedibe-Kuswani, 2010). The DQB served as an alternative communication channel, enabling students to express their questions alongside the lectures without worrying about interrupting the lecture. As other studies with ARS and backchannels suggested (Baron et al., 2016; Kay & LeSage, 2009), it allowed the instructor to gather students' instantaneous questions whenever they encountered confusions. Rather than saving it to themselves, as many did before, students could express their perplexity timely. Therefore, after every 20–30 minutes, it was more likely that the instructor would resolve their confusion.

As the DQB allowed students to answer peers' questions, the sources of students' help-seeking were enriched. Previous studies suggested that students preferred to hear explanations from their peers who spoke the same language and could explain problems and solutions more effectively than the instructor (Caldwell, 2007). Studies also showed that students felt they were better able to discuss and calibrate their understanding of specific concepts when peer instruction was employed (Draper & Brown, 2004). It was also consistent with previous researchers who found that some students regarded it helpful just to view others' questions and responses because "[knowing] it was the same thing another student was having trouble with and had asked the question and received an answer. [It] really made solving problems easier!" (Huang & Law, 2018, p.183). Besides, although the help came from the peers, researchers found that students were likely to perceive peer-help discourses as an impersonal source of help, which they preferred over personal sources (Makara & Karabenick, 2013). Therefore, using the DQB became an effective way for students to seek help from their peers. Meanwhile, the results suggested that with the DQB, the students still employed multiple ways to resolve their questions depending on specific situations; this digital questioning method did not dramatically change the way the students sought help but was an add-on to their help-seeking methods.

In addition to the improved proficiency of help-seeking, the technology enriched the types of questions that rarely happened in regular large lecture classes. Due to the limited time and space in a large lecture class, questions about assignments and exams often occurred after class. Questions about instructional strategies were even more rarely seen. However, with the help of an alternative communication channel, those questions emerged alongside the lecture. Although those questions were not on-task questions as they were not closely related to the lecture's content, they could be regarded as peripheral learning questions. Those peripheral questions about lectures and instructional strategies showed students' effortful learning because they actively reflected on the way they learned. Some peripheral questions helped the instructor modify instruction based on students' needs. Some peripheral questions helped students set up specific learning goals. For instance, knowing that a concept will be covered in the final exam, some grade-oriented students might be more likely to focus on the lecture. Thus, exam questions also suggested students' purposeful learning, which contributed to their cognitive engagement.

Technologies provided sufficient student autonomy so that student could personalize their ways of student questioning. Constructivism suggests learning processes are individual, based on learners' pre-knowledge and can only be best monitored by learners themselves. Learners should be given sufficient autonomy so that they can understand teaching objectives and teaching methods, set their learning objectives, choose suitable learning strategies, monitor their learning strategies, establish their learning outcomes, direct, and regulate actions toward goals of information acquisition, and expand expertise and self-improvement (Paris & Paris, 2001). Thus, with the help of technology, students actively employed and contributed strategies to use the DQB to facilitate their learning efficiently and effectively. They decided when, to whom, and in what formats to ask questions or not. They also tactically browsed DQB posts to use others' questions to assess and monitor their own understanding or get inspiration.

To conclude, in this setting, the data suggested that both student questioning and student engagement were improved when a mobile technology, the DQB, was provided to support Q&A in large lecture classes. It enriched the types of student questions, improved the efficiency of asking questions, enriched help-seeking methods, and enabled sufficient student autonomy in deciding how, when, and from whom to ask questions. All of these contributed to the improved student engagement.

Constructivist Learning Component Fostered Collaboration and Nurtured Cognitive Engagement

Due to the contextual limitation, constructivist learning could hardly be achieved in large lecture classes. In this study, students were equipped with a constructivist learning component through learning with a DQB, where they were prompted to interact and collaborate with peers. Such interaction and collaboration nurtured cognitive engagement and resulted in the co-construction of knowledge. It was confirmed by the fact that DQB access led to a significantly increased frequency of interactions between students and that students employed various types of responses to help each other; some types of posts were rarely seen in regular large lecture classes. Students also strategically browsed peers' posts to monitor their understanding and learn from peers' Q&As. Those learning behaviors all reflected a constructivist learning approach, which was hardly achieved in regular large lecture classes.

Learning is a social process, and meaningful learning occurs when students are engaged in social activities. As Koszalka and Ntloedibe-Kuswani (2010) suggested, m-technology is at its best when used for communicating among learners. Like other collaborative technologies, as a communication channel, the DQB encouraged idea exchange among students. Students actively asked questions in the DQB, answered peers' questions, and made their voices heard. Many interactions in the DQB moved beyond the initial question-answer level. Students posted a variety of follow-up questions or answers to the initial posts. They also corrected wrong questions, expressed a puzzle resolved, and proposed relevant new questions inspired by their peers' questions. Indeed, the increased interaction itself was an indicator of improved cognitive engagement. According to Vygotsky's (1978) ZPD, necessary assistant/help from either the teacher or more capable peers is needed to achieve a higher level of mastery. Q&A between students helped the less advanced students learn within their zones of proximal development (Vygotsky, 1978).

Resolving learning perplexity with others' help benefited students' cognitive improvement while helping others was also beneficial for the helpers' cognitive engagement and learning. It was consistent with many researchers who suggested that answering questions from other students may stimulate deeper cognitive processing, thus improve the engagement of helpers (Webb, 1982; Fiorella & Mayer, 2016). Vygotsky argued that "the knowledge progress achieved by cooperation with more knowledgeable others could reveal more about learners' capabilities" (as cited in Fosnot & Perry, 1996, p. 23). Specifically, experiencing multiple perspectives could help students develop multiple representations that facilitate their knowledge retrieval and development of more complex schemas relevant to the experience (Doolittle, 1999). Thus, this form of an alternative communication channel made it possible for learners to negotiate and construct knowledge from multiple perspectives to enrich their learning processes (Koszalka & Ntloedibe-Kuswani, 2010).

With the DQB students posted a variety of responses that were rare in face-to-face conditions, such as long detailed responses, using punctuation marks and formulas, expressing the same question, tentative answering, framing questions, developing questions, adding a relevant question, and written responses to the instructor's oral feedback. Many types of responses were restricted in regular large lecture classes because of the contextual limitation and social pressure. Take tentative answering, for example. In regular large lecture classes, usually, students would not stand up to answer a question that they are not sure about in front of many other students. They might feel embarrassed if their answers are wrong. With the help of technology, students could try their best to resolve peers' confusion, even if they are unsure about the answer; they could actively interact with each other to further the conversation. Keefer and Karabenick (1998) suggested that if students could ask peers for help, as student questioning can be directed at multiple targets rather than individuals, it reduced the perceived burden that the questioner imposed on any individual. Meanwhile, such tentative answering could also be regarded as another form of questioning that was only possible in a written format. As researchers found, students answered peers' questions to test their knowledge, as if they were taking quizzes and asking for help if they could not provide their answers (Baron et al., 2016). Therefore, this form of response benefited both the questioner and the answerer, contributing to their cognitive engagement. Similarly, asking for further explanation or examples might not be often seen in a lecture class, as it might interrupt the lecture or make the student feel embarrassed, especially when other students already understood the material. Some students particularly asked their peers for help. Without an alternative communication channel, such interaction might not be possible in large lecture classes.

Even students who did not ask or answer questions in the DQB learned from such a constructivist learning component. Social learning theory deems that students could learn through observation (Bandura, 1997). As researchers suggest, students "did not always know that [they] had a question, until [they] saw it" (Baron et al., 2016, p. 71). Browsing the DQB, therefore, contributed to the improved cognitive engagement, as it allowed students to monitor their learning processes and become aware of their levels of understanding. Consistent with earlier studies (Karabenick, 1996), most students browsed the DQB to see what questions other students posed, even if they did not have questions. It was evident from the regression analysis that for students who voluntarily browsed the DQB, the longer students used the DQB, the significantly higher the level of self-regulation was at the end of the semester after controlling for self-esteem, self-efficacy, and pre-test self-regulation. Content analyses and qualitative analyses also revealed that students got inspiration through browsing others' Q&A. Students could validate their thinking if they shared the same questions as peers; or, they could correct their thinking through learning from others' questions and responses. They could also be inspired to raise relevant new questions. In this way, the DQB was not only a source of Q&A but a learning repository where they could learn from each other (Er et al., 2015; Huang & Law, 2018). Individual student's questioning benefited and improved peers' cognitive engagement.

In conclusion, DQB access and the collaborative learning strategy contributed to a constructivist learning component where students were encouraged to pose a variety of responses to help each other, be engaged in student-student interactions, and browse DQB posts to monitor own learning progress and get inspiration. The interactions between students helped them to develop a more comprehensive understanding as they learned from multiple perspectives. Thus, DQB access fostered collaboration that resulted in the co-construction of knowledge and nurtured cognitive engagement.

Reduced Social Pressure Facilitated Emotional Engagement

The results suggested that most of the students were emotionally engaged. Students had a positive feeling towards learning with the DQB. They enjoyed their learning experiences with the DQB and regarded it useful. Meanwhile, as the students continued using the DQB to facilitate learning, they became more emotionally engaged. They actively helped each other and interacted with the instructor. The digital platform with anonymity reduced the social pressure of student questioning in large lecture classes. The commonality of questions reduced students' fear of being left behind and thus encouraged them to confidently express their confusion. The reduced social pressure and increased interactivity contributed most to their positive emotions, while technical problems, preference for face-to-face communication, and miscommunication mostly explained students' negative emotions.

Earlier studies suggested that social pressure hindered student questioning in large lecture classes (Harunasari & Halim, 2019; Newman & Schwager, 1993). Most students who were uncomfortable to ask questions verbally were concerned about how they would appear in front of their peers (Baron et al., 2016). Like many other technology-mediated environments, using a digital platform reduced the social pressure. It was evident that significantly more interactions were observed when a DQB was provided, and most of the interactions were anonymous.

Consistent with Pohl et al.'s (2012) study, most of DQB questions were lower-level thinking questions. The DQB and its anonymous feature enabled students to reveal their learning perplexity without interrupting the lecture or appearing less competent than their peers (Yates et al., 2015). As students could ask questions anonymously, they no longer needed to be afraid of being embarrassed about asking "silly" questions because of the absence of social (e.g., sex, age, race) and nonverbal cues (Keefer & Karabenick, 1998). Students also posted anonymous follow-up questions or responses to the instructor's oral responses to further their inquiry. In this way, the DQB and its anonymous feature benefited students who were shy, who preferred to craft their thoughts carefully, and who may be uncomfortable sharing (Carpenter, 2015). DQB access made lurkers' questions heard. Students felt more positive about classroom discussions (Harunasari & Halim, 2019) and became comfortable and confident to ask questions (Baron et al., 2016).

DQB access facilitated interpersonal communication that contributed to a positive social learning community. As Baron et al. (2016) found in their study, same questions had students realized that their peers might be equally confused, and the perceived social barrier to participation has thus diminished (Baron et al., 2016). Similarly, students reflected in the survey of Huang and Law's (2018) study that "If someone else was having the same problem, I did not feel too bad because it helped me realize that it was not just me. This gave me a sense of ease and understanding" (p. 183). When students actively expressed that they had the same questions, it helped reduce peers' pressure or anxiety of being lagged, confused, or less competent. Besides, expressions of the same question might help the instructor pay more attention to this common problem and modify instruction accordingly. Meanwhile, as mentioned above, DQB access enabled students to post tentative answers, which showed they were cognitively engaged in the co-construction of knowledge and indicated their emotional engagement as they actively helped each other. Also, students employed various ways to express their emotions, such as using emoji, mood words. Lastly, DQB access allowed students to express appreciation to both the instructor and their peers through social comments. These various types of responses actively gave students emotional support and encouragement.

To conclude, using the DQB reduced the social pressure of questioning in large lecture classes and facilitated interpersonal communication, contributing to increased questioning, and facilitating emotional engagement. It created a low-threat environment for questioning and encouraged voluntary participation. Especially those students who felt less competent than others were encouraged to take the challenge of expressing their opinions aloud (Carpenter, 2015;

Harunasari & Halim, 2019). The student interaction around the DQB also gave students emotional supports and contributed to a positive social learning community.

Systematically Disruptive DQB Uses Avoided Distraction and Encouraged Agentic Engagement

Providing an alternative communication channel is never enough for student questioning. Appropriate instructional and management strategies are needed to facilitate the effective use of the DQB. As this study showed, students' improved engagement should be partly credited to the systematically disruptive use of the DQB. Unlike in some studies where some students regarded asking questions digitally distractive (Yates et al., 2015), most students in this study did not think the DQB would distract them and cause disengagement. Meanwhile, students' on-task questions were dominant in the DQB. This finding was different from previous studies, which found that students were mostly posing off-task questions in backchannels (Bergstrom et al., 2011). It suggests that when students were informed that the instructor would try to resolve their confusion every 20–30 minutes, their questions were mostly content-related and reflected their perplexity in learning and they found using the DQB facilitating rather than disturbing their learning in large lecture classes. The "disruptive" use of the DQB changed the classroom dynamic from instructor-led teaching to student-centered learning, where students engaged more in the learning process through different means.

On the one hand, as the instructor ensured certain time for Q&A sessions, students were aware of the importance of their questions to the flow of instruction. In the beginning, students were encouraged to actively assess their understanding and propose questions as they knew that their questions must be heard. Then, responding to student questions, the instructor guided students as they endeavored to address the proximal learning goals (Fletcher, 2018). Gradually, students not only contributed questions but also employed various ways to solve their questions based on their needs. Moreover, they critically analyzed and evaluated the Q&A in the DQB as learning resources. As students intentionally and proactively tried to personalize their help-seeking methods and enriched their learning sources, it showed students' agentic engagement (Reeve & Tseng, 2011).

On the other hand, as the instructor informed students at the beginning, he would systematically review the DQB; this systematic instructional design reduced the likelihood of overwhelming or unnecessary uses of the DQB. Therefore, to balance using the DQB and being concentrated on lectures, some students browsed the DQB only when they encountered questions or during the Q&A sessions. Some students browsed the DQB many times to get inspiration from peers' questions. Students who could not handle using the DQB alongside the lecture browsed the DQB when the professor displayed it (i.e., during the Q&A sessions) to prevent themselves from being distracted or disengaged during lectures. As Flammer (1981) suggests, questions need not be asked immediately because students have the tolerance for not (yet) asking, as they expect that an answer will be given later without any question being asked. Despite the preferences, the instructor's systematic use of the DQB enabled students to personalize strategies to use the DQB to facilitate their learning. They critically analyzed and evaluated those choices and selected ones that most fit their needs.

Therefore, as students played an active role in the learning process, they constructively contributed to the flow of the instruction they received. Such constructive contribution to the flow of the instruction was regarded as agentic engagement by Reeve and Tseng (2011). This concept focuses on the process in which students intentionally and proactively try to personalize and enrich both what is to be learned and the conditions and circumstances under which it is to be learned (Reeve & Tseng, 2011). They defined student questioning as one of the five constructs of agentic engagement (Reeve & Tseng, 2011). Indeed, Reeve (2013) suggested that student questioning can be viewed not just as a student's contribution to the flow of instruction but also as an ongoing series of dialectical transactions between students and teachers. Meanwhile, the systematic use of the DQB also prevented overwhelming or unnecessary uses so that students could focus on the lecture and avoid distraction or disengagement.

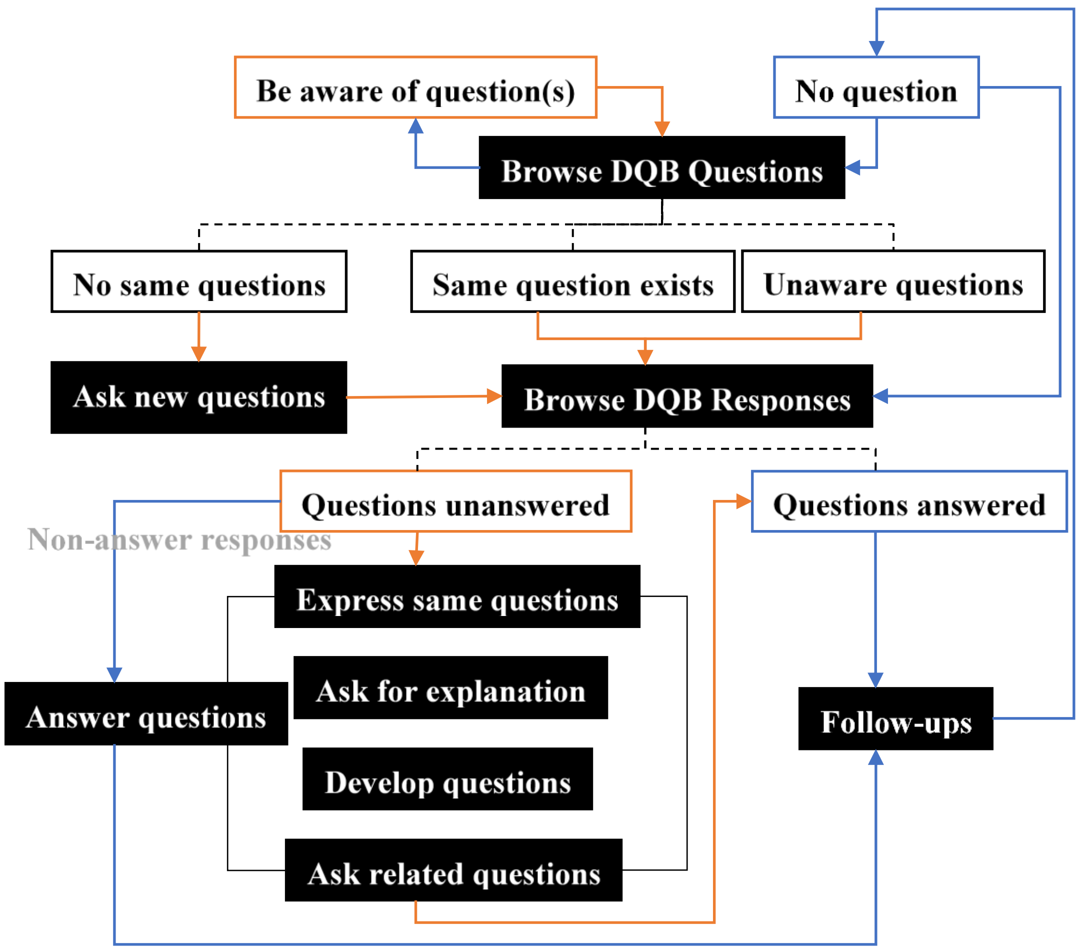
Contributions to Theoretical Understandings

This research might contribute to educational practices and theoretical understandings in several ways. It depicted the patterns of student questioning in large lecture classes with the presence of the DQB. It proposed and proved the effectiveness of the analytical framework of using technologies to facilitate student questioning and engagement based on constructivist learning theories. Moreover, this study also explained how student questioning facilitated student engagement with a technology-mediated social constructivist learning component.

As the literature review shows, without technology intervention, the process of student questioning was mostly described as a linear process, involving similar stages: awareness of the perplexity, decision to seek help, and expression of the question (Dillon, 1990; Nelson-Le Gall, 1981; Newman, 1994; Karabenick, 2011). However, this study showed that the presence of the DQB and the instructional strategies that followed constructivist learning theory, the ways of students' questioning differed from the linear process. Instead, as the below model illustrates (Figure 29), students employed a non-linear approach to solve their perplexity. This approach improved individual students' effectiveness and efficiency of questioning and contributed to their and other students' engagement. Meanwhile, the use of the DQB shifted the responsibility of instruction from a teacher-focused way to a more effective way that relied on students to engage in collaborative scientific inquiry (Mäkitalo-Siegl & Fischer, 2013).

Figure 29

Model of Social Constructivist Student Questioning in a DQB (MCSQ)



Note. Orange arrows indicate the flow of behavior of students who have questions. Blue arrows indicate students' flow of behavior who do not encounter questions. Grey boxes indicate actions.

In the MSCSQ, the student who has a question, could obtain help from existing questions and responses. Rather than directly initiating a new question, they could firstly browse existing questions. If the same questions exist, students could contribute to the commonality of questions by expressing the same perplexity or asking for an explanation. They could also develop initial questions. If no similar questions exist, they could therefore initiate a new question as well. If their questions have already received answers, they could learn from the responses and further interact with them. In this way, some "necessary" stages of questioning might even be omitted, such as the decision to seek help.

Students might be less likely to worry about the social cost of asking questions, as they already obtain the answer through browsing. Even for students who do not have a question in mind, browsing existing questions might also inspire them to assess their understanding. Therefore, while some researchers regard the answer (Karabenick, 2011) or the evaluation of help (Dillon, 1998; Nelson-Le Gall, 1981) as the final stage of questioning, this model portrays it as a cyclic process. Students could get inspiration from peers' questions and responses anytime and start a new loop of inquiry. In this way, learning could happen at each stage of the process rather than at the end. As Er at al. (2015) suggest, students utilized the technology as a learning repository, where they could (1) reexamine their understanding of a specific concept by reading numerous questions brought up by peers about that concept, and (2) locate existing answers to a question that was similar to theirs instead of spending time asking a question and waiting for an answer. Moreover, students could be inspired by browsing existing responses. They could also correct their misunderstanding when they interact with peers' follow-ups.

In sum, this non-linear process of questioning reflects a social constructivist way of learning, where students use multiple methods to seek help, construct knowledge through interacting with others and assess or enhance their understanding with existing questions and responses. In 1988 Dillon proposed five ways to sustain the questioning: (1) reinforce and reward the experience of perplexity and expression of inquiry, (2) help the student and classmates to devise a method to address the question, (3) find out the question that the student has in mind to ask, (4) examine together the grounds of the question, (5) appreciate the student's state of knowledge revealed by the question (Dillon, 1988a, p. 30). Those methods are likely to be achieved with the constructivist, non-linear questioning approach. Individual students' questioning benefits other students and contributed to the co-construction of knowledge. They shifted from acquiring to using knowledge, achieving a sense of ownership of the subject content and their learning experience, developing higher-order thinking skills, and generating more diverse and flexible thinking (Brown & Walter, 2005; Yu & Liu, 2009). Future implementation might also consider modifying the model in different contexts, with different populations to investigate whether a social constructivist approach of student questioning could bring about better student engagement.

This study also showed that technology had its unique contribution to a successful implementation of facilitating student questioning and engagement in large lecture classes, especially because of its synchrony, anonymity, interactivity, role as an alternative communication channel, and individualized options. Future studies could incorporate advanced technology to improve student questioning effectiveness and efficiency, which might also change or enrich students' questioning process.

Implications

Three Principles of Facilitating Student Questioning and Engagement

The results from this study suggested that a technology-enhanced Q&A environment with appropriate instructional strategies based on constructivist learning theories effectively improved student questioning and student engagement in large lecture classes. As the analytical framework (Figure 5) and MCSQ (Figure 29) illustrated, the fusions of instructional strategies and technology intervention might generate a more practical effect. Therefore, three principles were synthesized to guide the implications of future research with or without technology.

Principle 1: Improve the Opportunities, Effectiveness, and Efficiency of Student Questioning. Principle 1 deals with improving the possibility and efficiency of student questioning. The instructor should encourage student questioning and student inquiry, prompting students to find, formulate, and pose their questions. To do so, in each class, the instructor should allocate sufficient time, such as multiple Q&A sessions, for students to ask questions and give responses. If a digital platform for Q&A is available, the instructor could also review it frequently to respond to students' timely questions. Meanwhile, to further improve students' cognitive engagement, the instructor should provide constructive feedback and try to further students' conversation around a topic. It is also necessary to expand a question rather than end the conversation with an absolute answer, helping the student achieve higher-order thinking.

When a digital platform is available, it should first allow synchronous communication to serve as an alternative communication channel. The synchrony allowed timely Q&A to happen. As an alternative communication channel, students could post questions and responses without interrupting the lectures. Second, the platform should provide various options for posting so that student questioning could be individualized and efficient. For instance, students could choose from written formats, voice messages, or uploading multi-media files. The "like" feature might also be helpful. As Baron et al. (2016) found in their study, the "like" feature was rated as the most helpful to help students engage with the course material. Baron et al. (2016) suggest this feature is something that is not, and arguably could never be, part of a traditional lecture structure. Also, students could ask questions using different devices (e.g., smartphones, laptops, tablets) at their convenience. Thirdly, as Makara and Karabenick (2013) suggest that the Q&A

platform and other digital sources of help should be “user-friendly” and avoid having students click on multiple web links to get to it. Meanwhile, the fast development of technology brings more possibilities for facilitating student questioning and engagement in large lecture classes. An advanced platform might consider the following features to improve the effectiveness and efficiency: (1) a filter feature for quickly locating questions and excluding irrelevant questions; (2) a sorting feature to sort questions such as by time, views, and likes; (3) a search bar for searching keywords in questions; (4) automatically merged same/related questions.

In addition to the technology-based intervention, some studies involved facilitators in enhancing student questioning (Aagard et al., 2010). The use of facilitators might help reduce the workload of the instructor and improve the efficiency of Q&A. For instance, in Aagard et al.’s (2010) study, two graduate teaching assistants on laptops answered questions. Every 15 minutes or so, the instructor paused his lecture for a few minutes and took questions gathered by the teaching assistants. In some studies, students acted as facilitators of weekly discussions. However, to what extent facilitators should get involved in such conversations is to be investigated. If students act as facilitators, whether such a learning task requires extra cognitive load and distracts them from learning is also in doubt.

Lastly, the constructivist learning theory suggests that instructional scaffolding is important. Student questioning also needs scaffolding. On the one hand, the instructor should scaffold students to formulate and express good questions. When students ask vague questions or pose questions at the wrong time or for the wrong purpose, the instructor may provide contingent guidance to revise or modify the questions. The instructor could also provide sample questions to inspire students. If a digital platform such as a DQB is available, the instructor could classify questions by assigning different types of questions into specific areas of a question board.

Students could also be prompted to ask questions in different areas by topics. By organizing questions in groups, it would be easier for students to express similar perplexity and more manageable for the instructor and peers to resolve similar questions. Besides, it might also be useful to list frequently asked questions or question templates, as they help students more efficiently and conveniently formulate or organize their questions.

On the other hand, the instructor could scaffold students to obtain answers from peers who have the same language as the questioners. The instructor could invite students to answer peers' questions or frame peers' questions to make them more explicit. It is also necessary to inform students of the various types of feedback or responses available to their questions, such as instructors, peers, and digital resources (e.g., online resources, e-books).

In summary, Principle 1 suggests improving the possibility, effectiveness, and efficiency of student questioning through instructional scaffolding and an optimal design of the Q&A platform.

Principle 2: Empower Student Autonomy and Ensure Individualization in Questioning. To empower student autonomy, the pedagogy should enable the disruptive uses of digital Q&A platforms, and the instructor should systematically provide timely feedback to resolve students' questions. Some students acknowledged in the current study that they faced the challenge of balancing seeking help in the DQB and listening to the lecture. Doing two things at once requires some level of cognitive ability. For students who do not like the idea of doing two things at once, mandatory use of any digital Q&A tool is burdensome as it does not increase their autonomy but distract their learning. Students should have the full autonomy to decide whether to seek help digitally and when and how to use such a tool. Also, if students could only ask questions in a "backchannel" that the instructor does not specify when and how to give feedback, they lack the autonomy to control their help-seeking. They might not have proper expectations for obtaining an answer. Instead, only knowing that their questions will receive attention and contribute to the instruction, will students be cognitively and emotionally engaged in raising questions. It is also a way to prevent students from “overwhelming” uses of the tool, given that some students might lack sufficient cognitive ability to decide the proper strategy to use technology to seek help alongside the lecture. Therefore, systematically disruptive use of digital Q&A platforms might be necessary.

Second, it is necessary to provide students with multiple ways of seeking help and asking questions whenever they feel comfortable and urgent. For instance, besides encouraging students to ask the instructor orally, the instructor could occasionally pause the lecture and ask students to discuss their questions with partners or students in a group, then share with the whole class if their perplexity still exists. Meanwhile, researchers also suggest that, given the significant correlations between student questioning and learning strategy, students should be alerted to circumstances in which student questioning is appropriate and to the factors that inhibit its effective use (Karabenick & Knapp, 1991). For instance, for some concepts that take students plenty of time to digest, the instructor might suggest students take notes and re-visit them to reinforce learning after class.

However, due to contextual limitation and the lecture-centered nature of large lecture classes, providing students sufficient autonomy and personalized learning is still difficult, which calls for a technology intervention. When an alternative communication channel is available, it should support students’ individual needs for questioning. For instance, students should be able to choose from asking questions orally or in the written form. They should have options for being anonymous, using a real name, or using a pseudonym. Additionally, they should have the choices to seek help from the instructor, specific students, or the whole class. Finally, students should be allowed to ask questions with multi-media methods and even external resources (e.g., hyperlinks to external materials). If possible, students should be able to edit, vote, and like questions and responses.

In short, Principle 2 suggests that students should be empowered autonomy in questioning, and their ways of questioning should be personalized. On the one hand, both instructional strategies and technology intervention should provide students with various options to choose from; on the other hand, they should minimize the cognitive or environmental barriers that restrict students' choices.

Principle 3: Creating a Friendly Environment that Encourages Peer Collaboration. Creating a friendly environment for students to challenge themselves and encouraging peer collaboration might be crucial for a social constructivist learning environment. The instructor should not be the "only authority" or the "only knowledgeable other" as the source of students' help-seeking. Instead, instructors should encourage collaboration between students and peer instruction, allowing students with more knowledge to help students who need more assistance. Students should carry the dynamic of the question-answer interaction while the teacher listens, notes, guides, and appreciates the students' question-answer (Dillon, 1998).

When collaborative technologies are available, the interactivity associated with collaborative technologies was of great importance for peer collaboration and Q&A between students. It enables students to ask and answer questions from a broader range of students. The questioning-answering activity brings about multiple interpretations and expressions of learning, facilitates students' multiple representations, and contributes to the co-construction of the knowledge. Without interactivity, peer collaboration could hardly be achieved, and students could mostly obtain help from the instructor and students around. Meanwhile, the synchronous communication channel and its anonymity contribute to a friendly environment for peer collaboration. Students could ask and answer questions without social pressure in such a channel, as a technology-mediated environment and anonymity lessened the importance of social status, which could hardly be achieved in regular large lecture classes. Researchers suggest that communicants are less inhibited with complete anonymity and even when identifiers are present because the technology-mediated interface creates greater psychological distance, more information is thus communicated, and it is more evenly distributed (Keefer & Karabenick, 1998). Rather than being entirely anonymous, in some cases, technologies enable an alternative form of disidentification as well, such as using pseudonyms (Puustinen et al., 2015).

Due to the contextual limitation of large lecture classes, a technology-enhanced Q&A environment might be necessary; even without technologies, peer collaboration should be encouraged. For instance, students should be informed that their discourses all contributed to the co-construction of knowledge, including their expressions of the same questions and tentative answers. Whenever a student raises a question, the instructor should invite other students to further develop the question, modify the question, ask relevant questions, and answer the question.

Although a DQB was unnecessary for students who did not have a problem asking questions orally, they might also benefit from others' Q&A in such a constructivist learning component. Thus, before implementation, instructors might discuss its necessity, importance, and benefits from a constructivist learning perspective to encourage students to help each other. It could be regarded as an "emotional scaffolding" that might help build a positive learning atmosphere.

This study also showed that every question was valuable in the DQB. Even the lower-ordering thinking questions should be welcome because one merit of the DQB is to encourage "vulnerable" students to resolve their perplexity timely and equally, without the fear of appearing less competent than their peers (Yates et al., 2015). Therefore, instructors might emphasize that all the questions are welcome to help students define expectations for the DQB activities and contribute to their emotional engagement.

In summary, Principle 3 suggests creating a friendly environment and encouraging peer collaboration to make it easy for students to ask questions and obtain help without social pressure.

Summary of 3 Key Principles. Instructional strategies play significant roles in supporting student questioning and engagement in large lecture classes. The instructor should:

PRINCIPLE 1: improve the opportunities, effectiveness, and efficiency of student questioning.

PRINCIPLE 2: empower student autonomy and ensure individualization in questioning.

PRINCIPLE 3: creating a friendly environment that encourages peer collaboration.

Implication for Online Learning

This study suggested that a technology-enhanced learning environment could be beneficial to maximize the influence of constructivist instructional strategies on student questioning and engagement in large lecture classes. The benefits might also apply for online learning. In addition to the three principles just introduced, student questioning in online settings might face other challenges which require careful design and instruction.

For instance, most synchronous online courses are implemented through videoconferencing tools (e.g., Zoom). Although students could raise up their questions either orally or typing in the chatroom, some might still suffer from the social pressure of student questioning, especially when anonymous communication is not allowed. Meanwhile the layout of the chat room might not be optimal for peer collaboration because of its linear display of messages. Therefore, a discussion board or a digital canvas that allowed anonymous posts and interactions among students might better choices. In addition, the instructor of the online course might also encounter the difficulty of balancing the lecture and spending time answering students' questions and guiding discussions among students. As is suggested, the instructor could consider reviewing students' questions in a systematic manner. This might help students to balance their listening to the lecture and question-asking as well.

As for asynchronous online courses, one challenge for students might be difficulty of obtaining timely answers. On the one hand, frequently asked questions could be incorporated into each unit of the content, so that students could receive timely help. Although students could learn in different pace, they might encounter similar questions in each stage. On the other hand, a question board might still be useful because some students benefit most from peers' answers as they have the same language. As Flammer (1981) points out students' tolerance for not (yet) asking, they should have clear expectations of how frequently and how timely they could obtain an answer. Therefore, the instructor could notify students how frequent she or he would review their questions and provide responses. If possible, several facilitators could be assigned to summarizing and answering student questions.

It should also be noted that, regardless of the format of online course, e.g., synchronous, asynchronous, or blended, although it is likely that some students solve their questions by themselves through either consulting friends, searching online resources, or asking the instructor individually, they should be encouraged to share both their questions and answers they received in the collaborative learning place (e.g., a question board) so that their peers could benefit from the shared learning resources.

Finally, instructors should be prepared for the change and equipped with the ability to integrate the technology into their traditional or online classroom. For instructors who have never used such technology before, proving a technology integration training is a must.

Limitations

Given the positive results of the current study, there are still some limitations.

Context Limitation. First, this study was contextualized in a Chinese classroom at a Chinese university. Asking questions after class rather than interrupting the instructor was considered the norm by most of the students. Students were reluctant to interact because of sociocultural factors and cultural connotations (Li & Jia, 2006; Lu & Han, 2010). These factors were likely to vary based on culture, educational level, and education system expectations. Thus, the necessity and effect of such a digital Q&A intervention might differ in different contexts. The generalizability of the findings is restricted.

The sample was comparatively homogeneous as all the students were freshmen, majored in education, and had positive attitudes toward learning. Thus, whether such intervention still works with a different sample is to be investigated. Future research could focus on a broader population with more diverse academic majors and statuses.

As a proactive behavior, some researchers suggest that student questioning differs by gender (Wakefield et al., 2011). However, this study's sample consisted of mostly female students (86.56%), because this study took place in a normal university, where the gender was unevenly distributed. Thus, it was impossible to investigate how the influence of the intervention differed by gender. However, the gender imbalance might not influence the results of the current study because in both groups, female students were dominant with only few male students. Future studies might consider conducting studies with a more balanced sample.

Methodological Limitation. The full effect of the intervention is limited to three weeks as compared to the control group (comparative group), while some conclusions drawn from this study showed the difference between a 3-week intervention (E-comparative) and a 6-week intervention (Experimental group). Because of the limited time, this study could not examine whether students became more willing to ask questions verbally and would do so in the future even without a DQB. However, for equality of groups, I had to design this way within the context. Comparing shorter and longer intervention was also a way to eliminate the effect of novelty influence. Future researchers may consider a longer period of intervention.

***Technology Limitation*.** The technology used also had a limitation that limited the measurement. As the platform did not allow researchers to track the source of anonymous posts, I was unable to know which students posed anonymous questions. Students reported their frequency and occasions of browsing the DQB in the post-surveys, which might not be sufficiently objective and reliable. Therefore, the technology limitation reduced statistical analysis power. Future analysis might use digital platforms that permit researchers to link anonymous posts to specific students (with consents). Using pseudonyms might also be a solution.

Selected Measurement. Researchers measure student engagement in many ways. This study employed multiple methods to measure each of the dimension of student engagement. However, the selection of indicators still had limitations. For instance, attendance has been included in some studies as an indicator of behavioral engagement (e.g., Heafner & Friedman, 2008; Stewart et al., 2011), results from the pilot study suggested that it was not applicable in this study. Firstly, by the rule of the university, attendance of this course was required and mandatory. All the students were required to scan a QR code before they entered the classroom. Secondly, when students had to be absent from a class, they could switch to the other section for a make-up lesson with permission. As a result, the attendance data could barely capture students' voluntary participation, behavioral engagement, and thus was excluded from the measurement plan. In the meantime, some studies collect students' time spent on learning tasks as an indicator of behavioral engagement (NSSE; Ouimet & Smallwood, 2005; Wise et al., 2012), it is not applicable in this study because this study focuses on student engagement during lecture classes rather than after class. Use of the DQB is voluntary and could be anonymous. Thus, it was not meaningful to examine the length of time a student spent with the tool in class.

***Language Barriers*.** The instructor was a Chinese native speaker who received education in China for more than 18 years. He taught this course in Chinese but using English instructional materials, including the PowerPoint slides. The bilingual learning environment brought some difficulties to the participants who were all Chinese native speakers. However, such influence was not investigated in the current study, as both groups received the same instruction.

Although all the researchers involved in this study were fluent in English, presenting the findings in English was still challenging, as it required thorough translation from Chinese into English. However, none of the researchers majored in interpretation or translation studies. All the data were collected and analyzed in Chinese to ensure the reliability of the findings. Only the findings reported in the manuscript were translated into Chinese by me and proofread by two other research assistants and a native English speaker. Two online translators (Baidu translator and DeepL translator) were used to translate the Chinese findings back into English to ensure the accuracy of the translation. Despite all this, the precision of translation was restricted, and the descriptions of the findings might not perfectly reflect students' authentic discourses.

Positionality. Researcher bias might have also influenced the qualitative analysis and its conclusions. As a Chinese student who spent 25 years in China, having a similar background helped me understand my participants from an insider perspective; so were my six research assistants. They all received education in China for more than 16 years. Thus, we were familiar with the Chinese education system and the cultural norm, making it easy to communicate with participants using our native language. As we shared a similar identity, language, and experiential base with the participants, it was easy for the researchers to interpret and analyze students' written posts in the DQB. The participants could also be more open with us to allow for a greater depth of data to be gathered.

However, the phenomenon might have already changed compared to when I was studying in China eight years ago. As Narayan (1993) suggests that the extent to which anyone is an authentic insider is questionable, and that "factors such as education, gender, sexual orientation, class, race, or sheer duration of contacts may at different times outweigh the cultural identity we associate with insider or outsider" (Narayan, 1993, p. 672). The way I perceived learning might also have already changed because of five years' study in the U.S., which might be reflected through my advocation for a social-constructivist learning environment rather than a lecture-centered, passive learning environment. Therefore, it might be difficult to identify myself as either "insider" or "outsider," making it more difficult to ensure sufficient objectivity in interpreting the qualitative data. The same dilemma also applied to other research assistants.

Unexpected Findings

Lastly, some questions were not investigated in this study, and some unexpected findings suggested that other variables and effects should be further explored in further research.

Influence on the Instructor. This study focused on how the intervention with a DQB influenced students' questioning and engagement. No assumptions were made regarding how such intervention affected the instructor. However, both the interview with the professor and casual conversations after the experiment suggested that this experience brought him influence. On the one hand, the professor acknowledged the effectiveness of the DQB and regarded it useful in facilitating student interaction. He felt the students were more active than he expected as they asked many questions. He even deemed the learning atmosphere was more active and positive than that in his American classroom, though the class size was much smaller. Thus, the instructor's reflection might be good evidence of how the technology-enhanced Q&A intervention contributed to a constructive, positive learning environment.

On the other hand, in his words, some types of student questions "had never caught his attention before," which prompted him to modify his instruction accordingly. It was expected that student questioning triggered teachers' point-of-need teaching concerning providing students with individual feedback within the students' zone of proximal development. However, this study focused on students' behavior and engagement; how the use of the DQB influenced the instructor was not examined. Whether the use of a DQB hindered or facilitated the weekly lecture content was not investigated as well. Therefore, the professor's reflection suggested that it might also be meaningful to investigate how the intervention influences the instructor's instruction and pedagogy.

Distribution of Questions. The results suggested lower order thinking questions were dominant in the DQB, especially questions regarding "understanding," which was not expected before, as some researchers found backchannels encouraged difficult questions (Baron et al., 2016). Although it was assumed that the presence of the DQB might encourage more on-task questions, they were assumed to vary based on the revised Bloom's Taxonomy. However, the findings showed very few higher-order thinking questions. The difference might have been observed because of the subject and content.

It might because this study was situated in an introductory research methodology course. The lecture contents focused more on introducing basic concepts rather than challenging students' higher-order thinking. Meanwhile, it might also be because of the sample's background, which consisted of all freshmen who had little-to-no prior knowledge of research methodology. It was quite difficult for them to move beyond low order thinking within six weeks.

If such an intervention is conducted in a more advanced research methodology course in a longer experiment, students might ask more higher-order thinking questions. Besides, future research with other subjects might reveal different distributions of question types. It should also be noted that large lecture classes are mostly designed for introductory courses. In any case, encouraging higher-order thinking questions is necessary as it indicates cognitive engagement.

Unexpected Responses. As expected, most students were emotionally engaged with the presence of the DQB, and their emotions were mostly positive. The content analysis of DQB posts showed enriched questions and responses, most of which were rarely seen in regular large lecture classes. Among many, two unexpected types of responses gathered my attention.

Expressing the Same Questions. Findings from the qualitative analysis showed that expression of the same questions not only indicated and benefited students' cognitive engagement but also facilitated other students’ emotional engagement as the commonality of questions reduced students’ fear of being left behind or less competent, encouraged them to ask questions, and contributed to a positive social learning community. It was unexpected that students employed a variety of ways to express that they had the same questions. Indeed, the most convenient way to express the same question was to “like” an existing question. However, students posted lots of expressions such as “want to know,” “+1”, and even “I do not know :(.” There were also many cases that students asked for explanation and examples. Based on my positionality as a Chinese student, I assume that students regarded multiple written expressions of the same questions more obvious for the questions to stand out, so the instructor would prioritize it to answer the common question. Further study might better explain such a phenomenon.

Anonymous Response to the Instructor. I was most surprised by students’ anonymous written responses to the instructor’s oral feedback. On the one hand, it showed that students’ social pressure of questioning existed, as they did not want to unveil their identity even if the instructor resolved their questions. On the other hand, even if the instructor did not know their names, they politely expressed their appreciation and furthered their conversations. It suggested that students actively interact with the instructor in a “secret” and “safe” way. They also used emoji to make their conversations more personal. Future research could explore why students posted anonymous responses to the instructor. It might contribute to the understanding of students’ inner thoughts and complex motivation for interaction in large lecture classes.

Technology-enhanced Measurement. Moreover, the advances in technology not only facilitated learning and teaching but also enhanced research. Many researchers use various learning statistics to assess students’ learning. For student questioning, in addition to students’ questions and responses, many other behaviors could also be analyzed to map out the process of student questioning and learning, such as how many times each student accessed the platform, browsed each post, or the time they spent reading or writing a question.

Despite the unanswered questions and unexpected findings, this research did not intend to answer all these questions; instead, the intent was to show that there was yet much to be answered about what may be useful in implementing technology-enhanced instruction to facilitate student questioning and engagement in large lecture classes.

Doing Research at a Distance

This study was a collaboration between researchers in the U.S. and the instructor and research assistants at the site. There were many challenges of doing research at distance.

Preparation. Numerous communications were done with the sample school to know the context and population, especially the technology access. The technology-enhanced intervention could not be implemented without a stable wi-fi connection and personal devices of all participants. Students were informed at the beginning that if they did not have a smartphone or other devices to participate in the experiment, our research team could provide them with the necessary tools. Fortunately, the pre-test survey suggested that all the students had smartphones, and the wi-fi connection was stable in the classroom.

The instructor of this study was a professor at an American University and taught a course during summer and winter vacations in China. Most communications with the professor were done in the U.S. before he went to China. Two research assistants helped prepare the instructional materials, created the DBQ, and trained him to use technology.

Two on-site teaching assistants in China helped with the observation. They were assigned rather than recruited to do the observation. They were diligent but lacked research experience.

Therefore, online training was conducted through SNS to familiarize them with the observation protocol and the research procedure.

To familiarize students with the tool also required instruction. Various instructional tutorials and manuals were created for them before the semester began. Those tutorials included step-by-step guidance of downloading the APP, installing the APP, and using the DQB to ask questions and respond. Around 20 students who needed extra help with the technology set-up approached us through WeChat individually and received personalized instructions.

Implementation. Although I was not on-site during each class, another research assistant and I observed students' interactions in the DQB at distance. We were prepared to solve any unexpected technical problem. After each class, I contacted the professor via WeChat to track his teaching and experiment progress. The observers also sent me the observation notes in a timely manner. Mostly the implementation was controlled by the instructor.

Data Collection. Almost all the data collection was done online, except for the consent forms and observation. As introduced before, the automatically recoded DQB data enabled researchers to study students' interactions in the digital platform unobtrusively. Online surveys made it easy for distribution, collection, and later analysis. However, collecting responses at a distance could hardly ensure the response rates, as some students might forget to do the survey, fail to submit, or encounter other technical problems. In the meantime, email was not widely used by Chinese students for communication; most of them used SNS such as WeChat instead. Thus, for the missing data, it was difficult to remind individual students of the survey submission through email.

Interviews were also conducted online. To build a closer relationship with interviewees and best capture their authentic reflection on their learning experience, the video chat feature of

WeChat was used. The online interview allowed the flexibility for interviewees to be in a place where they felt comfortable. For instance, during interviews, students were at home in their bedrooms, in the dormitory, and even walking in the playground. As participants regarded it as less formal than face-to-face communication, they were more open to share their thoughts. Video chat also made it possible for the interviewers to observe the interviewees' authentic facial expressions and body gestures, which all contributed to the understanding of their discourses. A few participants preferred voice chat because they felt less anxious and more comfortable off the screen. With consent, both video and audio were recorded for later data analysis, making it convenient to write up the transcripts. Despite the flexibility and advantages of online video interviews, it was still more impersonal than face-to-face communication, which might restrict the depth of qualitative analysis.

In summary, doing research at a distance required considerable preparation and management, especially when the intervention was conducted in a different country, in a different time zone. The advances of technologies brought about more flexibility and possibilities but required a comparatively higher technology competency level. It also involved multiple personnel that needed training and frequent, effective communications. Although it is challenging to conduct research at distance, it might become more popular as the world is becoming closer and transnational exchanges of culture, education, and business flourish.

Conclusion

This mixed-methods study revealed that, when the instructor discussed student questions after every 20–30 minutes in large lecture classes, the presence of the DQB with appropriate instructional strategies based on constructivist learning theories effectively facilitated student questioning and student engagement.

Students with DQB access had significantly higher questioning and answering frequency. The presence of the DQB enriched the types of questions responses and encouraged mostly on-task questions and peripheral questions that indicated their cognitive engagement. Students employed a non-linear process of questioning with DQB access, which facilitated their cognitive engagement. They employed appropriate strategies to resolve perplexity and browsed peers' Q&A to monitor their own learning. Those active attempts led to their improved self-regulation after six weeks. The presence of the DQB, the anonymity associated with it, and the commonality of questions all helped reduce the social pressure of questioning in large lecture classes and fear of being left behind or less competent. Thus, students were more confident to express their thoughts, which led to positive emotional engagement. They transformed from passive listeners to active "constructor." Lastly, with DQB access students actively provided help to those in need and posted various responses to help build a positive learning community, which benefited all students' engagement, contributing to a social constructivist learning environment.

Thus, this study suggested that a technology-mediated Q&A intervention might be useful for students who suffer from social pressure of posing questions, encouraging them to confidently express their confusion and receive feedback without fear of embarrassment and being judged. Such an intervention could also benefit other students, as it created a social constructivist learning component in large lecture classes to allow students to co-construct knowledge.

Closing Thoughts

This research topic emerged because of my own experience as a Chinese student who used to be silent in the class, having lots of thoughts and questions, but rarely made my voice heard. It was also common for many Chinese students I observed. In the meantime, students in the American classroom always amazed me with their confidence and openness in asking questions. Many professors in the U.S. also friendly encouraged us to express our thoughts verbally. I certainly believe that student interaction benefits learning, especially from a social constructivist perspective. However, it was difficult because of my cultural background and many motivational factors. Similarly, students in this study showed their preference for collectivism rather than individualism. Many students considered it disruptive to orally ask a question in large lecture classes. They prioritized other students' learning experience over solving their perplexity, which somehow inhibited them from obtaining timely help. They also attributed the reluctance of questioning to the culture-norm. Although we acknowledged the individual differences in learning, we advocated for openness and braveness. Why not enable students to voice silently? Why not allow students to contribute to the co-construction of knowledge silently? Fortunately, the fast development of technology brings possibilities for education. This study achieved my wish to provide students with an alternative communication channel to express their thoughts without the fear of embarrassment or being wrong. In this case, technology did not change the way students learn but enhanced it and provided students with more possibilities. Technology helped integrate a constructivist learning component into a large lecture class which was not initially ideal for constructivist learning.

This study also amazed me with the power of a social constructivist learning environment, where students not only cognitively contributed to the co-construction of knowledge but gave each other emotional supports, which had been easily ignored. Although there were still many deficiencies in this study, it has paved the way for my future research. I would like to try to integrate technology into teaching and learn to make education more inclusive.

Appendix A: Selected Examples of Engagement Measurement

Table A1

Selected Surveys Used to Measure Student Engagement at the Course or Activity Level

Name of instrument	Authored by	No.	Internal consistency (Cronbach's alpha)	Methods used to assess construct validity
Classroom Survey of Student Engagement (CLASSE)	Ouimet & Smallwood, 2005	N/A	N/A	N/A
Classroom Engagement Survey	Guertin et al., 2007	1	N/A	N/A
Engagement Questionnaire	Yang, 2011	20	N/A	N/A
Engagement Scale	Fredricks et al., 2005	19	0.67-0.86	Exploratory factor analysis
Learning Object Evaluation Scale	Kay & Knaack, 2009	12	0.78-0.89	Principal components factor analysis
National Survey of Student Engagement (NSSE)	Indiana University; Kuh, 2001	67	0.84-0.90	Principal components analysis
Online Student Engagement Scale (OSE)	Dixson, 2010	19	0.91	Exploratory factor analysis
Student Course Engagement Questionnaire (SCEQ)	Handelsman et al., 2005	23	0.76-0.82	Exploratory factor analysis
Agentic Engagement Scale (AES)	Reeve & Tseng, 2011; Reeve, 2013	22	0.78-0.94	Exploratory & confirmatory factor analyses

Table A2

Engagement Measurement Plan: Multimedia Learning Activity by Reading (2008)

Type	Indicator	Measurement method
Behavioral		
conduct	adhere to ICT-use rules	teacher-reported
work involvement	attention to learning	student-reported
participation	fulfill the role in groupwork	observer
Emotional		
relating to schoolwork	like to use ICT	student-reported
positive affect	enthusiasm for using ICT	teacher-reported
positive affect	confidence in ability	self-reported

Type	Indicator	Measurement method
Cognitive		
self-regulation	the transition between	teacher-reported
higher order thinking	activities synthesis of ideas	student-reported
instructional discourse	asks authentic questions	observer

Table A3

Zhu's (2006) Analytical Framework for Cognitive Engagement in Discussion

Category	Type	Characteristics	Example
Question	Type I	Seeking information (Vertical)	Question that has a direct and correct answer (e.g., What is an asynchronous discussion?)
	Type II	Inquiring or starting discussion (Horizontal)	Question that has no direct and correct answer. (e.g., How can we facilitate an online discussion?)
Statement	Type I	Responding	Statement that is made in direct response to a previous message(s), offering feedback, opinion.
	Type II	Informative	Statement that provides information (anecdotal or personal) related to the topic under discussion.
	Type III	Explanatory	Statement that presents factual information with limited personal opinions to explain related readings or messages.
	Type IV	Analytical	Statement that offers analytical opinions about responding to messages or related reading materials.
	Type V	Synthesizing	Statement that summarizes or attempts to provide a summary of discussion messages and related reading materials.
	Type VI	Evaluative	Statement that offers evaluative or judgmental opinions of key points in the discussion/related readings.
Reflection	Type I	Reflective of changes	Statement that reflects on changes in personal opinions and behaviors.
	Type II	Reflective of using cognitive strategies	Statement that explains or reflects on one's use of cognitive strategies/skills in accomplishing certain learning tasks.
Mentoring	Type I	Mentoring	Statement that explains or shows how the understanding of a particular concept is reached.
Scaffolding	Type I	Scaffolding	Statement that guides students in discussing concepts and in learning content materials by offering suggestions.

Table A4

Guo et al.'s (2014) Cognitive Coding Schema for Original Posting and Replying Postings

Cognitive Level		Standard, detailed description
Original posting	**Level 1**	Simple, layperson description.
	Level 2	Events labeled with appropriate terms.
	Level 3	Explanation with tradition or personal preference given as the rationale.
	Level 4	Explanation with principle/theory given as the rationale.
	Level 5	Explanation with principle/theory and consideration of context factors.
Replying posting	**Level 1**	Simple agreement or disagreement to the original postings.
	Level 2	Explanation with tradition, personal preference, or principle/theory given as the rationale.
	Level 3	Explanation with tradition, personal preference, or principle/theory given as the rationale, and consideration of context factors.

Table A5

Veerman and Veldhuis-Diermanse's (2001) Coding Scheme

Message	Example	Knowledge construction
Not task-related		
- **Planning**	*"Shall we first discuss the concept of "interaction?"*	---
- **Technical**	*"Do you know how to change the diagram window?"*	---
- **Social**	*"Smart thinking!"*	---
- **Nonsense**	*"What about a swim this afternoon?"*	---
Task-related		
- **New Idea**	*"Interaction means responding to each other"*	X
- **Explanation**	*"I mean that you integrate information of someone else in your own reply."*	X
- **Evaluation**	*"I do not think that is a suitable description because interaction means also interaction with computers or materials, see Laurillard's definition!"*	X

Table A6

Selected Examples of Content Analysis of Engagement

Content Types/Sources	Indicators/taxonomy/coding scheme	Authored by
Cognitive engagement		
Responses in the backchannel	Topic-relevant questions	Harunasari & Halim, 2019
Responses to a post quiz	Understanding reflected by the content	Harunasari & Halim, 2019
Interaction during online discussions	Types of questions; Bloom's learning hierarchy; Reflection, Mentoring and Scaffolding	Zhu, 2006
Posts in the discussion board	Gagne's (1968) hierarchy of thinking and Van Manen's (1977) idea of critical reflection	Guo et al., 2014
Posts in the discussion board	Messages that contain explicit expressions of knowledge construction (Veerman & Veldhuis-Diermanse, 2001)	Giesbers et al., 2014
The behavior of learning with the computer	Exploration (Student–software transaction, manipulation of the soft-ware, body posture, and off-task behavior)	Bangert-Drowns & Pyke, 2001
Text from an asynchronous discussion board, written reflections, responses in interviews	Exploration	Paulus et al., 2006
Samples of Twitter exchanges	Exploration	Junco et al., 2011
Comments from three open-ended questions	Exploration (Reflection of how the intervention influences students' likelihood of thinking about questions and responding to them during a lecture)	Barr, 2017
Emotional engagement		
Responses to open-ended survey questions	Exploration, e.g., "What, if anything, did you LIKE about the learning object?"	Kay & Knaack, 2009
Answers to four open-ended questions	Exploration, e.g., "Describe your experience with Twitter over the past semester. What did you like? What did you not like?"	Welch & Bonnan-White, 2012
Responses to a series of open-ended questions about students' experience in the use of microblogging	Exploration	Yates et al., 2015
Semi-structured online interviews of students' perspectives	Exploration	Harunasari & Halim, 2019

Appendix B: Training Protocol

1. Installation

- How to download the APP (iOS/Android).
- How to install the APP (iOS/Android).
- How to sign up, log in and log out the APP (iOS/Android/PC).

2. Functions & Features

- How to create/delete a Padlet.
- The layouts of a Padlet.
- How to create/delete a post.
- How to response to others/add comments.
- How to "like" a post.
- The multi-media options.

3. Uses of the DQB

- How to access the DQB (iOS/Android/PC)
    - Display to students a PPT that includes a QR code and link to the DQB.
- How to set up a DQB.
- The components and layouts of a DQB.
- How to browse the DQB.
    - New posts display at the top left.
    - The meanings of various icons (e.g., "+" & "❤")

4. Instructional Strategies

- Inform students at the beginning of each class that the instructor would review the DQB and give responses once after a while.
- When to review student questions.
    - The frequency of browsing the DQB: after every 20-30 minutes' lecture.
    - The length of Q&A sessions: 5-10 minutes depending on the frequency of questions and responses.
- How to give responses.
    - Prioritize question(s) with the most "likes" or multiple comments, and ones have incorrect student responses.
    - Do not ignore "simple" questions.
    - If all the questions could not be resolved within 5-10 minutes, make random selection.
- Encourage oral interactions between students.

Appendix C: Survey Instruments

Pre-test

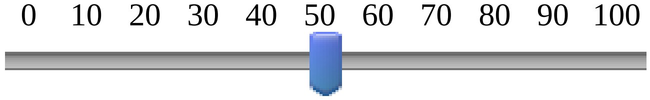
Dear Student,
Hello! The purpose of this questionnaire is to understand your attitudes and perceptions of this course regarding classroom interaction, online interaction, etc. to analyze whether online interactive software could be used in this course to create a better learning experience for you to facilitate teaching and learning. The information in the questionnaire will be used for research purposes only. There are no right or wrong answers, but your answers are critical to the implementation and improvement of the course, so please make sure you answer based on your own thoughts and circumstances. Please select and click on the one that most closely matches your knowledge and experience. Wait until you see "Thank you for taking the time to participate in this survey. Your response has been recorded." This indicates that you have successfully completed the survey.
Thank you for your cooperation!

1 What is your name? ____________
2 What is your ID? ____________
3 How you define your gender?
- o Female
- o Male
- o Other

4 Your current GPA is approximately closest to ( )
- o 4.0
- o 3.0
- o 2.0
- o 1.0
- o unknown

5 What is your expected grade for this course? Click and drag the lower ruler to the corresponding value.

0 10 20 30 40 50 60 70 80 90 100



6 This semester, on average, I interacted with the instructor and peers ( ) times in class in other courses.
- o 0
- o 1~2
- o 3~4
- o 5~6
- o 7 and above

7 Do you own the following devices or accounts? (check all that apply)

	Yes	No
Desktop	o	o

Laptop or tablet	o	o
Smartphone	o	o
WeChat account	o	o
Weibo account	o	o
QQ account	o	o
E-mail	o	o

8 Have you ever used a smartphone to participate in the interactions in other classes through an audience response system (e.g., clickers)?

o Yes
o No

9 In which stages or scenarios have you used the audience response system? Check all that apply.

- ☐ Primary school
- ☐ Middle school
- ☐ High school
- ☐ Other undergraduate classes
- ☐ after-school training institutions
- ☐ Other, please specify___________.

10 Have you ever used a smartphone for learning purposes after class?

o Yes
o No

11 How did you use a smartphone for learning? (check all that apply)

- ☐ Searching information, materials for learning purposes
- ☐ Discussing with classmates
- ☐ Learning English
- ☐ Note-taking
- ☐ Doing E-homework
- ☐ Exercising with Question Bank
- ☐ Other, please specify__________

12 What brand(s) of smartphone do you use?

- ☐ Huawei
- ☐ Xiaomi
- ☐ OPPO
- ☐ iPhone
- ☐ Samsung
- ☐ Vivo
- ☐ Rongyao
- ☐ Other, please specify__________.

13 The following ten items are designed to understand how you see yourself. Please read the sentences below carefully and choose the option that best fits your situation. Please note that the answer here is what you actually think of yourself, not what you think you should be.

1 = Very untrue of me
2 = Untrue of me

3 = Somewhat untrue of me
4 = Neutral
5 = Somewhat true of me
6 = True of me
7 = Very true of me

	1	2	3	4	5	6	7
On the whole, I am satisfied with myself.	○	○	○	○	○	○	○
At times I think I am no good at all.	○	○	○	○	○	○	○
I feel that I have a number of good qualities.	○	○	○	○	○	○	○
I am able to do things as well as most other people.	○	○	○	○	○	○	○
I feel I do not have much to be proud of.	○	○	○	○	○	○	○
I certainly feel useless at times.	○	○	○	○	○	○	○
I feel that I am a person of worth, at least on an equal plane with others.	○	○	○	○	○	○	○
I wish I could have more respect for myself.	○	○	○	○	○	○	○
All in all, I am inclined to feel that I am a failure.	○	○	○	○	○	○	○
I take a positive attitude toward myself.	○	○	○	○	○	○	○

14 Please choose the number between 1 and 7 that best suits your situation and your feelings.

1 = Very untrue of me
2 = Untrue of me
3 = Somewhat untrue of me
4 = Neutral
5 = Somewhat true of me
6 = True of me
7 = Very true of me

	1	2	3	4	5	6	7
I think I can apply what I learn in this course to another course.	○	○	○	○	○	○	○
I believe I will receive an excellent grade in this class.	○	○	○	○	○	○	○
I am certain I can understand the most difficult material presented in the readings for this course.	○	○	○	○	○	○	○
I am confident I can understand the basic concepts taught in this course.	○	○	○	○	○	○	○

I am confident I can understand the most complex material presented by the instructor in this course.	○	○	○	○	○	○	○
I am confident I can do an excellent job on the assignments and tests in this course.	○	○	○	○	○	○	○
I am certain I can master the skills being taught in this class.	○	○	○	○	○	○	○
Considering the difficulty of this course, the teacher, and my skills, I think I will do well in this class.	○	○	○	○	○	○	○

15 The following ten items are designed to help you understand your classroom strategies and habits, so please choose the number from 1 to 7 that best suits your situation. Choose based on your first impressions.

1 = Very untrue of me
2 = Untrue of me
3 = Somewhat untrue of me
4 = Neutral
5 = Somewhat true of me
6 = True of me
7 = Very true of me

	1	2	3	4	5	6	7
Before the class begins, I often look at the outline to learn the objectives.	○	○	○	○	○	○	○
I set goals for myself in order to facilitate my learning in each class.	○	○	○	○	○	○	○
During class time, I often miss important points because I am thinking of other things.	○	○	○	○	○	○	○
When listening to the lecture, I try to determine which concepts I do not understand well.	○	○	○	○	○	○	○
I ask myself questions to make sure I understand the content.	○	○	○	○	○	○	○
I often find that I have been listening to the lecture but do not know what it was all about.	○	○	○	○	○	○	○
I try to think through a topic and decide what I am supposed to learn from it rather than just listening to the lecture.	○	○	○	○	○	○	○
If I get confused during the lecture, I make notes and plan to sort it out afterward.	○	○	○	○	○	○	○
If I get lost during the lecture, I often cannot concentrate anymore.	○	○	○	○	○	○	○
Sometimes I do not even know if I understand the content or not.	○	○	○	○	○	○	○

Thank you for taking the time to participate in this survey. Your response has been recorded. Enjoy your studies! ：）

Post-test 1 (Phase 1)

Dear Students,
To understand your experience and feelings of this course in the past three weeks and design instructional activities to accommodate your learning needs and create a better learning environment, please take about 10~15 minutes to fill in the following questionnaire: link.
Your answers in this survey will not influence your course grade. There is no difference between right and wrong in the answer itself. Please answer each question to the best of your knowledge. Your responses will be kept completely confidential. Thank you again for taking the time to complete this questionnaire.

1 What is your name? ____________
2 What is your ID? ____________
3 What section are you in?
- o Thursday Morning (Section A)
- o Thursday Afternoon (Section B)

4 In the past three weeks, except the first time being introduced to the DQB, have you ever voluntarily browsed the DQB?
- o Yes
- o No

5 During the weekly 3.5-hour lecture class, how frequently did you browse the DQB?
- o ≦1
- o 2~3
- o 4~5
- o 6~7
- o ≧8

6 How did you use the DQB?
- o I only browsed the DQB when I had questions
- o Even if I did not have questions, I browsed the DQB to review other students' questions.
- o Other (please specify__).

7 In the past three weeks, have you ever asked questions in the DQB?
- o Yes
- o No

8 In the past three weeks, have you ever answered others' questions in the DQB?
- o Yes
- o No

9 How many questions did you ask in the DQB in the past three weeks?
_______ with real name
_______ anonymously

10 How many questions did you answer in the DQB in the past three weeks?
_______ with real name
_______ anonymously

11 Were your question(s) answered/resolved?

- o Yes
- o No

12 How were/was your question(s) answered/resolved? (check all that apply)

- ☐ The instructor answered my question(s).
- ☐ My question(s) were covered by later lecture.
- ☐ My peers answered my questions in the DQB.
- ☐ I asked the instructor after class.
- ☐ I did not have questions to ask.
- ☐ Other, please specify__________.

13 Why didn't you browse the DQB?

- ☐ I encountered a technical
- ☐ I was concentrated in class and had no time to browse.
- ☐ I thought we should browse it after class.
- ☐ Other, please specify__________.

14 The following ten items are designed to help you understand your classroom strategies and habits, so please choose the number from 1 to 7 that best suits your situation. Choose based on your first impressions.

1 = Very untrue of me
2 = Untrue of me
3 = Somewhat untrue of me
4 = Neutral
5 = Somewhat true of me
6 = True of me
7 = Very true of me

	1	2	3	4	5	6	7
Before the class begins, I often look at the outline to learn the objectives.	○	○	○	○	○	○	○
I set goals for myself in order to facilitate my learning in each class.	○	○	○	○	○	○	○
During class time, I often miss important points because I am thinking of other things.	○	○	○	○	○	○	○
When listening to the lecture, I try to determine which concepts I do not understand well.	○	○	○	○	○	○	○
I ask myself questions to make sure I understand the content.	○	○	○	○	○	○	○
I often find that I have been listening to the lecture but do not know what it was all about.	○	○	○	○	○	○	○
I try to think through a topic and decide what I am supposed to learn from it rather than just listening to the lecture.	○	○	○	○	○	○	○
If I get confused during the lecture, I make notes and plan to sort it out afterward.	○	○	○	○	○	○	○

	1	2	3	4	5	6	7
If I get lost during the lecture, I often cannot concentrate anymore.	○	○	○	○	○	○	○
Sometimes I do not even know if I understand the content or not.	○	○	○	○	○	○	○

Thank you for taking the time to participate in this survey. Your response has been recorded. Enjoy your studies! ：）

Post-test 2 (Phase 2)

Dear Students,
Hello! This questionnaire is designed to capture your experience and feelings of this course in the past three weeks, as well as your overall experience with the course this semester. The information in the questionnaire will be used for research purposes only. There is no difference between right and wrong in the answer itself. Please answer each question to the best of your knowledge. Wait until you see "Thank you for taking the time to participate in this survey. Your response has been recorded." This indicates that you have successfully completed the survey. Thank you for your cooperation!

1 What is your name?

____

2 What is your ID?

____

3 What section are you in?

- o Thursday Morning (Section A)
- o Thursday Afternoon (Section B)

4 The following ten items are designed to help you understand your classroom strategies and habits, so please choose the number from 1 to 7 that best suits your situation. Choose based on your first impressions.

1 = Very untrue of me
2 = Untrue of me
3 = Somewhat untrue of me
4 = Neutral
5 = Somewhat true of me
6 = True of me
7 = Very true of me

	1	2	3	4	5	6	7
Before the class begins, I often look at the outline to learn the objectives.	○	○	○	○	○	○	○
I set goals for myself in order to facilitate my learning in each class.	○	○	○	○	○	○	○
During class time, I often miss important points because I am thinking of other things.	○	○	○	○	○	○	○

When listening to the lecture, I try to determine which concepts I do not understand well.	○	○	○	○	○	○	○
I ask myself questions to make sure I understand the content.	○	○	○	○	○	○	○
I often find that I have been listening to the lecture but do not know what it was all about.	○	○	○	○	○	○	○
I try to think through a topic and decide what I am supposed to learn from it rather than just listening to the lecture.	○	○	○	○	○	○	○
If I get confused during the lecture, I make notes and plan to sort it out afterward.	○	○	○	○	○	○	○
If I get lost during the lecture, I often cannot concentrate anymore.	○	○	○	○	○	○	○
Sometimes I do not even know if I understand the content or not.	○	○	○	○	○	○	○

5 Have you encountered perplexity in class when the instructor was lecturing?

- o Yes
- o No

6 When you encountered perplexity in class, what did you do to resolve your problem/confusion? (check all that applies)

- ☐ Asked classmates orally in class
- ☐ Asked the instructor orally in class
- ☐ Asked questions in the DQB
- ☐ Asked classmates after class
- ☐ Asked the instructor after class
- ☐ Figured it out on my own
- ☐ Other, please specify__________

7 In the past three weeks, except the first time being introduced to the DQB, have you ever voluntarily browsed the DQB?

- o Yes
- o No

8 During the weekly 3.5-hour lecture class, how frequently did you browse the DQB?

- o ≦1
- o 2~3
- o 4~5
- o 6~7
- o ≧8

9 How did you use the DQB?

- o I only browsed the DQB when I had questions
- o Even if I did not have questions, I browsed the DQB to review other students' questions.
- o Other (please specify__).

10 In the past three weeks, have you ever asked questions in the DQB?

- o Yes

- No

11 In the past three weeks, have you ever answered others' questions in the DQB?

- Yes
- No

12 How many questions did you ask in the DQB in the past three weeks?

_______ with real name

_______ anonymously

13 How many questions did you answer in the DQB in the past three weeks?

_______ with real name

_______ anonymously

14 Were your question(s) answered/resolved?

- Yes
- No

15 How were/was your question(s) answered/resolved? (check all that apply)

- ☐ The instructor answered my question(s).
- ☐ My question(s) were covered by later lecture.
- ☐ My peers answered my questions in the DQB.
- ☐ I asked the instructor after class.
- ☐ I did not have questions to ask.
- ☐ Other, please specify__________.

16 Why didn't you browse the DQB?

- ☐ I encountered a technical
- ☐ I was concentrated in class and had no time to browse.
- ☐ I thought we should browse it after class.
- ☐ Other, please specify__________.

17 Have you ever encountered a technical problem when you accessed the lecture?

- Yes, _____ times.
- No
- I never used the DQB.

18 What technical problems have you encountered? (check all that apply)

- ☐ I could not access the DQB.
- ☐ It took too long to load the DQB/display the content.
- ☐ The APP directed me to the web automatically.
- ☐ Other (please specify)

19 In general, are you satisfied with learning with the DQB?

- Very satisfied
- Satisfied
- Somewhat satisfied
- Neutral
- Somewhat dissatisfied
- Dissatisfied
- Very dissatisfied

20 How much did the interactions with the DQB help your learning?

- o Very useful
- o Useful
- o Somewhat useful
- o Neutral
- o Somewhat useless
- o Useless
- o Very useless

21 How much did browsing the DQB help with your understanding in class?

- o Very useful
- o Useful
- o Somewhat useful
- o Neutral
- o Somewhat useless
- o Useless
- o Very useless

22 What suggestions or opinions do you have regarding the uses of the DQB?

____

____

____

23 What would you change about this course and why?

____

____

____

24 What would you recommend keeping in this course, and why?

____

____

____

25 Do you have any other suggestions or comments?

____

____

____

Thank you for taking the time to participate in this survey. Your response has been recorded. Enjoy your studies! ：）

Appendix D: Interview Protocol

Opening:

Hi [Interviewee]! Thank you for participating in this interview! I am the teaching assistant for the course. During this interview, I will ask you to share some experiences and feelings about your learning in this course and other large lecture classes. The interview will last about 45 minutes. The whole process will be recorded. All your personal information will be kept confidential and will only be used for data analysis. Once the analysis is completed, the recorded data will also be deleted. I hope you can say what you really think, which is very important for improving the course and helping you learn better! You can also refuse to answer any questions. To begin this interview, I would like to ask you some questions about your background information. Let us get started, shall we?

1. Questions regarding students' background information

- What is your ideal major? Is education your desired major? How did you decide to study education?
- What is your future plan? What is your desired career? Do you plan to be a teacher or researcher? Is this course helpful for your career development?
- Do you plan for a master's or doctoral degree? If so, what major will you pursuit? Why? Will you go to graduate school?
- How was your English proficiency before you entered college? What score did you get for the English test of the college entrance examination? What is your CET-4 score?
- What city are you from? Where is your hometown?
- How was your teacher-student relationship in high school/college? What about in this course and other courses?

2. Attitude towards the research method course

- What did you know about the research method before you took the course?
- How did you decide to take this course?
- What was your expectation out of this course (research method)? What did you expect to learn from this course?
- Are you interested in this course? If so, where? If not, why not?
- What did you learn in this course? Can you give me an example?
- What do you think about learning activities, assignments, and assessments?

- How do you think of the professor's style of teaching? Do you think the professor encourages interaction or student questioning?
- Compared with other courses this semester, how difficult do you think of this course from 1-10? Ten is the most difficult. What is the average difficulty of other courses?
- How do you evaluate the course and the instructor? Is this course useful to you?
- Do you have any suggestions for improving this course?

3. Opinions and attitudes regarding large lecture classes in general

- Have you ever experienced large lecture classes besides this course? In your experience, how many students were there in the largest class you have been in?
- If yes, what were the courses? Can you describe their formats and how the instructors organized the courses? What instructional strategies did you observe? Please describe how the teachers give lectures and the way students interact with each other. What learning activities have you participated in? Can you give an example?
- Could you describe your general learning pattern in a large lecture class?
- How was the interaction in the large lecture classes you experienced? Did you and your classmates actively interact (ask questions, discuss, exchange ideas) in those classes?
- If you always observed silence (e.g., lack of interaction, student questioning) in large lecture classes, what might be the reasons?
- Do you think it is necessary to encourage student interaction or questioning in large lecture classes, and why?
- Compare large lecture classes to smaller sized classes; what are the differences? Which one do you prefer and why? Do you learn differently?

4. Learning strategies

- What were some learning strategies you employed in class? Did you take notes in class?
- Do you usually ask questions in class?
- Have you ever been absent-minded in class? How do you stay focused in class?
- Where do you usually sit in the classroom?
- Do you usually prepare the lesson in advance? Do you usually review the lesson after class? If so, how often and how long do you review or preview?

- What do you think of interaction? What different interaction habits have you observed among students?
- What did you do if you encountered perplexity in class? How do you usually ask for help? Who do you usually turn to for help (classmates, teachers, Internet, Library)? Why?

5. Experience and attitudes of learning with the DQB

- Describe your experience with the DQB over the past semester. What did you like? What did you not like?
- Compare this course to your other large lecture classes that did not use the DQB. What are the differences?
- Did you find yourself enjoy this class more or less?
- How do you evaluate the DQB?
- Have you used/browsed the DQB voluntarily? If yes, how frequently did you use it? How did you use it? If not, what are the reasons?
- Have you ever asked questions in the DQB? If so, has your question been answered? How was your problem solved?
- Does the DQB prevent you from concentrated in class?
- Have you ever shared with other students the experience of learning with the DQB?
- What other functions do you want the DQB to have to promote learning?
- What are the strengths and weaknesses of this tool? What are the advantages and disadvantages of this tool (compared with other learning software)?

6. Other

- Is there anything you want to share that I did not ask?
- Do you have any suggestions for future students to take this course?
- Please summarize the two aspects of this course that you like best and the two aspects that need improvement.

Appendix E: Observation Protocol

Week:___Group: A__Observer:_____Date:____Time:____Number of students: ______

At the beginning of class, did the instructor:	
Inform students how frequently the instructor would review the DQB.	☐
Encourage students to ask questions and answer others' questions	☐
Encourage students to modify or answer their own questions if they resolve them during the lecture to help other students with similar questions.	☐

Lecture session 1	**Start:**	**End:**
Overall observation Overall impression of the lecture, e.g., Were most students focused? was the instructor tired? Was the instructor energetic? Did the student sleep or chat?	"Students: When the instructor talked about learning objectives, most of the students were taking notes, 2 students were chatting, and 2 students took a photo of the PPT." "Instructor: energetic."	
Student Questioning Do students pose any questions orally during the lecture? What are the questions?	*None*	
Instructor-Student interaction How does the instructor respond to the questions? How do the students react?	*None*	

Q&A session 1	**Start:**	**End:**
Student behavior		
• By the time of observation, in the DQB, how many questions are there?		11
• How many "likes" are there?		several
• How many "responses/answers" are there?		0
Student behavior in the classroom What are students doing when the instructor reviews the question board (before he starts to answer questions)? Dido students ask questions or respond to the instructor's feedback orally?	Most students bow their heads, and some students are watching PPT/computer.	
Instructor behavior		
How many questions does the instructor select to answer?		3
What are the questions? How does the instructor provide oral feedback to students' questions and responses? *(make a screenshot)*	(attached a screenshot of the questions, among which the observer crossed ones that have been answered by the instructor)	
Overall observation	Student: few students look at the screen; most bow down and look at their computers. Instructor: energetic	

Note: for each class, there are three-four same sections for lecture or Q&A sessions. To save place, there is only one set of sections included here. The current examples were filled by Observer 1 for Week 7, Experimental group.

Appendix F: IRB Approval

SYRACUSE UNIVERSITY

INSTITUTIONAL REVIEW BOARD
MEMORANDUM

TO: Qiu Wang
Jing Lei
DATE: November 30, 2018
SUBJECT: **Determination of Exemption from Regulations**
IRB #: 18-364
TITLE: *The Influence of Audience Response System on Students' interaction in a Blended Course*

The above referenced application, submitted for consideration as exempt from federal regulations as defined in 45 C.F.R. 46, has been evaluated by the Institutional Review Board (IRB) for the following:

1. determination that it falls within the one or more of the five exempt categories allowed by the organization;
2. determination that the research meets the organization's ethical standards.

It has been determined by the IRB this protocol qualifies for exemption and has been assigned to category **1**. This authorization will remain active for a period of five years from **November 29, 2018** until **November 28, 2023**.

CHANGES TO PROTOCOL: Proposed changes to this protocol during the period for which IRB authorization has already been given, cannot be initiated without additional IRB review. If there is a change in your research, you should notify the IRB immediately to determine whether your research protocol continues to qualify for exemption or if submission of an expedited or full board IRB protocol is required. Information about the University's human participants protection program can be found at: http://researchintegrity.syr.edu/human-research/ Protocol changes are requested on an amendment application available on the IRB web site; please reference your IRB number and attach any documents that are being amended.

STUDY COMPLETION: Study completion is when all research activities are complete or when a study is closed to enrollment and only data analysis remains on data that have been de-identified. A Study Closure Form should be completed and submitted to the IRB for review (Study Closure Form).

Thank you for your cooperation in our shared efforts to assure that the rights and welfare of people participating in research are protected.

Tracy J. Cromp

Tracy Cromp, M.S.W.
Director

DEPT: Higher Education, 350 Huntington Hall

STUDENTS: Jiaming Cheng, Lili Zhang

Research Integrity and Protections | 214 Lyman Hall | Syracuse, NY 13244-1200 | 315.443.3013 | **orip.syr.edu**

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No. 3663, North Zhongshan Road, Shanghai, China, 200062
Tel:（86-21）62233333 Http://www.ecnu.edu.cn

November 8, 2018

Office of Research Integrity and Protections
214 Lyman Hall
Syracuse, NY 13244

To Whom It May Concern:

Drs. Qiu Wang (PI) and Jing Lei (Co-PI) have requested permission to collect de-identified research data from first-year students in the Faculty of Education (FOE) at East China Normal University (ECNU), through a project entitled *the Influence of Audience Response System on Students' interaction in a Blended Course*. I have been informed the purposes of the study and the nature of the research procedures. I have also been given an opportunity to ask questions of the research. I believe that the proposed anonymous procedures with experimenter-blind design will minimize potential risks and maximize interactive learning effects in the proposed technology rich interactive online-and-face-to-face blended environment.

As the Director of International Affairs Division and an official of the Ethics Committee (IRB equivalent) at ECNU, I grant permission to the research team led by Drs. Wang and Lei to conduct the proposed project and collect data through the FOE first-year course of *Educational and Psychological Research* at ECNU. We will also assist the implementation of the proposed research design and data collection protocols at ECNU. Given the Exempt-nature of the application, we defer to the SU's Office of Research Integrity and Protections and we will accept the SU-IRB committee's review approval(s) of this line of research.

Please feel free to contact me if you have any questions.

Sincerely,

Fuyi Yang

Fuyi Yang, Ph.D.
Director of International Affairs Division
Professor of Special Education
Faculty of Education
East China Normal University
3663 North Zhongshan Rd., Shanghai, China, 200062
Email: fyyang@spe.ecnu.edu.cn
Tel: +86-21-62224962
Fax: +86-21-6222725

Appendix G: Recruitment letter

Dear student name,
As a teaching and research team of *the Introduction to Educational Research Method*, we invite you to participate in the study on the effectiveness of the audience response system.
Your participation could help us to improve the design of these courses, bringing better learning experiences to future students. Your contribution is also very important for researchers, scholars, and practitioners to get a better understanding of the design of other method courses.
By participating in this in-class study, **no additional time commitment** is needed. We only seek your permission to use all your **course materials**. All information will be kept confidential.
Your participation in this study is voluntary, and you may withdraw at any time.
Please follow the link below to open the Consent Form for more details:
Consent Form (*the link to the consent form will be added here*)
Alternatively, you could copy and paste the URL below into your internet browser:
The link to the consent form
Sincerely invite you to participate in this study.
Thanks for your time.

Sincerely,
Dr. Qiu Wang
Associate Professor, Higher Education, School of Education, Email: wangqiu@syr.edu
Dr. Jing Lei
Professor, Chair of IDD&E, School of Education, Email: jlei@syr.edu
Jiaming Cheng
Doctoral Candidate, IDD&E, School of Education, Email: jcheng06@syr.edu
Lili Zhang
Doctoral Student, IDD&E, School of Education, Email: lzhan16@syr.edu

Appendix H: Consent Form

INSTRUCTIONAL DESIGN, DEVELOPMENT, AND EVALUATION
259 Huntington Hall, Syracuse, NY, 13224
The Influence of Audience Response System on Students' interaction in a Blended Course

Dear Student,

We are doctoral students at Instructional Design, Development, and Evaluation Department of Syracuse University School of Education. We are Jiaming Cheng and Lili Zhang. We are inviting you to participate in a research study. Involvement in the study is voluntary, so you may choose to participate or not. If you decide to take part and later no longer wish to continue, you have the right to withdraw from the study at any time, without penalty. This sheet will explain the study to you and please feel free to ask questions about the research if you have any. I will be happy to explain anything in detail if you wish.

We are interested in learning more about the design for research method introduction course for undergraduate students. We hope to improve the quality of the course and provide empirical evidence for the design of other method courses. We are requesting that you give us permission to analyze your completed course assignments, quiz scores and class discussions for research purposes. Additionally, the questionnaires about classroom interaction you will filled out and course evaluation will also be collected. You will not be required to do anything more than what is required in the course syllabus and instructions.

All information will be kept confidential. No one will access to your course materials except the researchers. This means that your name will not appear anywhere, and your specific answers will not be linked to your name in any way. Your agreement (or not) to allow us to use your course data will have no effect on your course grade, and the instructor will not know who has participated in the research until final grades are entered in the system. Not consenting does not excuse you from any required courses activities. We will access and analyze course materials after the course ends, looking for evidence to support future gamification design. There is a possibility that the results of this study will be published or used for instructional purposes. Your name and other personal identifiable information will be removed, and your personal information will not be revealed.

The benefit of this research is that you will be helping us to enhance research method course design; it also helps researchers and educators who share the same interests to provide high-quality method courses to students. The risk to you is minimal; you may feel anxious or resistant to being honest in your feedback when responding to evaluations. We hope to minimize your risks and anxiety by accessing data only after grades have been submitted and using codes instead of your name in the evaluation. Your final grade will not be affected whether you grant permission to use your course assignments, or not.

By signing this form, you agree to release all your course assignments and participation records for research purposes. A copy of this signed consent form will be provided to you. You have the right to refuse to release the materials, without penalty. In that case, none of your materials (assignments, discussions, course evaluation) will be used. Also, the participation is voluntary,

and you can withdraw from the study at any time without penalty.
Please feel free to contact us if you have any questions, concerns or complaints. Our contact information is listed below. You may also contact the Institutional Review Board (contact information listed below) if you have questions regarding your rights as a participant, or if you have questions, concerns, or complaints that you wish to address to someone other than the investigators, or if you cannot reach the investigator.

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All my questions have been answered, I am 18 years of age or older, and I wish to participate in this research study.

Please type/ print your name below and sign and date the form.

________________________________ ____________________
Signature of participant Date

____
Printed name of participant

________________________________ ____________________
Signature of researcher Date

____
Printed name of researcher

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B.S. - English for Economics and Trade 2012
Southwestern University of Finance and Economics, Chengdu, China

DISSERTATION

The Use of a Digital Question Board to Facilitate Student Questioning and Engagement in Large Lecture Classes: A Mixed-Methods Study
Committee: Dr. Jing Lei (Chair), Dr. Tiffany A. Koszalka, Dr. Moon-Heum Cho

WORK EXPERIENCE

Syracuse University 2017/8-2020/5

- Taught IDE201, Integrating Technology into Instruction I; IDE401, Integrating Technology into Instruction III.
  - This series of undergraduate courses are designed for pre-service and in-service teachers and students who are interested in technology use in educational settings, especially in PreK-12 schools. This series of courses help students develop an understanding of the concept of technology integration and help bring relevance to the how and why of technology integration into instruction.
- Designed and took the lead of workshops IDD&E department provided for Fulbright Scholars, covering Web 2.0, Web Accessibility, Web info evaluation; Digital Storytelling, Visualization, Gamification and Technology-enhanced assessment for diverse learners.

Sichuan Assessment & Evaluation Center for Basic Education
Sichuan Education Science Research Institute 2014/6-2017/6

- Designed and managed information system (data collection and analysis system, item bank); designed and developed series of tutorials.
- Organized series of educational assessment and evaluation projects, participating in every phase including design and development of test tools and methods, organization of both online and offline test, online marking, designating of standard, data analysis and report writing:
  - *2016 National Quality Monitoring and Evaluation of the Chinese and Art Study of Students at the Stage of Compulsory Education in Sichuan*.
  - *2015 Assessment and Evaluation of the Reading Literacy of Students at the Stage of Compulsory Education in Sichuan*.
  - *Survey of the Degree of Satisfaction of Country Compulsory Education in Sichuan*.
  - *Survey of the Evaluation of the Balanced Development of Country Compulsory Education in Sichuan* (2014 & 2015 reports published).
- Drafted the provincial standard of the *Quality Evaluation Criterion of the Academic*

Quality Monitoring Tool of Basic Education (DB51/T 2115—2016, published).

- Participated in the *Research on the K-12 Innovation Education Based on the Innovation Course Laboratory* and gave the opening report.
- Designed and organized the *Contest of the Application of WeChat Public Platform to Display K-12 School Culture in Sichuan*.

Chengdu Eastedu Science and Technology Ltd & Chengdu Eastedu No.7 High School E-campus

Full-time: 2012/01-2012/06; 2014/01-2014/7; Part-time: 2012/06-2016/05

- Designed and developed series software and systems such as *Future Classroom App* (E-Classroom), *Synchronous Test and Analysis tool*, *Item Bank.*
- Participated in the operation and evaluation of the full-time live distance education projects of elementary and middle schools.
- Directed live courses to more than 200 high schools and assisted lectures with teaching courseware.
- Participated in the preparation of the visit of Michelle Obama to Chengdu No.7 High School and gave the introduction of the distance education project on the scene.

SCHOLARLY WORKS

Journal Articles

- **Zhang, L**., Cheng, J., Lei, J., & Wang, Q. (2020). The Use of Digital Question Board to Facilitate Large Lecture Class. Manuscript in preparation.
- **Zhang, L**., Cheng, J., Lei, J., & Wang, Q. (2020). How the Anonymous Feature of Audience Response System Influences the Interactions of Students by Different Types of Questions. *Journal of Educational Technology Development and Exchange* (JETDE). Reviewed and resubmitted.
- **Zhang, L**., & Zhang, Y. (2018). A pilot study of the influence of social anxiousness on students' classroom interactions among Chinese undergraduates. *Journal of Global Education and Research*, 2(1), 61-71. Retrieved from https://scholarcommons.usf.edu/jger/vol2/iss1/5
- **Zhang, L**. (2017). Use Interactive Video to Improve Online Learning. *The Chinese Journal of ICT in Education*. 20, 94-96.
- **Zhang, L**. (2017). Misuse of Gamification in Educational APP. *The Chinese Journal of ICT in Education*, 2, 16-19.
- **Zhang, L**., Liu, Y., Tang, H. (2016). *Comparative-effectiveness research of two types of smart bilingual subtitles*. International Journal of Instructional Technology and Distance Learning, 13(8), 37-47.
- **Zhang, L**., Li, W. (2016). The Gamification of MOOCs. *China Information Technology Education*. 13, 117-120.
- **Zhang, L**., Zhang, X. (2016). Artificial Intelligence and Basic Education. *Education Science Forum*. 10, 28-29.

Book Chapter

- Koszalka, T.A., Wilhelm-Chapin, M.K., Hromalik, C.D., Pavlov, Y., & Zhang, L. (2019). Prompting deep learning with interactive technologies: Theoretical perspectives in designing interactive learning resources and environments. In P. Díaz, A. Ioannou, K.K. Bhagat, & J.M. Spector (Eds.), *Learning in a digital world: Perspective on interactive technologies for formal and informal education* (pp. 13–36). Singapore: Springer. doi: 10.1007/978-981-13-8265-9_2

Conference Presentations

- **Zhang**, L., Cheng, J., Lei, J., & Wang, Q. & Yang, F. (2021, Accepted). *The Use of a Digital Question Board to Engage "Vulnerable Students" in Large Lecture Classes*, 2021 AERA Annual Virtual Meeting.
- **Zhang, L**., Yang, T., Niu, Z., Lei, J., & Wang, Q. (2020, Accepted). *Using a Digital Canvas to Improve Student Interaction and Engagement in Large Lecture Classes*, 2020 AECT International Convention in Jacksonville.
- **Zhang, L**., Cheng, J., Lei, J., Wang, Q. & Yang, F. (2020, Accepted). *The Use of a Digital Question Board to Encourage Student Questioning and Improve Engagement in Large Lecture Classes*, 2020 AECT International Convention in Jacksonville.
- Lei, J., **Zhang, L.,** Cheng, J., Yang, T., & Wang, Q. (2019, Accepted). *Digital Natives as Preservice Teachers: What Technology Do They Use and How*, 2020 AERA Annual Meeting in San Francisco, California.
- **Zhang, L.,** Cheng, J., Lei, J., & Wang, Q. (2019). *The Use of Digital Question Board to Facilitate Large Lecture Class*, 2019 AECT International Convention in Las Vegas.
- Lei, J., **Zhang, L**., Cheng, J., Yang, T., & Wang, Q. (2019). *Digital Natives as Preservice Teachers: What Technology Do They Use and How*, 2019 AECT International Convention in Las Vegas.
- Cheng, J., Lei, J., **Zhang, L**. (2018*). The influence of gamification design on students' interaction in an online discussion forum*, 2019 AERA Annual Meeting in Toronto, Canada.
- Cheng, J., **Zhang, L**., Lei, J. (2018). *Assessing Online Academic Discussion from a Knowledge Building Perspective: An Exploratory Case Study*, 2019 AERA Annual Meeting in Toronto, Canada.
- **Zhang, L**., Cheng, J., Lei, J. (2018). *The Influence of Anonymous Feature of ARS on the Interactions of Students with Different Levels of Social Anxiousness*, 2018 AECT International Convention in Kansas City, MO, United States.

GRANTS, HONORS, AWARDS

Syracuse University

- Nomination for the Outstanding Dissertation Award — 2020
- IDD&E Dissertation Fellowship
- IDD&E Project Leadership Award
- Margaret & Alexander Charters Award for Scholastic Excellence in Adult and Continuing Education
- School of Education Research & Creative Grant — 2019
- IDD&E Design and Development Award — 2014
- School of Education Scholarship — 2013

AECT — 2019

- SICET Best Paper (the Society of International Chinese in Educational Technology)

Southwestern University of Finance and Economics — 2008 - 2012

- The First Prize Scholarship, Merit Student, Scholarships for Culture and Arts Prize
- Outstanding Graduates Award