INFLUENCE OF MICROLEARNING APPROACH ON INTRODUCTORY DATABASE PROGRAMMING CONCEPTS

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To the Supreme Lord, Vishnu, “the original seed of all existences, the intelligence of the intelligent, and the prowess of the powerful”

Bhagavad Gita 7.10.

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Rajagopal Sankaranarayanan

INFLUENCE OF MICROLEARNING APPROACH ON INTRODUCTORY DATABASE PROGRAMMING CONCEPTS

Teaching and learning in introductory programming courses is an overwhelming task for many course instructors and learners. Given the rise of digital and technological advancements, it is only wise to use these affordances for education. Microlearning is a successful technology-enhanced learning format with many features that might help instructors and learners to master the introductory programming concepts. Specifically, the microlearning approach is well-suited for the learning needs of the current generation of learners. In the microlearning approach, the learning content is divided into small, focused activities that are delivered digitally in an easily digestible form (Emerson & Berge, 2018; Grevtseva et al. 2017; Nikou & Economides, 2018). However, some questions remain on the effectiveness of microlearning as a viable instructional strategy. For example, there are very limited empirical studies on the specific influence of microlearning as an instructional approach and there is no clear evidence in terms of the advantages and limitations of what microlearning can and cannot do. Moreover, the perceptions of the course instructors and students while using the microlearning approach have not been sufficiently studied. Grounded within the frameworks of cognitive theories of learning – Cognitive load theory, Cognitive theory of multimedia learning, and Cognitive affective theory of learning with media, the present study explored the influence of the microlearning instructional approach and the perceptions of the students' and the course instructor using microlearning for teaching and learning introductory database programming concepts in an online introductory database programming classroom. The purpose of this dissertation study is to inform the educators and instructional designers on the influence of microlearning as an instructional approach to facilitate student learning outcomes and to put these considerations

into designing and developing microlearning content to maximize student learning outcomes. The study findings have shown that the students scored significantly higher in topic quizzes while using microlearning instruction compared to the recorded video lectures. The results further revealed both the course instructor and the students prefer microlearning as an effective online learning strategy. The learners experienced less cognitive load, and were more motivated and engaged throughout the learning process while learning through microlearning instruction. However, the learners faced some challenges including missing social aspects of learning, fragmented learning for some complex topics, and Canvas LMS platform issues. Overall, this inquiry further suggests the potential of microlearning as an instructional approach for introductory programming concepts. Some key implications of the findings are also addressed.

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Chapter 1: Introduction

Context and Background

In recent years, the field of Computer Science and Information Technology has seen rapid growth, has enjoyed immense popularity, and had increased demand for a skilled workforce, and it is projected to grow by 22 percent from 2020 to 2030 (Bureau of Labor Statistics, 2022). Due to its popularity, the number of students enrolling in Computer Science and Information Technology (CS & IT) education has been on the rise across the globe (Skala & Drilk, 2020). Emergent fields such as Big Data and Data Science require new CS & IT graduates to demonstrate mastery in data acquisition, data management, and data inference skills (Mithun & Luo, 2020). Data management and data programming skills are considered desirable and valuable to be successful in the workplace (Veerasamy et al. 2019). Therefore, the introductory programming courses such as database design and database programming represent crucial milestones in CS & IT education, as they reflect students' ability to solve problems and design appropriate solutions (Skala & Drilk, 2020).

Even though introductory programming courses are core courses for many Computers Science and Information Technology-related undergraduate degree programs, teaching and learning the introductory programming courses is still a daunting task for many instructors and learners (Alammary, 2019). This is because of the following reasons. First, teaching programming courses depends on a myriad of factors such as (a) the teaching methods employed by the instructor, (b) the nature of the programming course itself, (c) student characteristics, and (d) their motivation (Alammary, 2019; Alturki, 2016). Moreover, for some students, learning introductory programming concepts could be difficult because in most the universities the introductory programming courses are taught using a combination of lectures and labs, which

might be ineffective for some of the students as it only reinforces the negative effects of passive non-participatory learning (Skala & Drilk, 2018; Wang et al. 2009). This is especially true for students who do not have prior programming knowledge (Mathews et al. 2014).

Secondly, learning to program is a challenging task for novice programmers (Malik & Coldwell-Neilson, 2017). This is because the learners need to apply both syntax and semantics of the programming language as well as try to solve the problem while designing and writing programs (Malik, 2019). Learning the concepts, as well as using the programming language structures, and simultaneously applying these in parallel; results in cognitive overload for these learners (Malik et al. 2019). Cognitive load is the effort invested by the learner to comprehend a new instruction. According to Sweller, all learners have limited cognitive capacity to cognitively process the learning content and learning will be hindered if an instruction requires too much of that capacity (Sweller, 2011). Thus, effective, and efficient instruction should integrate the notion of limited human cognitive capacity to avoid cognitive overload (Sweller et al., 2019).

Thirdly, the current digital and technological advancements are triggering new challenges and opportunities in our everyday lives. Education also needs to be transformed and adapted accordingly (Giurgiu, 2017). Digital technologies such as computers and smartphone devices provide the required stimuli that need the learner's attention; therefore, it is only wise to use these affordances toward education (Javorcik, 2021). The current university students are tech-*savvy,* and their learning needs are becoming more immediate and interactive (Aldosemani, 2019). Some of their learning preferences include: (a) autonomy, (b) learning in a short time, and (c) immediate application of the knowledge they acquired (Skala & Drilk, 2018). Therefore, there is a need to utilize the affordances of digital technologies to provide better learning experiences for these modern learners.

Finally, the COVID-19 pandemic has inflicted some major changes in the educational landscape. Online learning has now become a common learning medium across the world (Martin et al. 2020). Though online course offerings have been steadily increasing for the last two decades, the ongoing COVID-19 pandemic has forced higher educational institutions to quickly pivot most of their course offerings to an online format (Hodges et al. 2020). The introductory programming courses were no exception. This change imposed by the COVID-19 pandemic has introduced some additional challenges to teaching and learning introductory programming courses. For instance, many instructors use pre-recorded video lectures as the instructional format to teach introductory online programming courses. The problem arises when the learners skip some of these video lectures as viewing long, static videos is not very interesting for them; thus, this lack of motivation to complete the required video lectures is making the course content overwhelming for them (Sobral, 2021), which in-turn might result in huge drop-out rates (Alturki, 2016; Konecki, 2014; Luxton-Reilly et al., 2018; Mathew et al. 2019).

Microlearning (micro learning, micro-learning) is a successful technology-enhanced learning format with many features that might help instructors and learners to master the introductory programming concepts. Educational researchers refer to microlearning as a term that to any pedagogical approach that encourages learning in small segments, supported through technology (Major & Calandrino, 2018). In the microlearning approach, the learning content is divided into small, focused activities that are delivered digitally in an easily digestible form (Emerson & Berge, 2018; Grevtseva et al. 2017; Nikou & Economides, 2018). As a popular training and development approach, microlearning is more prevalent in corporate settings. The corporate microlearning modules are self-contained training units, which don't take more than 15

minutes to complete (Job & Ogalo, 2012). The idea behind microlearning is to provide learning content to learners in short manageable units, which are ready for immediate consumption in an engaging manner (Major & Calandrino, 2018). Thus, *microlearning* refers to the process of learning through bite-sized learning content, short-term-focused activities within a well-designed module targeted toward a single learning objective (Allela, 2021).

Allela (2021) argues that the microlearning approach is NOT just chunking the long content into small pieces. In the microlearning approach, the microlearning modules are purposefully designed with short learning content called *micro content* with interactive activities, by identifying the learning objective that enables learners to achieve a specific learning outcome or knowledge gain (Allela, 2021).

Some of the educational benefits of microlearning include: (a) reduced cognitive overload (Bruck et al., 2012), (b) an effective learner-centered instructional approach (Allela, 2021), and (c) increased student learning performance (Mohammed et al. 2018), (d) better knowledge retention (Emerson & Berge, 2018), (e) easier and faster creation of learning content (Donahue, 2016), (f) increased learner engagement and satisfaction (Dolasinski & Reynolds, 2020), and (g) improved student attitudes and learner satisfaction (Inker et al. 2020; Nikou & Economides, 2018).

One of the important educational benefits of the microlearning approach as depicted in the literature is that it helps to alleviate cognitive overload in learners. According to Hug (2005), microlearning imitates the structure of the working memory of human cognitive architecture and thus helps avoid cognitive overload in learners. Because the microlearning approach is cognizant of the learners' cognitive architecture; it helps reduce the cognitive overload which in turn helps in the effective learning process (Bruck et al. 2012; Dixit et al., 2022).

Similarly, as a learner-centered approach to instruction, microlearning helps the learners to take control of their learning process – that is, the learners can control what, how, and when they are learning the content assigned to them. This not only gives the learners autonomy in their learning process but also promotes motivation and satisfaction (Allela, 2021).

Therefore, as discussed, the microlearning approach can help avert some of the challenges faced by the instructors and the current undergraduate students teaching and learning introductory programming courses. Specifically, the microlearning approach is well-suited for the learning needs of the current generation of learners enrolled in the introductory programming courses for the following reasons.

First, some of the challenges related to students feeling overwhelmed or bored after watching long static video lectures could be prevented using the microlearning approach. This is because the microlearning approach delivers only *must-know* information about a single topic in a compact and focused manner that takes less than 15 minutes to complete (Dolanski & Reynolds, 2020; Kovachev et al. 2011).

Second, the microlearning approach works because it is a learner-centered approach to instruction. While using microlearning instruction, learners have a sense of autonomy in their learning processes (Allela, 2021). They can decide how, when, and where to access the learning content.

Third, one of the biggest concerns the instructors face is that their learners are not paying enough attention and are not motivated enough - when the lecture exceeds 15 minutes (Bradbury, 2016; Cicekci & Sadik, 2019) and this is particularly true for online learning environments (Balan et al. 2020). The microlearning approach averts these issues because it takes students'

attention span and motivation into consideration while presenting the content to learners (Alquraishi, 2007; Grevtseva et al. 2017).

Finally, the microlearning approach works by mimicking the working memory (Hug, 2006); thus, some of the problems such as learner boredom, disengagement with learning content, and poor knowledge retention due to cognitive overload could be avoided (Allela, 2021).

Despite the burgeoning interest in microlearning as an effective instructional strategy for teaching and learning introductory programming concepts, the literature is scant in terms of empirical studies on the specific influence of the microlearning instructional approach and there is no clear evidence in terms of advantages and limitations of what microlearning can and cannot do (Janke et al. 2020). Additionally, some of the researchers reported that the learners' microlearning experiences have not been sufficiently studied (e.g., Lee et al. 2021). Learner perceptions of instructional technologies such as video lectures are very important because they influence the way learners engage with the content and affect their academic performance directly (Hooper, 2021). Based on the recent bibliometric analysis of microlearning publications from 2005 to 2021 in the Scopus database, it was found that more than sixty percent of the microlearning publications reported in the literature are conceptual studies, and the other twenty percent of the publications were quantitative (Sankaranarayanan et al., 2021). Hence, there is a perceived need for more empirical studies utilizing qualitative and mixed-method approaches.

Purpose of the study and Research questions

This dissertation study explored the influence of microlearning as an instructional approach and the students' perceptions while using microlearning instruction in an introductory

database programming online course. Additionally, this study also explored the course instructor's perceptions while teaching introductory database concepts using a microlearning approach. The purpose of this dissertation study is to inform educators and instructional designers on the influence of the microlearning instructional approach to facilitate student learning outcomes and to put these considerations into designing and developing microlearning content to maximize student learning. Ultimately, this study aims to address the gaps in the microlearning literature through unpacking and exploring the experiences of undergraduate students using microlearning as a viable instructional approach for teaching and learning introductory programming concepts. The following research questions guided this study:

(RQ1) Are there any differences in student performances between the two learning modes: microlearning instruction and recorded video lectures?

(RQ2) How do undergraduate students perceive microlearning as a learning approach?

(RQ3) How does the course instructor perceive microlearning as an instructional approach?

Significance of the study

Contributions of this dissertation study are expected from several perspectives**.** First, the findings from this study might provide empirical evidence for utilizing microlearning as a viable instructional method for teaching and learning introductory online programming courses. Second, this dissertation also focuses on the instructional design aspects of the microlearning approach that facilitated undergraduate students' understanding of introductory programming concepts in an online programming course. Thus, the findings from this study might provide valuable insights into their microlearning design. Furthermore, the findings from this dissertation

study might help the online course instructors to understand the undergraduate students' perceptions of using microlearning instruction, which in turn might help with their successful teaching strategies for the programming courses in general and introductory programming courses in particular. Finally, in terms of higher education, the findings of this dissertation study might help with the microlearning instructional design to be suitable for the introductory programming courses, which can potentially help to address the high drop-out rates and turnover issues in CS & IT education (Alturki, 2016; Konecki, 2014; Luxton-Reilly et al., 2018; Mathew et al. 2019).

Chapter 2: Literature Review

This chapter provides information about previous studies on related topics, specifically on the definitions and characteristics of microlearning, theoretical foundations of microlearning, educational effects of the microlearning across various contexts, limitations of microlearning, and the related literature on teaching introductory programming courses using the microlearning instructional approach. This literature review will detail the previous studies as well as the gaps in the research which, thereby, led to the rationale for this dissertation study.

Microlearning approach - Definitions and Characteristics

Microlearning is a subset of e-learning that is gaining popularity among learning professionals both in higher education and corporate settings due to its notable features such as being learner-centric, interactive, and well-designed instruction (Jomah et al., 2016). Tipton (2020) defines microlearning as, "short bursts of focused *right-sized* content to help people achieve a specific outcome" (p. 2). Similarly, Allela (2021) refers to the microlearning approach as "the process of learning through bite-sized, *well-planned modules* and short-term learning activities" (p.7).

As per the extant literature, the microlearning approach emerged from *micro-teaching* in the 1960s, but the new definition pertaining to the modern digital media emerged in 2005 (Skala et al. 2020; Zhang & Ren, 2011). Javorcik (2021) notes that the term *microlearning* was coined in 2003, at *Research Studios Austria* while developing educational content applications that focused on reducing cognitive load. However, Zhang and colleagues state that the term *microlearning* was introduced by *Lindner*, who expressed it based on micro-media and micro-

content (Zhang et al., 2010; Zhao et al., 2010). Nevertheless, the researchers agree that the microlearning approach was first theorized by Theo Hug in 2005.

Hug (2005) describes micro-learning as an instructional framework based on seven dimensions. These dimensions are (1) Learning *Content*: small learning units, simple issues, and narrow topics, (2) Course *Curriculum*: set of modules, course structure, and type of learning modality such as informal learning, and (3) Learning *Form*: fragments, knowledge episodes, and nuggets, (4) Learning *type*: behaviorist, cognitivist, constructivist, and social learning, (5) Learning *Medium*: learning objects, face-to-face, and multimedia, (6) Learning *Process*: Situated Stand-alone, integrated, and iterative, and (7) Learning *Time*: relatively short measurable time, effort and degree of time consumption.

Few researchers studied microlearning based on the Hug's dimensions framework. For example, Job and Ogalo (2012) conducted a qualitative study to identify the effectiveness of Hug's seven dimensions of microlearning using 85 questionnaires at Britain's workplace training. The results showed that the learners selected the *Process* dimension followed by *curriculum* and *form* dimensions as the three most important dimensions out of the seven (Job & Ogalo, 2012; Zhang & West, 2020). However, some educational researchers criticized Hug's definition as primarily focusing only on design aspects but not on the technological aspects or pedagogical aspects (Alqurashi, 2017; Baumgartner, 2013). Nevertheless, Hug's definition based on the seven dimensions is still predominantly used by many researchers in the published literature. For example, Zhang et al. (2017) note the general characteristics of the microlearning approach could be attributed to Hug's seven dimensions framework:

- *Form*: Microlearning uses a variety of micro-resources called micro-contents and micro activities in a multidimensional learning form that helps learners to acquire knowledge.

- *Time*: Since the microlearning approach utilizes short-term learning units with digestible chunks of information, it takes a shorter time to complete.
- *Medium*: Microlearning is predominantly delivered digitally, so learners could get rid of the limitations of space and time.
- *Curriculum*: The micro-content is stand-alone independent learning units, but they could also be chained to form microlearning modules. Thus, it makes knowledge points modularized.
- *Learning Type*: As a learner-centered instructional approach, learners have some form of autonomy over their learning and the learning content. But the knowledge structures are not lost.

Since Hug published the seven-dimensional framework in 2005, many researchers have added a lot of theoretical and empirical work to the existing body of knowledge, which extended the definition of microlearning. For example, Kovachev and colleagues added a technology component to Hug's definition and defined microlearning as a *technology-enhanced learning format* that uses small, focused learning units that could be learned in a short time (Kovachev et al., 2011). Similarly, Bruck and colleagues added two more additional constructs to Kovachev et al.'s definition namely (1) interactivity and (2) instant feedback. They defined microlearning as learning in small chunks of learning content with a *high-level interaction* and *instant feedback* component.

An assessment component was added later by other researchers for the learners' potential learning (e.g., Lim et al., 2019). Göschlberger and colleagues defined microlearning by focusing on the *digital delivery* medium. They defined microlearning as a *didactic concept*, where short,

self-contained, and coherent learning content is delivered through *digital media* (Göschlberger, 2017; Göschlberger & Bruck, 2017).

Thus, the microlearning approach has evolved from a seven-dimensional framework proposed by Hug (2005) to a technology-enhanced, multimodal learning format, that focuses on short-term learning units called *micro contents* which are highly interactive, outcome-oriented and that contains some form of assessment for learning (Bruck et al. 2012; Hug, 2005; Kadhem, 2017; Kovachev et al. 2011). According to Buchem and Hamelman (2010), the didactical design of microlearning content is based on five essential design principles namely (1) autonomy, (2) addressability, (3) focus, and (4) format, and (5) structure. The authors also note that the design of the microlearning approach is not just about ordering and sequencing the learning content but should include strategies to encourage learner participation (Buchem & Hamelman, 2010). Therefore, the design of microlearning is based on the micro content and the resulting micro activities from the micro-content.

Other researchers contend that microlearning is an effective instructional strategy because of its well-designed features, accessibility, and learner-centeredness (Jomah et al., 2016). For example, in the microlearning approach, the students may be able to *control* their learning progress and *access* the learning content (Reynolds & Dolasinski, 2020). Based on this, we could derive some additional characteristics of the microlearning approach such as:

- *Assessment* - Microlearning that should contain some form of assessment. The types of assessment depend on the type of learning content.
- *Accessibility* - In microlearning, the learners should be able to easily point out the resources they are looking for (Yin et al. 2020). Thus, Microlearning focuses on just-in-

time support and easy access to the learning content so that the learners could interact with the content.

To sum up, microlearning can be defined as an instructional strategy, where the learning content is divided into small, focused activities, and is delivered digitally in an easily digestible form that is outcome-oriented (Emerson & Berge, 2018; Grevtseva et al. 2017; Nikou & Economides, 2018).

Theoretical Foundations of Microlearning approach

I selected cognitive theories of learning such as the cognitive load theory (CLT), Cognitive theory of multimedia learning (CTML), and the Cognitive Affective Theory of Learning with Media (CATLM) as the theoretical frameworks that undergird my understanding of the microlearning approach. There is no clear unequivocal support in the literature regarding the theoretical basis for the microlearning approach. While some scholars noted that the majority of published studies in microlearning literature lack a specific theoretical grounding for teaching and learning (e.g., Khong & Kabilan, 2020); others pointed out that microlearning cannot be assigned to a specific learning theory because it is based on the concrete learning situation.

For example, Busse and Schumann (2019) suggested that technology-enhanced formats like microlearning have some orientation towards all three prominent learning theories: behaviorism, cognitivism, and constructivism. Likewise, some researchers associate microlearning with other prescriptive theories such as Connectivism, Andragogy, and Self Determination Theory. For instance, De Gagne and colleagues argue that microlearning is based on Siemens connectivism theory, which proposes learning occurs when the human brain processes information through neural networks (De Gagne et al., 2019).

The underlying theoretical frameworks for the microlearning approach differ based on the discipline in which the research is being conducted. For example, researchers in the field of adult and continuing education suggest that microlearning is based on andragogy and self-regulated learning principles (e.g., Zaqoot et al. 2020). Similarly, educators in higher education point out motivation and affective factors play a major role (e.g., Khong & Khabilan, 2020). For instance, Yin and colleagues posit that students' learning performance in microlearning instruction can be enhanced through their motivation to learn the content, and self-determination theory as proposed by Ryan and Deci helps support the motivational aspects of the microlearning approach (Yin et al. 2020). Therefore, it is very clear that there is no single theoretical framework that could be used to study microlearning.

In this dissertation research, the study context is an introductory online database programming classroom. In introductory online programming courses, learners often learn the programming concepts through instructional videos (Mithun & Luo, 2020). An instructional video is a form of multimedia (Artman, 2020; Hooper, 2021). Therefore, exploring microlearning instruction based on the underlying design principles of multimedia learning theory might shed some light on effective instructional design. As such, Mayer's Cognitive Theory of Multimedia Learning, one of the prominent multimedia theories of learning and instruction, is an apt framework for this study. The Cognitive Theory of Multimedia Learning borrows the same underlying assumptions from Sweller's Cognitive Load Theory (Sweller, 1988) and uses the same instruments to capture the learner's perception of perceived effort during multimedia instruction (Hopper, 2021).

Likewise, based on the extant literature, it is clear that learner motivation plays a central role in technology-enhanced learning environments such as microlearning (e.g., Huang et al.

2022). Therefore, Moreno's Cognitive Affective Theory of Learning with Media, which extends Mayer's Cognitive Theory of Multimedia Learning, could help enhance our understanding by adding motivational aspects to this study. Therefore, an integrated framework of cognitive theories of learning is used as the prominent theoretical framework for this study.

In summary, as an evolving field of educational/instructional technology, there are multiple conversations and multiple theoretical frameworks that have guided and supported microlearning as an instructional approach. But, using the theoretical lens of cognitive learning theories such as Cognitive Load Theory (Sweller, 1988), Cognitive Theory of Multimedia Learning (Mayer, 2014), and Cognitive Affective Theory of Learning with Media (Moreno & Mayer, 2007) and exploring the learner and the instructor perceptions while using the microlearning instruction could help enhance our understanding microlearning intervention for this introductory online database programming course. In the next section, the cognitive theories of learning and how we could extend these theories as an integrated model for exploring microlearning as an instructional approach are discussed in detail.

Cognitive Load Theory

As one of the prominent instructional design theories, cognitive load theory (CLT) was theorized by Sweller while investigating the problem-solving process in a high school mathematics course in the late 1980s (Sweller, 1988). The main goal of CLT is to help explain how the instructional design and its associated cognitive processing could affect the learner's ability to learn the learning content and construct new knowledge (Sweller et al. 2019). CLT uses aspects of human cognitive architecture (see figure 1) to generate empirically supported instructional effects (Sweller, 2011). The central tenet of cognitive load theory is that humans

have limited cognitive capacity and if an instruction requires too much of that capacity, the learning process will be impeded because of cognitive overload (Sweller, 2011). Thus, by integrating the notion of human cognition and its associated memory structures such as working memory and long-term memory, CLT helps to design effective and efficient individualized learning environments (Ayres & VanGog, 2009; DeJong, 2011).

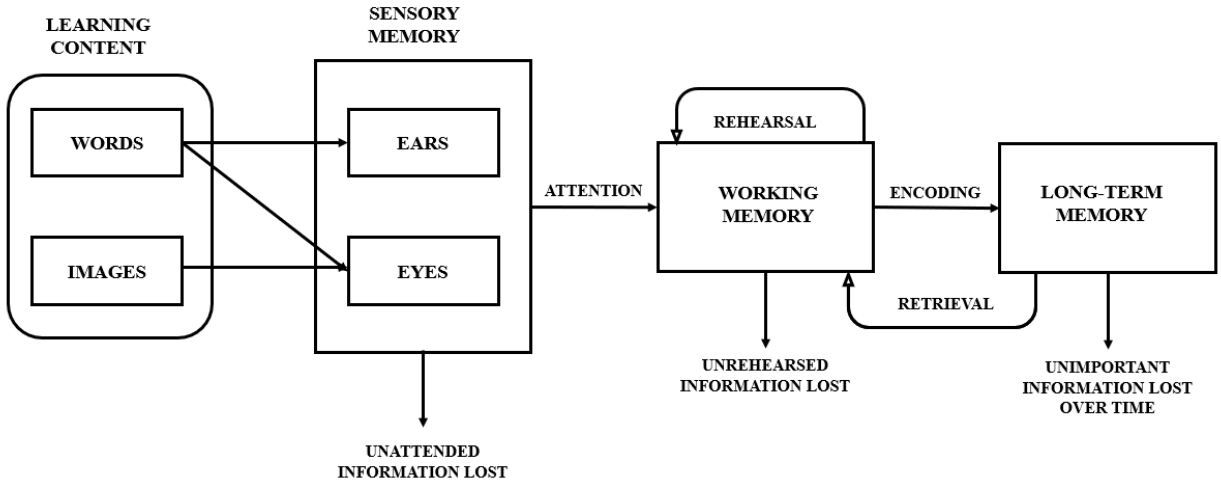


Figure 1. Human cognitive Architecture and associated memory structures

Theoretical assumptions of Cognitive Load Theory

According to Moreno and Park (2010), Cognitive load theory attempts to explain psychological or behavioral phenomena resulting from an instruction (p. 9). It was suggested that *cognitive load* was not a novel concept at the time of its inception, and it is closely related to the well-established psychological construct of *mental load*, which is defined as the difference between task demand and the person's processing capability of managing these task demands (Moreno & Park, 2010). According to cognitive load theory, our human cognitive architecture consists of two main memory structures namely (1) *working memory* - which is limited in processing capacity and can hold only a few information elements in a given time; and (2) *long-term memory* - a virtually unlimited information store that holds information in the form of

schemas. Any new learning content with instructions is said to impose three kinds of cognitive loads on the learner's working memory; (1) *intrinsic cognitive load*, the load imposed by the inherent complexity of the learning content; (2) *extraneous cognitive load*, the load imposed by the effort required to process the way the learning content is presented; and (3) *germane cognitive load*, the load imposed by the effort invested by the learner to understand the learning content (Sweller, 2011). The learner's cognitive capacity is the additive of the three cognitive loads (Paas et al. 2003). Figure 2 visually depicts the cognitive load theory with the three cognitive loads and working memory.

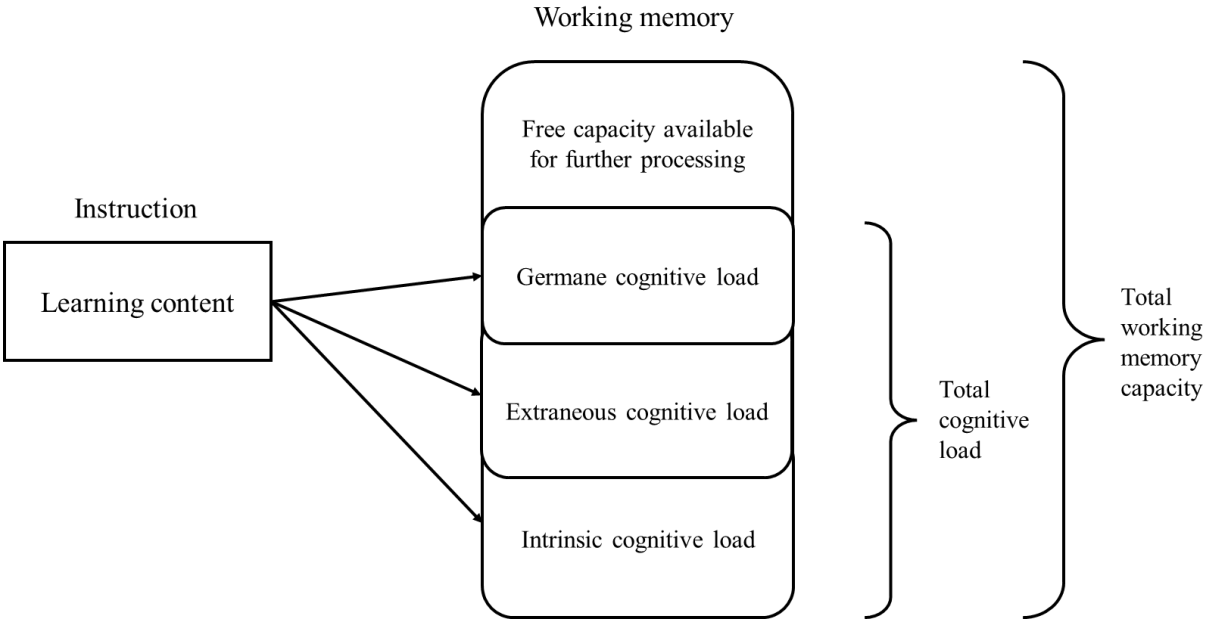


Figure 2. Sweller's cognitive load theory (Moreno & Park, 2010)

As discussed earlier, when an instruction requires more than the cognitive processing limit of the learner's working memory, then the learner experiences cognitive overload that impedes their learning process (Sweller, 2011). For example, Sweller and colleagues suggest that if an instruction requires more cognitive resources to deal with extraneous cognitive load, then

learners will have a lower cognitive capacity to deal with intrinsic cognitive load, which likely will result in unsuccessful learning (Sweller et al. 2019). The solution to this problem is to carefully design an instruction that is cognizant of the human cognitive architecture (such as long-term memory and working memory), so it could avoid such cognitive overload in learners (DeJong, 2011). Table 1 outlines the theoretical assumptions of CLT. There are some criticisms of cognitive load theory discussed in the literature. One of the prominent issues is the non-consideration of psychological factors such as individual beliefs, motivation, and expectations on the learner's perception of cognitive load; the only individual characteristic that is explicitly discussed in the cognitive load theory is *prior knowledge* (Moreno & Park, 2010).

Table 1

Theoretical Assumptions of CLT (Sweller et al. 2019)

Assumption	*Description*
Limited capacity and duration of working memory	For novel instructions, learners' cognitive processing is severely constrained by their working memory, which can process and hold only a limited number of new information at a given time.
Unlimited capacity of long-term memory	Learners' long-term memory is unlimited information storage organized in the form of knowledge schemas. The information retrieval between long-term memory to working memory is also unlimited and almost automatic.
Triarchic cognitive load	Any new instruction imposes three types of cognitive load in a learner's cognitive system: (1) intrinsic cognitive load, (2) extraneous cognitive load, and (3) germane cognitive load.

Instructional design principles based on Cognitive load theory

For the last three decades, the focus of cognitive load theory research was to empirically investigate various educational effects to effectively design instruction for individual learning

environments that avoid cognitive overload (Ayres & VanGog, 2009). So far, seventeen of those instructional strategies or principles have been reported through various experimental studies (see Table 2). Out of these seventeen principles, two of them - The variability and isolated elements are reported for managing the intrinsic cognitive load on learners and eleven strategies - The goal-free, worked example, split-attention, modality, redundancy, element interactivity, expertise reversal, problem completion, guidance fading, imagination, and transient information are reported for reducing the extraneous cognitive load. These instructional strategies help educators and instructional designers to design effective individual learning environments.

Table 2

Instructional design principles based on CLT (Sweller et al. 2019)

Instructional principle	*Description*
1. Goal-free	When learners are explicitly trying to solve a problem, it requires a lot of attention in their working memory, which could lead to cognitive overload. Thus, this principle states to replace conventional tasks with goal-free tasks that provide learners with a non-specific goal to reduce cognitive overload.
2. Worked example	Worked examples principle posits that the novice learners will experience less cognitive load if they study the example solutions for the problems before attempting to solve them. Therefore, if we replace conventional tasks with worked examples that provide learners with a solution that they must carefully study, it reduces cognitive overload.
3. Completion problem	The completion problem principle states that when learners are given part of the solutions to the problems with guidance, it helps them alleviate some cognitive overload. Thus, if we replace conventional tasks with completing tasks that provide learners with a partial solution they must complete, the learners experience less cognitive load.
4. Split-attention	By integrating multiple sources and forms of learning content, the

	cognitive overload experienced can be reduced and the learner's performance can be increased. Thus, replace multiple sources of information, distributed either in space or time, with one integrated source of information to reduce cognitive overload.
5. Redundancy	Providing multiple sources of learning content that are redundant could interfere with learners' cognitive processing of learning content resulting in cognitive overload. Thus, replace multiple sources of information that are self-contained with one source of information to reduce cognitive overload.
6. Element-interactivity	This effect states that the cognitive load of learning material or information depends on the complexity of interacting elements within the instruction. Thus, the cognitive load effects found in high element interactivity materials are not found for low element interactivity materials.
7. Variability	Organizing the learning tasks of increasing difficulty or variability can help learners with managing the intrinsic complexity of the learning tasks. Therefore, replace a series of tasks with similar surface features with a series of tasks that differ from one another.
8. Modality	This effect depicts that using multi-modal information helps learners to manage the cognitive overload imposed by the learning task. Therefore, replace written explanatory text and another source of visual information (unimodal) with spoken explanatory text and the visual source of information (multimodal) to reduce cognitive overload.
9. Self-explanation	By asking learners to self-explain given information, the learners can improve their problem-solving ability. Therefore, replace separate worked examples or complete tasks with enriched ones containing prompts, to the self-explain given information.
10. Imagination	when the learner is asked to imagine/mentally practice the concept or procedure, it helps with better use of their available working memory resources and doesn't impose an additional load when trying to study from them. Therefore, replace the conventional study of a procedure or concept to learn with imagination to reduce cognitive overload.
11. Isolated elements	Instead of initially presenting a complex set of information with all interacting elements at once in a fully interactive form, replace

	elements of information sequentially in an isolated form to manage intrinsic cognitive load.
12. Expertise reversal	The expertise reversal effect states that when the same instructional strategies are used for both novice and advanced learners, the advanced learners might experience extraneous cognitive load that results in low performance. Therefore, the instructional design must be adjusted as learners acquire advanced knowledge to reduce extraneous cognitive load.
13. Guidance fading	The guidance fading effect states that the cognitive load effects that are relevant at the beginning of a longer educational program are no longer relevant in the later stages of the program after the learners acquired sufficient expertise. Therefore, the instructional design should be adjusted over some time to reduce cognitive load.
14. Collective working memory	This effect states that, while working in groups a collective pool or reservoir of working memory is created that could be used to increase the cognitive processing capacity of the learners. Therefore, replace the individual learning tasks with collaborative tasks to reduce extraneous cognitive load for complex tasks.
15. Transient information	This effect states that for complex tasks the animation that appears only for a short period needs to be replaced with new information to avoid cognitive overload.
16. Human movement	Replace static or unrealistic visualizations showing human movements to reduce load.
17. Self-management	This effect states that when learners apply the cognitive load theory principles themselves, their cognitive load is reduced. This is achieved by giving learners control over the instruction.

Cognitive Theory of Multimedia Learning

As discussed earlier, in the introductory online programming courses, learners often learn the course concepts through instructional videos and an instructional video is a form of multimedia (Artman, 2020; Hooper, 2021; Mithun & Luo, 2020). Therefore, Mayer's Cognitive

theory of multimedia learning (See figure 3) could be a very helpful theoretical framework to explore the microlearning instructional approach.

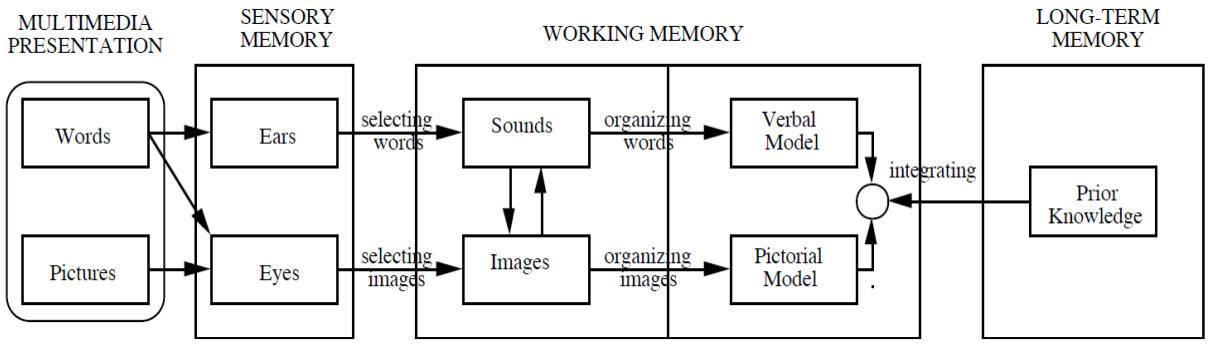


Figure 3. Mayer's Cognitive Theory of Multimedia Learning (Mayer, 2017, p. 405)

Dr. Richard Mayer theorized the Cognitive Theory of Multimedia Learning in the early 2000s by extending the cognitive load theory for multimedia instruction (Hooper, 2021; Sorden, 2012). The CTML uses the same underlying memory structures and assumptions of Sweller's cognitive load theory (Ibrahim, 2012).

Mayer (2014) asserts that using multimedia such as instructional videos by combining both words and pictures can support the way the human brain learns rather than just learning by words alone. According to CTML, the main purpose of multimedia instruction is meaningful learning. Meaningful learning is achieved when the presented instruction prims appropriate cognitive processing by guiding the learners to select relevant learning content; helping learners organize the learning content into a coherent cognitive representation; and integrating the learning content with learners' prior knowledge (Mayer, 2014). When learners actively participate in the meaning-making process, learning occurs through increasingly sophisticated schemas construction in the form of new knowledge in the learners' long-term memory (Sorden, 2012; Ibrahim, 2012).

Theoretical Assumptions of Cognitive Theory of Multimedia Learning

In addition to the existing assumptions of cognitive load theory, Mayer, and Moreno (2003) outline three basic assumptions of the CTML namely (1) Dual channel assumption; (2) Limited capacity assumption; and (3) Active processing assumption (see Table 3).

Table 3

Theoretical Assumptions of CTML (Mayer & Moreno, 2003)

Assumption	*Description*
Dual Channel	Learners process multimedia instruction in two different channels. The auditory information is processed through the verbal channel and the pictorial information is processed through the visual channel.
Limited capacity	Learners' verbal and visual channels are limited in terms of capacity and duration.
Active processing	While processing multimedia instruction, learners have to invest substantial cognitive effort to process it in their verbal and visual channels.

CTML mainly draws its theoretical assumptions from three prominent cognitive theories namely (1) Baddeley's working memory model (Baddeley, 1992); (2) Paivio's dual coding theory (Paivio, 1986); and (3) Sweller's Cognitive Load Theory (Sweller, 1988). As per CTML, we all have three main cognitive structures that help with the learning process. They are sensory memory, working memory, and long-term memory (See Figure 2). Mayer (2010) notes that the human cognitive information processing system contains two separate channels - a verbal channel for processing sounds, words, and verbal representations and a visual channel for processing pictures, images, and pictorial representations (Mayer & Moreno, 2003). It is worth

mentioning that these dual channels are also limited in capacity and duration, which is only limited cognitive processing that can take place in the verbal and visual channels (Mayer, 2014; Sweller, 2011).

Meaningful learning happens when the learners actively process the information in their cognitive system and construct knowledge. This involves five processes involving these three cognitive structures when a multimedia instruction is presented to a learner. First, the learner *selects* relevant *words* from the multimedia instruction for cognitive processing in their verbal working memory. Second, they *select* the relevant visual *images* for cognitive processing in their visual working memory. Third, they *organize* the selected words into a *verbal model* in their working memory. Then, they *organize* the selected images into a *pictorial model* in their working memory. Finally, they *integrate* the verbal and pictorial models with their *prior knowledge* and create or alter schema structures in the long-term memory from controlled processing to automatic processing (Sorden, 2012). For instance, when a learner is presented with the lightning process in an instructional video, they might recall an image of a lightning strike from a storm they have experienced before (Mayer, 2011).

Instructional Design principles based on CTML

The central challenge of multimedia instructional design is to prime appropriate cognitive processing without overloading the working memory while the learner is actively processing the learning content (Mayer, 2017). CTML describes that while processing multimedia learning content such as instructional video, learners incur three types of cognitive demands in their visual and verbal channels in the working memory (Ibrahim, 2012). As per the limited capacity assumption, these channels are limited in their capacity and duration. Sorden (2012) notes as per the triarchic model of cognitive load theory when the learners incur cognitive load while actively

processing the most important information or the information to be learned from the instructional video, it is called *essential processing*, (i.e. Intrinsic cognitive load); similarly, *extraneous processing* happens when the learners process the information that is not related to the instructional goal that could hinder their learning process, (i.e., Extraneous cognitive load). Finally, *generative processing* is incurred by the learner's cognitive processing system while making sense of the learning content presented, (i.e., germane cognitive load) (Sorden, 2012).

Mayer (2017) suggests that to overcome this limited cognitive processing challenge, the main goal of a multimedia instruction should be (1) to *reduce extraneous processing* – that is avoiding the learning content that doesn't support the instructional goal due to bad instructional design; (2) *manage essential processing* – promote learning content aimed at helping learners to understand the complex learning content, and (3) *foster generative processing* – motivate learners in continued participation of the multimedia instruction to make sense of the presented information (see Table 4).

Table 4.

Types of cognitive processing incurred in multimedia learning (Mayer, 2014)

Type of cognitive load	*Associated cognitive processing*	*Description*	*Instructional goal*
Extrinsic cognitive load	Extraneous cognitive processing	Caused by bad instructional design; unrelated to the instructional goal	Reduce extraneous processing
Intrinsic cognitive load	Essential cognitive processing	Caused by the inherent complexity of the material; contains essential information to be learned	Manage essential processing

Germane cognitive load	Generative cognitive processing	Caused by learner's effort to make sense of the material;	Foster generative processing

Based on the above instructional goals, CTML proposes the following eleven instructional design principles for effective instructional design with five principles focusing on reducing extraneous processing, three principles focusing on managing essential processing, and three principles focusing on fostering generative processing (Mayer, 2017). These CTML instructional design principles and the rationale for these principles are presented in Table 5.

Table 5

Instructional design principles based on CTML (Mayer, 2017)

Principle	*Description*	*Theoretical Rationale*
For reducing extraneous processing		
1. Coherence	When extraneous material is excluded, learners learn the content better.	By eliminating extraneous material, learners can focus on the essential material without distraction.
2. Signaling	When important information is highlighted, learners learn the content better.	By highlighting essential information, learners are attentive. Thus, essential, and generative processing is managed, and extraneous processing is reduced.
3. Redundancy	Instead of using graphics, narration, and on-screen text, learners learn the content better from graphics and narration alone.	Learners might not waste precious processing capacity by trying to reconcile two verbal streams of information, thus extraneous processing is reduced.
4. Spatial contiguity	When on-screen words and corresponding graphics are placed next to each other, learners learn the content better.	Learners might be able to build connections between corresponding words and graphics. Thus, extraneous processing is reduced.

5. Temporal contiguity	When corresponding graphics and narration are presented simultaneously, learners learn the content better.	Learners might be able to build connections between corresponding words and graphics. Thus, extraneous processing is reduced.
For managing essential processing		
6. Segmenting	When the learning content is presented in small, user-paced segments, learners learn better.	By fully processing the chunk of learning content before having to move on to the next one, the learner's essential processing is well managed.
7. Pre-training	When the learners receive the key terms before receiving the learning content, learners learn better.	Helps with the causal connections and explanations in the learning content if the learners know the key terms, thus essential processing is managed.
8. Modality	When words are presented in the spoken form, learners learn better.	Helps learners to offload some of the processing in their visual channel onto the verbal channel, thus essential processing is managed.
For fostering generative processing		
9. Personalization	When the words are presented in a conversational style, learners learn the content better.	A conversational style can prime social presence in the learners; thus, they might try harder to make sense of the content by engaging in generative processing.
10. Voice	When learning content is presented in a human voice, learners learn the content better.	The human voice can prime social presence in the learners; thus, they might try harder to make sense of the content by engaging in generative processing.
11. Embodiment	When an onscreen agent uses human-like gestures and movement, learners learn the content better.	Human-like action might create a sense of social presence with the instructor, thus fostering generative processing.

Cognitive Affective Theory of Learning with Media (CATLM)

Moreno's Cognitive Affective Theory of Learning with Media (CATLM: Moreno & Mayer, 2007) extends the Cognitive Theory of Multimedia Learning by adding motivational factors, thus providing a coherent perspective to learning in multimodal and technology-enhanced learning environments (Huang et al. 2022; Wang et al. 2022). Specifically, CATLM introduces a new concept to the cognitive theory of multimedia learning called *affective mediation,* the idea that motivational factors mediate learning by affecting the cognitive engagement of learners (Leutner, 2014). Mayer and Estrella (2014) note that learner motivation instigates and maintains generative processing, thereby leading to better learning outcomes. Thus, the CATLM shares the same theoretical foundations as the other cognitive theories of learning such as Cognitive load theory and cognitive theory of multimedia learning but includes three additional assumptions which are discussed below.

Theoretical Assumptions of CATLM

Moreno and Mayer (2007) outline seven assumptions specific to CATLM (p. 313). The first four assumptions (1) Dual-channel; (2) Limited capacity; (3) Active processing; and (4) Unlimited Long-term memory are based on CLT and CTML (Mayer, 2014; Sweller, 2011). The last three assumptions namely (5) Affective mediation; (6) Metacognitive mediation; and (7) Individual indifference mediation are specific to CATLM (See Table 6).

Table 6

Theoretical Assumptions of Cognitive Affective Theory of Learning with Media

Assumption	*Description*
Dual-Channel	Learners process instruction presented through multimedia in two different channels - auditory information is processed through the verbal channel and pictorial information is processed through the visual channel.
Limited capacity	Learners' verbal and visual channels are limited in terms of capacity and duration.
Active processing	While processing the instruction through multimedia, learners have to invest substantial cognitive effort to process it in their verbal and visual channels.
Unlimited long-term memory	Learners' long-term memory holds unlimited information in the form of schemas related to their prior experiences and domain knowledge.
Affective mediation	Learners' motivation factors influence the way they process the instruction by increasing or decreasing their cognitive engagement.
Metacognitive mediation	Learners' metacognitive factors mediate the way they process the instruction by regulating their cognitive engagement.
Individual indifferences mediation	Learners' abilities and prior knowledge might affect the way they process the instruction based on the type of instructional media.

Instructional Design principles based on CATLM

Moreno and Mayer (2007) assert that in interactive learning environments, such as microlearning, the learner's cognitive processes are guided by the feedback and the instructional methods embedded in the learning environment, and the learner's motivation and metacognitive skills during the learning process. As such, they proposed the following five instructional design principles based on the underlying theoretical assumptions of CATLM. The five CATLM

instructional design principles and the rationale for these principles are presented in Table 7.

Table 7

Instructional design principles based on CATLM (Moreno & Mayer, 2007)

Principle	*Description*	*Theoretical Rationale*
Guided Activity	Learners learn better when they have some interaction with the learning content	By promoting and guiding learners to engage in the selection, organization, and integration of new information; essential and generative processing is managed.
Reflection	Learners learn better when they reflect upon their learning while learning the content	By promoting active organization and integration of new information and helping learners to reflect; essential and generative processing is managed.
Feedback	Learners learn better through explanatory feedback	Through proper feedback, learners can correct their misconceptions and repair schemas, thus extraneous processing is reduced.
Pacing	Learners learn better when they have control of their learning process	By processing smaller chunks of information in the working memory, essential processing is managed.
Pre-training	Learners learn better when they receive focused pre-training or activation of their prior knowledge	By showing aspects of prior knowledge to integrate with incoming information, generative processing is fostered.

Extending cognitive theories of learning to the microlearning approach

The most obvious support for microlearning comes from educational psychology. For example, in their seminal paper, Simon (1974) argued that learners learn more effectively when the content is broken into small, digestible chunks (as cited in Bruck et al., 2012). As such, the cognitive theories such as the cognitive theory of multimedia learning (Mayer, 2005; Mayer,

2014) and the cognitive load theory (Sweller et al., 2011; Sweller et al., 2019) might be more closely associated with the microlearning approach as seen in the literature. For example, Grevtseva and colleagues note that microlearning offers the perfect platform for the implementation using Mayer's (2005) cognitive theory of multimedia learning principles, such as *the segmentation principle* which refers to breaking down the learning content into more digestible chunks and the *Modality principle,* which refers to using multiple learning media formats to ensure learners can learn the content effectively than just plain text or using single modal instruction such as recorded video lectures (Grevtseva et al., 2017; Mayer, 2014a).

Similarly, Inker and colleagues argue that cognitive load theory forms the theoretical foundation for microlearning along with the spaced learning theory (Inker et al., 2020). They contend that *spaced learning* in smaller repeated intervals is more effective because, it alleviates cognitive loads and aids in forming schema structures in long-term memory than *massed learning*, as suggested in spaced learning theory by Ebbinghaus (Ebbinghaus, 1913 *as cited in* Inker et al., 2020). Javorcik and Polasek (2019) agree and cite Miller's (1956) magical number -- seven plus or minus two, the number of objects a human short-term memory can hold on to on average. They posit that, in addition to the cognitive overload, the human attention span also plays a major role in the learning process. From that point, they argue that if the attention span increases, cognitive overload also increases, which might hamper the learning process. Microlearning prevents all these issues by keeping learners engaged and mindful of human attention span issues (Javorcik & Polasek, 2019). Some researchers go on to suggest that the microlearning approach mimics the way how our human brain processes information and thus reduces cognitive fatigue that results from the long lessons (e..g. Yin et al., 2021). Thus, based on the review of literature, we can safely assume that the microlearning approach could be

represented by the cognitive theories towards learning.

Previous research has shown that the learners with higher motivation could handle complex learning tasks persistently and are more satisfied and enjoy learning the material using microlearning instruction to acquire new competence/knowledge (Lin et al. 2021). In microlearning instruction higher levels of perceived motivation and self-directed learning, the behavior was observed (Nikou & Economides, 2018). Motivation and self-directedness lead to satisfaction with the learning content and results in enhanced performance (Nikou, 2019).

Mayer's (2014) learner-centered principles towards designing multimedia environments through CTML (e.g., segmentation) and Sweller's suggestions to include motivational variables to improve learner performance (Khong & Kabilan, 2020) along with Moreno's CATLM led me to conceptualize the integrated microlearning framework. The dynamic interplay between the cognitive and motivational aspects offers a more nuanced instructional design approach as shown in figure 5.

In this integrated framework, both CLT and CTML help with designing the learning content that is cognizant of the human cognitive architecture to maximize the learning outcomes. Specifically, these theories can help understand how microlearning responds to the two major learning challenges: (1) The overflow and complexity of learning content through structured microcontent design; and (2) flexibility, affordance, and conducive learning environment that adapts to learners' preferences (Khong & Kabilan, 2020). For instance, as technology enhances the multimodal learning environment, microlearning instruction activates both visual and verbal channels and facilitates integrative cognitive processing of learning content. This successful integration and cognitive processing in turn make the learners feel confident and competent when they eventually meet the learning challenges of the complex learning content (Khong &

Kabilan, 2020). This will in turn trigger their willingness to invest effort and engage with the content as per CTML. When the required motivation is present, learners will actively process the information even if the learning content is complex; however, if the learners are not motivated enough, even though cognitive resources are available they may not engage in active processing of information (Moreno & Mayer, 2007). In other words, as suggested by Moreno and Mayer (2007), "Motivational factors mediate learning by increasing or decreasing cognitive engagement" (p. 313).

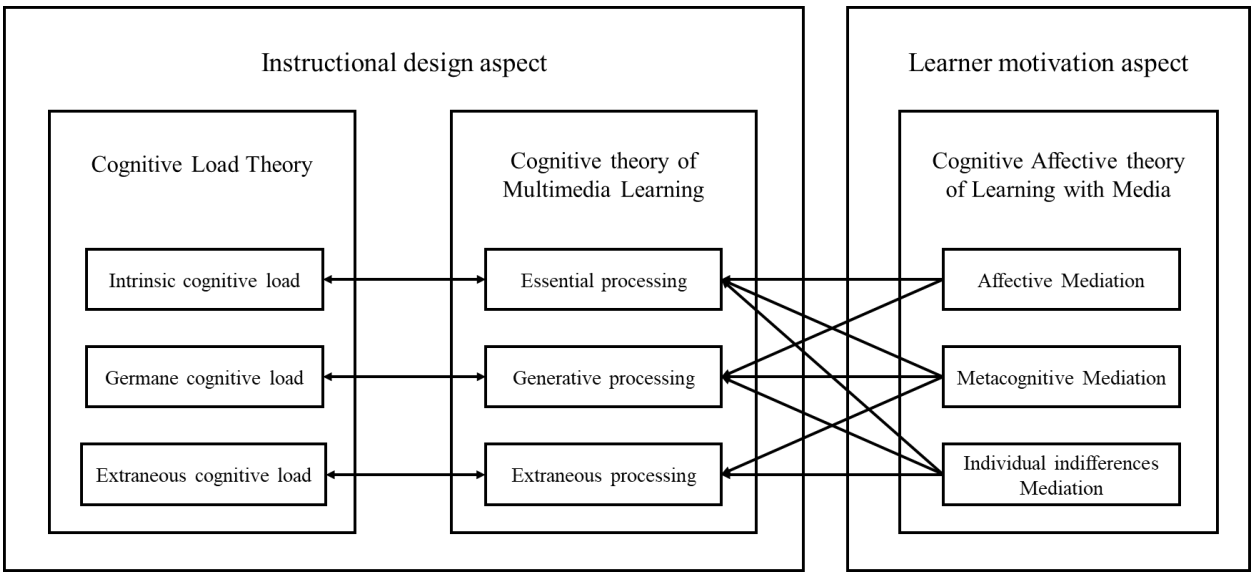


Figure 5. Integrated microlearning framework based on cognitive theories of learning

Educational Effects of the microlearning approach

Researching and exploring the best instructional strategies is one of the most important necessities of higher education (Aldosemani, 2019). Though still in its infancy, many studies discuss the educational effects of microlearning.

First, extant literature shows microlearning could be a promising approach that enhances learner experience and learning outcomes. Many studies support microlearning to be an effective instructional strategy. For example, Giurgiu (2017) assessed whether students using microlearning could perform better and retain knowledge than the traditional approach. They found that students were able to retain at least 20% knowledge compared to learners who did not learn using microlearning content (Giurgiu, 2017). In a similar study, Mohammed and colleagues found that microlearning increased student performance by up to 18% compared to the control group. In addition to that, the microlearning approach also increased knowledge retention for extended periods (Mohammed et al., 2018). Leela and colleagues used an AR-based microlearning approach called living book to teach mathematics. They found higher learning achievement and increased satisfaction with the learning content compared to the traditional group (Leela et al. 2019). Wang et al. (2017) also found that microlearning significantly improved learning outcomes while investigating the effect of microlearning on mechanical engineering content. However, this study's results showed there was very limited interaction between student-to-student and student-instructor although increased interaction between student to content (Wang et al., 2017).

As a second strand of research, few studies focused on the learners' motivational aspect while using microlearning content. Nikou and Economides (2018) did a comparison study to investigate the effect of microlearning on student motivation and learning performance. They found that the microlearning approach increased learning performance and increased students' intrinsic motivation compared to the traditional classroom (Nikou & Economides, 2018). However, a recent study by Yin and colleagues showed no significant difference in students' learning performance between the traditional groups and microlearning groups. However, they

reported students indicated stronger intrinsic motivation in the microlearning environment compared to the traditional learning environment (Yin et al., 2021). Building on the motivational effect of microlearning, new teaching strategies such as using interactive microcontent, and using gamification approaches by incorporating gamified learning activities were explored by a few researchers (Aitchanov et al. 2018; Göschlberger & Bruck 2017; Lee et al. 2021). Some other educational effects of microlearning include: (a) Increased learners' autonomy, (b) increased engagement, retention, and transfer, (c) improved self-directed learning, (d) improved reflexivity, and (e) reduced cognitive load.

Aldosemani (2019) states that microlearning instruction results in increased learners' autonomy because they have control of what and when they are learning the content, which results in effective transfer and retention of knowledge. Other researchers agree with this claim and also state that microlearning also increases engagement and knowledge retention because the lessons are short and focused, and the learners tend to be more engaged with the instruction which results in better retention and increased transfer (Donahue, 2016; Emerson & Berge, 2018; Kovacs, 2015).

Few other researchers mention that microlearning harness a way of self-directed learning called *Heutagogy,* which means approaching information in a dynamic way that promotes critical thinking and critical reasoning through learner agency, self-directedness, and metacognition (e.g., De Gagne et al., 2019). In similar veins, Göschlberger and Bruck (2017) state that, microlearning improved reflexivity in students because of the instant feedback and the interactive activities that help to reflect on the learning content.

Finally, *reduced cognitive load* - Alqurashi (2017) argues that because the learning content is designed in a manner that is cognizant of the human cognitive architecture,

microlearning avoids cognitive overload. In a similar vein, Bruck and Colleagues point out that because the microlearning content is broken down into digestible chunks of information, it aids people to learn effectively (Bruck et al., 2012).

In summary, there are many educational effects of the microlearning approach found in the literature. These include:

- Microlearning enhances learning performance and learner outcomes (Giurgiu, 2017; Jomah et al., 2016; Leela et al., 2019; Mohammed et al., 2018; Wang et al., 2017)
- Microlearning increases intrinsic motivation in learners (Aitchanov et al. 2018; Göschlberger & Bruck 2017; Nikou & Economides, 2018; Lee et al. 2020; Yin, 2021)
- Microlearning results in increased knowledge retention because of learner autonomy (Aldosemani, 2019)
- Microlearning reduces learners' cognitive load (Alqurashi, 2017; Bruck et al., 2012; Busse et al., 2020; Grevtseva et al. 2017)
- Microlearning results in increased self-directed learning, learner agency, and metacognition (De Gagne et al., 2019)
- Microlearning results in increased learner engagement, retention, and transfer (Donahue, 2016; Emerson & Berge, 2018; Kovacs, 2015)
- Microlearning results in improved reflection on learning content due to instant feedback (Göschlberger & Bruck, 2017)

Limitations of the microlearning approach

One of the widely found criticisms of the microlearning approach is the lack of empirical evidence about what microlearning can and cannot do (Clark et al., 2018; Decker et al. 2017;

Jahnke et al. 2019; Lee et al. 2020). Few researchers highlight some of the potential limitations of using the microlearning approach. First, they cite limited empirical research available concerning the learners' long-term goals (Lim et al. 2019). Second, learning complex skills using microlearning might result in fragmented knowledge because of learning in short segments in short periods (Emerson & Berge, 2018; Lim et al. 2019). Third, some researchers point out potential accessibility and equitable issues due to the digital divide as not all learners have equal access and resulting in increased costs (Javorcik & Polasek, 2019). Finally, Diversity, Equity, and Inclusion issues in microlearning content are not studied as well (Jahnke et al. 2019; Lee et al. 2020). Some researchers also point out limitations that are specifically related to mobile microlearning. These include (a) fitting in too much information in too little screen space, (b) usage of mobile devices might distract learners (Zaqoot et al., 2020), and (c) potential confusion to learners as microlearning content uses a wide variety of formats and switching between these formats might create confusions (Javorcik & Polasek, 2019).

Therefore, to sum up, some of the limitations of the microlearning approach include:

- Limited empirical evidence on what microlearning can and cannot do
- Learning in short segments and short periods might result in fragmented learning
- Potential accessibility, equity, and gender bias issues
- Challenges fitting information in too little screen size of mobile devices
- Usage of mobile devices might distract learners
- Potential confusion to learners due to a wide variety of learning formats

Microlearning approach as an instructional method to teach programming concepts

Computer science and Information technology disciplines are some of the early adopters of the microlearning approach. For example, Matthews and colleagues designed learning objects (LO) based on the number of pages, access time, and logical content for teaching introductory C programming concepts. They compared Micro-learning objects (LO: *takes 20 to 30 minutes to complete*) with Microlearning Objects (MLO: *takes 5-15 minutes to complete*). They found that the students in the MLO group scored better in the post-test and quizzes (Matthews et al. 2013, 2014). Similarly, Khadem (2017) examined the effectiveness of mobile microlearning in the retention of IT concepts and skills. The results showed that the microlearning approach helped with the retention of IT concepts and theories but retained fewer problem-solving skills. Likewise, Javorcik and Polasek conducted a series of studies comparing the microlearning approach with the e-learning approach in the IT education contexts (Javorick & Polasek, 2018; Javorick & Polasek, 2019 a, b, c; Polasek, 2019; Polasek & Javorick, 2019 a, b). For example, while comparing the eLearning course and microlearning course format for the same course offering, they found no statistically significant differences in the learning outcomes. However, the students in microlearning courses achieved course learning outcomes more comfortably and the microlearning course contents were accessed twice the amount of e-learning course content (Javorick & Polasek, 2019a). As a follow-up study, the same authors presented two models - Model A and Model B to transform eLearning courses into microlearning courses in Moodle LMS. Model A microlearning course was the direct transformation of an eLearning course with fewer thematic units and Model B included more thematic units so that they could be used as shorter courses. Based on the pilot study results, they found model B is appropriate for first-year university students (Javorick & Polasek, 2019b).

Skala and Drilk published multiple conceptual papers utilizing the microlearning approach for teaching programming concepts (Skala & Drilk, 2018a, b, c; Skala & Drilk, 2020, Skala et al. 2020). For example, the authors particularly focused on the didactical design of micro-content as microlearning is based on micro-content and micro-activities (Skala & Drilk, 2018). In one of their recent publications, based on longitudinal data from 2016 to 2019, the authors proposed a microlearning model to predict at-risk students and student outcomes in the introductory programming courses (Skala & Drilk, 2020). The results showed that the use of microlearning principles in the introductory programming courses did not show statistically significant differences in student learning outcomes; but the students' perception was positive while using microlearning content (Skala & Drilk, 2020).

In summary, microlearning as an instructional method is a widely used learner-centered teaching approach for teaching and learning introductory programming courses. Having said that, the microlearning literature portrays mixed results on the effectiveness of microlearning as an instructional method. Specifically, there are only a handful of empirical studies focusing on microlearning as an instructional strategy for teaching and learning introductory programming concepts. Some of the reasons for this could be that microlearning is a relatively new but emerging trend in higher education (Leong et al. 2020). Hence this dissertation study aims to explore the influence of microlearning in an introductory database programming course.

Chapter 3: Methods

This chapter provides information about the research design, data collection, and data analysis methods used to answer the research questions. This chapter also provides detailed explanations of study participants, data collection procedures, and data analysis methods. The purpose of this study was to explore the influence of the microlearning approach in terms of student learning outcomes in an introductory database programming online class. This study also seeks to find out the ways undergraduate students and the course instructor perceive the usefulness of microlearning as an instructional approach for teaching and learning introductory database programming concepts. The research questions of this study include

RQ1: Are there any differences in student performances between the two learning modes: microlearning instruction and recorded video lectures?

RQ2: How do students perceive microlearning as a learning approach?

RQ3: How does the course instructor perceive microlearning as an instructional approach?

Research Design

To answer the research questions, this dissertation study used an exploratory single case study design (Yin, 2014). The unit of analysis or the *case* is the introductory database programming online classroom. The reasoning behind selecting this classroom as a case stem from the instructors' commitment to implementing the microlearning instructional strategy along with the recorded video lectures. An exploratory research design was chosen because it was considered a robust research design when a holistic in-depth investigation of a complex phenomenon is required (Merriam, 2009).

Since the 1970s, case study research design has been used to evaluate the curriculum design and innovation methods in educational research (Harrison et al. 2017). Educational researchers often used case study design to understand and describe the case through research questions and/or the use of a theoretical framework (Merriam, 2009). A case study design is used for in-depth inquiry of the complex phenomenon being studied (a case) using multiple data points for the triangulation of evidence (Yin, 2014, p. 24). The case study design uses methods that explore factors such as participants' perspectives and curriculum success and failures (Harrison et al., 2017). Stake (1995) notes that a case study design could use qualitative, quantitative, or mixed-method research approaches.

The mixed-methods approach was chosen for this dissertation study because of the following reasons. First, the researchers' epistemological view is that undergraduate students experience multiple realities, and to capture these realities, the researcher needs to collect both student performance data and also interact with the learners to understand how they learn database programming concepts while using the microlearning approach. Second, the learner's perspective may differ from the researcher's perspective who has designed this microlearning content. An exploratory approach helps to understand the experiences while using microlearning content and thus help inform future design. Finally, collecting data from multiple sources helps to triangulate the findings and increases the credibility of the research design (Yin, 2014). Table 8 shows the matrix of research questions, data sources, and data analyses used in this study.

Table 8

Matrix of research questions, data sources, and data analyses

Research Questions	*Data Sources*	*Data Analyses*
RQ1: Are there any differences in student performances between the two learning modes: microlearning instruction and recorded video lectures?	Quiz scores Assessment exam scores	Descriptive Statistics paired *t*-test
RQ2: How do undergraduate students perceive microlearning as a learning approach?	Reflection prompts Perception's survey Semi-structured interviews with students	Descriptive Statistics Thematic Analysis
RQ3: How does the course instructor perceive microlearning as an instructional approach?	Semi-structured interview with Instructor	Thematic Analysis

Study context and participants

This dissertation study was conducted in an online introductory database programming class, designed to teach Structured Query Language (SQL) and database design concepts to undergraduate students at a midwestern university in the United States. This online course was structured in a fifteen-week semester format and was taught using recorded video lectures and microlearning modules as instructional methods. The course utilized the canvas LMS to deliver the course content and to assess the students' learning. The course content was divided into ten distinct course topics and was delivered using microlearning modules and the pre-recorded hour-long video lectures (see Table 9 for the course content and the corresponding teaching method). All the students were asked to complete quizzes after completing each topic to assess their understanding of their course content and reflect on the course content based on open-ended reflection prompts on the topic content. In addition to that, the students were assessed using two exams, Exam 1 which covered the first five course topics during week 8, and Exam 2 which

covered the last five-course topics during week 15. Students also completed an individual final project by the end of the semester. The study participants were 33 undergraduate students (13 females; 20 males) in their sophomore year, who are enrolled in the Spring 2022 academic year. These students majored in Computer Science and Information Technology (CIT) department, and this is one of their core courses as part of the CS & IT curriculum. The students did not have any prior experience with the database programming language and the design concepts.

Table 9.

Course contents and corresponding teaching method

Course topic	*Corresponding Teaching Method*
Topic 1: Database concepts	Recorded video lecture 1
Topic 2: SQL Introduction	Recorded video lecture 2
Topic 3: Single Table Queries	Microlearning Module 1
Topic 4: MySQL Update and Alter	Recorded video lecture 3
Topic 5: Normalization Process	Microlearning Module 2
Topic 6: Foreign Key Placement	Recorded video lecture 4
Topic 7: Logical Design	Microlearning Module 3
Topic 8: Multiple Table Queries	Recorded video lecture 5
Topic 9: DBMS Functions	Microlearning Module 4
Topic 10: DBMS Administration	Microlearning Module 5

Microlearning Intervention

A microlearning intervention in the form of microlearning modules consisting of micro lessons was designed to deliver the course content for the alternate topics during the semester (See Table 9). From the literature (e.g., Jahnke et al. 2019; Lee et al. 2021), The researcher has identified the following inherent design principles (See Table 10) for the microlearning

intervention design. Some of these design principles are originally proposed for mobile microlearning but based on the literature most of these design principles are applicable for any form of microlearning.

Table 10.

Microlearning design principles (adapted from Jahnke et al. 2019; Lee et al. 2021)

Design Principles	*Implementation Details*
Principle #1- Design of Micro-content and Micro-Activities ● Provide learner interaction ● Has a single objective ● Short lessons	The Microlearning modules used in the course consisted, 1. Micro lessons in which the learner could interact with learning content. 2. Micro lessons consist of a single learning objective and are present in small chunks. 3. Micro lessons are arranged in short periods that are easy to understand.
Principle #2 Instructional Flow ● Provide learning paths ● Multi-modal instruction ● Provide instant Feedback	The microlearning modules in this course support 1. Multiple learning pathways, where learners can choose the micro lesson, they want to start with. 2. Micro lessons included diverse media like video, text, and images. 3. The instant feedback was provided during the practice assessment.
Principle #3 Systems Design ● Easily accessible content ● Learners to track progress ● Multiple device access	The microlearning modules are designed in such a way 1. They can be accessed through Canvas LMS 2. Learners can track their progress using a progress bar 3. They can access the modules on any mobile device such as Laptop, Tablet, or smartphone.
Principle #4 Learner Motivation ● Supports learner needs and Preferences ● Increase learner motivation toward content ● Designed for target learners	The microlearning modules were designed in a way 1. The learner's needs and preferences are supported through interactivity and short lessons 2. The short lessons, interactive elements, and practice assessment helps with learner motivation 3. The learning content was specifically designed for the students of this course.

These microlearning modules were created by the researcher from the course instructors' pre-recorded video lectures using the *Articulate Rise 360,* a web-based authoring application (https://articulate.com/360/rise). The reasons for selecting Rise 360 include (1) convenient website-like interface, (2) easy to create modular course structure, (3) responsive to various screen sizes and devices (such as mobile, laptop, tablet, etc.), and (4) compatibility to integrate with canvas LMS. There was a total of five microlearning modules namely (1) Single table Queries - 8 micro-lessons, (2) Normalization process - 10 micro-lessons, (3) Logical database design - 5 micro-lessons, (4) DBMS administration - 5 micro-lessons and (5) MySQL Administration Functions - 8 micro-lessons, comprising of 36 micro lessons in total covering the five major course topics in SQL programming and database design concepts.

Each micro lesson contains three elements namely (1) a short, focused video with *must-know* information with a single learning objective, (2) an interactive element such as matching cards, flashcards, list tabs, etc., that requires student action, and (3) a practice knowledge check related to that lesson. These micro lessons were organized based on the course topics and built upon each other. The microlearning modules were made available via modules in the canvas LMS at the start of the topic week. Learners could go back to microlearning modules and re-watch the microlessons as needed in any order they want. The structure of the microlearning module is as follows.

- A user interface that allows the student to select the micro lesson they want to start with
- A progress bar that indicates their completion rate of that module,
- A short, focused video on a single learning objective
- Review of contents in the micro lesson
- A practice knowledge check

Figure 6 shows a sample microlearning module. A sample microlearning module could be accessed below (https://rise.articulate.com/share/QnHw7zx6I7DTaIXLsU7NTQnbxsP6DzAJ).

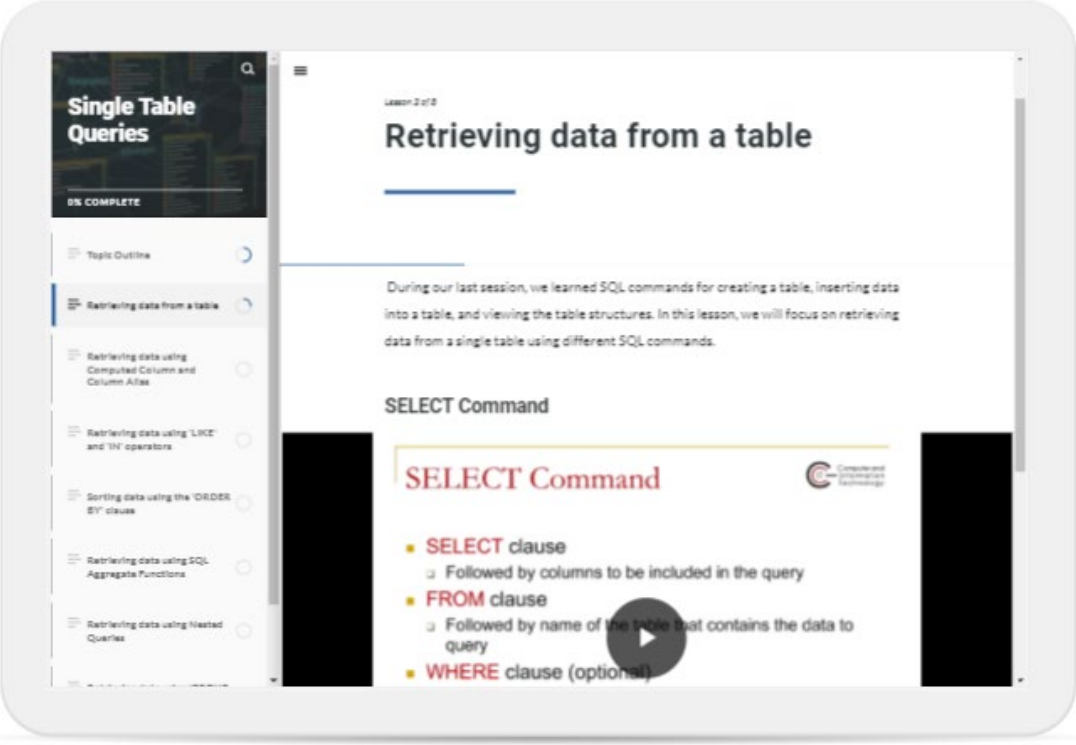


Figure 6. *Topic 3 Single Table Queries microlearning learning module*

Recorded video lectures

The recorded video lectures are based on the voice-over PowerPoint presentation on the topic of course content as mentioned in Table 9. They were recorded by the course instructor using the Kaltura screencast tool and they are approximately 1 hour in duration. These recorded video lectures do not contain any interactive elements and mostly contain five to seven learning objectives clubbed together for each course topic. The instructor goes through the learning objectives at the start of the lecture. The recorded video lectures are integrated directly into the canvas modules page for the week and are directly accessed by the students in the Canvas LMS.

Data Sources

A total of six data sources are used to collect data for this dissertation study. These are (1) Topic quiz scores (of all ten-course topics), (2) Assessment exam scores (exam 1, exam 2), (3) Reflection prompts for each topic, (4) Microlearning perception survey responses, (5) semi-structured interviews with students, and (6) semi-structured interview with the course instructor. Each of these data sources is explained in detail in the below sections.

Topic quizzes

All the students are encouraged to take quizzes after completing a course topic to help with their understanding of the course content. The instructor has created these quizzes as a form of formative assessment of the course content. The topic quizzes consisted of a minimum of five and a maximum of twelve multiple-choice questions based on the course topic. The quiz score was calculated by converting them into percentage points. The students are allowed to take these quizzes multiple times and the course instructor considers the highest quiz score for the grading purposes. For the statistical analysis purposes, I considered their first completed quiz attempt to score was considered for the data analysis purposes

Assessment Exams

The students were assessed using two exams - Exam 1 during the mid-term of the course and Exam 2 by the end of the course. These exams act as summative evaluations of the course topics. The exam1 consisted of a combination of five multiple-choice questions (worth 15 points), five true/false questions (worth 15 points), four short paragraph-type questions (worth 20 points), and writing SQL program queries (Worth 100 points), for a total of 150 points. Exam 1 covered the learning content from the first five topics of the course.

Likewise, Exam 2 covered the learning content from the last five topics of the course. It had a combination of eight multiple-choice questions (worth 20 points), eight true/false questions (worth 20 points), three short paragraph-type questions (worth 15 points), and writing SQL program queries (Worth 95 points).

Reflection prompts

The students were asked the below open-ended reflection question on the course topics "*In 2-3 sentences can you explain the interesting or challenging moments with respect to the Topic XX using (microlearning or recorded video lectures)*". These questions gave students a chance to reflect not only on the course topics but also on the way the course content was delivered to the students. These reflection prompts were added for both the conditions at the end of the course topic, and they completed this before the start of the new topic.

Microlearning Perceptions Survey

A survey is a systematic method for gathering information from (a sample of) entities to construct quantitative descriptors of the attributes of the larger population of which the entities are members (Groves et al. 2009, p. 2). In this dissertation study, to capture the students' perceptions while using microlearning instruction, a 15- item survey instrument questionnaire was created based on Leppink et al., 2013's cognitive load questionnaire and Inker et al. 2020's microlearning intervention feedback (see Appendix A for the survey instrument). This survey was created and administered using the Qualtrics application and distributed to students in Week 10.

The first part of the survey consists of 12 statements based on a ten-point Likert scale using *not at all the case* (1) to *completely the case* (10). Out of these 12 statements, the first

three items (items one through three) measured the learner's perceptions of essential processing (intrinsic cognitive load) while using microlearning instruction; the second three items (items four through six) measured the learner's perceptions of the extraneous processing (extraneous cognitive load) of microlearning instruction; and items seven through nine measured the generative processing (germane cognitive load) of microlearning instruction, and the final 3-items (items ten through twelve) measured the motivational aspects while using the microlearning instruction.

The second part of the survey consisted of questions asking about the desirable microlearning features and an open-ended question asking for the top three takeaways of learning database concepts using microlearning instruction.

Finally, there was an open-ended question that asked participants if they would be willing to participate in a semi-structured interview to share their detailed experiences while using microlearning instruction. The survey instrument was piloted with the students enrolled for the same course in the Fall 2021 semester to test the feasibility of the instrument. Based on the Pilot survey feedback, the survey instrument administered in this study was revised accordingly.

Semi-structured Interviews

While the survey responses could help with *whether* microlearning was a viable instructional strategy for understanding database concepts, the semi-structured interviews could help understand *why* microlearning may or may not be a viable instructional strategy for understanding database programming concepts. Through these semi-structured interviews, participants explained how they experienced microlearning as an instructional method in detail and whether it aligned with their expectations.

During the pilot study, the researcher conducted 3 semi-structured interviews at the end of the Fall 2022 semester with the students through the zoom application. The pilot interview questions mainly focused on their experiences while using microlearning content related to their learning performance, challenges they faced while using microlearning content, and the usefulness of microlearning content to support their understanding of database concepts (See Appendix B for pilot interview protocol). These pilot interviews are recorded, transcribed, and member-checked. Based on the students' feedback, the microlearning intervention was modified accordingly.

For this dissertation study, the researcher conducted a total of seven semi-structured interviews in the Spring 2022 semester through the zoom application. The interview questions (see Appendix C for interview protocol adapted from Carspecken, 2013) were aimed at learners to reflect more intentionally on the influence of microlearning intervention in addition to the survey and weekly reflection prompts. The interview protocol was content validated by an expert in the field. These semi-structured interviews lasted between 30 minutes to 45 minutes. In addition to the interviews with the students, the instructor was also interviewed to get their perception of the microlearning intervention.

The Interview participants are sampled from the survey participants based on their willingness to share detailed experiences while using the microlearning intervention. The semi-structured interviews were conducted with the participants until the data saturation point was reached, meaning no new information could be obtained from those interview responses. Zoom application was used to conduct interviews given the uncertain pandemic situation. The interviews were recorded and transcribed immediately after the interview. The transcribed verbatim interviews were sent to the participants for member-checking to confirm the accuracy

of the collected data. All interview participants received a $20 Amazon gift card as compensation for their participation.

Study Procedure

The study procedure is outlined in figure 7. In phase 1, A pilot study was conducted in the Fall 2021 semester that started with the document analysis of the course syllabus, canvas modules, and course assignments. This helped the researcher to understand the course content and the target learners. Then, a feasibility test was conducted with the target learners to get feedback on the design of the microlearning perceptions survey instrument and the interview protocol. An electronic survey was administered on Week 8 of the course and a semi-structured interview study was conducted around week 16 with target learners specifically focusing on the perceived usefulness and the challenges of using microlearning content. The pilot study results and the feedback was used to improve the design of microlearning modules in the next phase.

In Phase 2, to examine the influence of the microlearning approach on student learning performance outcomes, a quasi-experimental study was conducted during the Spring 2022 semester. As shown in Table 9, the course content was divided into ten-course topics, which were delivered via canvas LMS either in recorded video lectures (control condition) or microlearning modules (experimental condition). After each course topic, the students completed multiple choice quizzes, which acted as a formative evaluation of their knowledge of the topic. There was a total of ten quizzes for the entire course - five of them were for recorded video lectures (control condition) and five of them were for microlearning intervention (experimental condition) respectively. As part of the formative assessment of students' performance, the

cumulative quiz scores of students were compared between the control and the experimental conditions.

Likewise, as part of the summative assessment, the students completed two assessment exams - exam 1 during week 7, which covered topics 1 through 5; and exam2 during week 15, which covered topics 6 through 10. The students' cumulative exam scores in Exam 1 and Exam 2 (i.e., all ten-course topics) were compared between the conditions to see if there are any statistically significant differences between both instructional approaches.

In Phase 3, to understand the student perceptions and experiences while using the microlearning modules, a three-step approach was followed. First, students' reflection prompts for each course topic were collected and analyzed. As discussed earlier, after each course topic, the students completed a short reflection prompt on their experience related to the course content and the corresponding teaching method, a total of ten reflection prompts throughout the course.

Second, a microlearning perceptions survey was administered to the whole class. The main focus of the survey was to understand students' perceived cognitive effort while processing the course topics through microlearning instruction and their motivational aspects towards microlearning as an instructional approach.

Finally, semi-structured interviews were conducted based on the students' voluntary participation and with the course instructor in which the participants' detailed experiences while using microlearning content were sought.

The informed consent document (See Appendix C), that outlines the study information was shared as a course announcement in canvas LMS to all students by the instructor, and a formal email interview invite was sent to the course instructor. The researcher was added as an

observer in the canvas course by the course instructor, which provided the access to analyze the course topics on canvas.

After creating the microlearning modules for the specific course topics, the respective microlearning modules were exported from the Articulate Rise application and were provided to the course instructor in the SCORM format (canvas compatible), so that the course instructor imported them into the canvas LMS accordingly.

During Week 10, the microlearning perceptions survey (Appendix A) was administered to all students in the online class. The survey link along with the informed consent form (see Appendix D) was sent as a course announcement by the course instructor. The students had a week to complete the survey. An email reminder was sent on the last day of the week before closing the survey. The survey had a question asking "Can we contact you to get a little more detail about your experience using microlearning? If yes, please share your email address." The respondents who were willing to participate in the interview were contacted by the researcher with an invite email asking for their preferred time and date for the Zoom interviews. During the semi-structured interview, the participants were asked to pick one microlearning module of their choice and explain their detailed experiences learning the database programming concepts using that microlearning module (see Appendix C for interview protocol).

Phase 1 data collection was conducted in the Fall 2021 semester and Phase 2 and Phase 3 data collection were conducted in the Spring 2022 semester. The details of the data analysis procedures that were used in this dissertation study are explained in the next section.

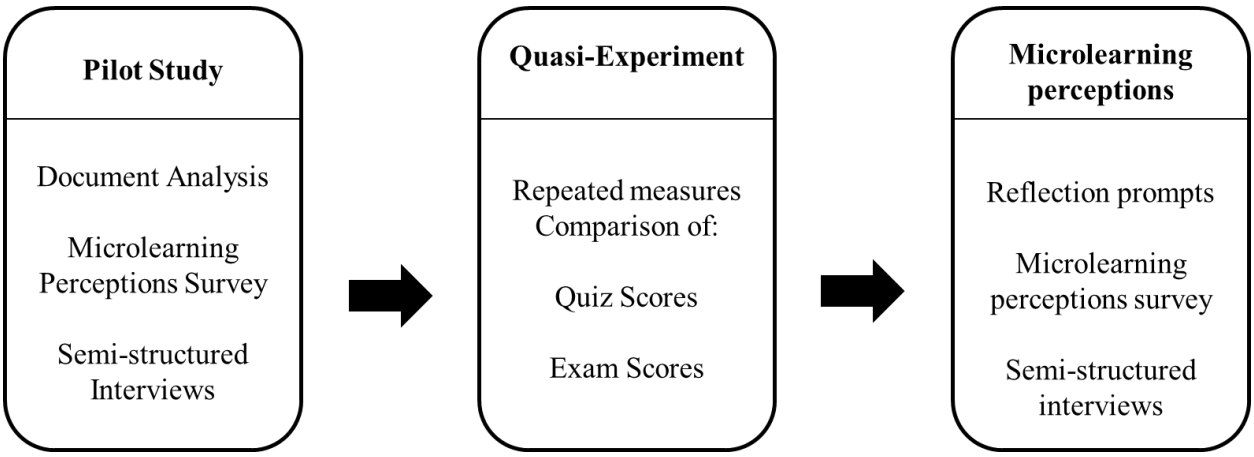


Figure 7. *Study Procedure*

Data Analysis

This section outlines the steps followed by the researcher during all three phases of the study.

Phase 1 - Pilot study

For the pilot study, first, the data analysis started with the analysis of the course documents such as the course syllabus, canvas modules, weekly course objectives, and assignments. The purpose of document analysis is to gain a deeper understanding and make sense of the course material by systematically reviewing and analyzing the course materials (Zhu, 2019). Some researchers argue that data gathered and analyzed from documents are more credible than other data sources such as interviews and the survey because of their objective nature, as it is recorded without a researcher's intervention (e.g., Pershing, 2002). In this study, the document analysis was conducted throughout the study to complement other forms of data and as means of data triangulation. Some of the documents included in the analysis are the course syllabus, review of canvas modules, homework assignments, and student project-related

documents. The analysis of these documents helped the researcher to understand the course content and analyze the change over time qualitatively.

Second, the microlearning perceptions survey used a ten-point Likert scale to measure the student's perceptions of using microlearning instruction to learn database programming concepts. We used descriptive statistics such as mean, frequency, and percentage in excel.

Finally, the semi-structured interviews were transcribed and then transcribed verbatim was analyzed using Braun and Clarke's six-phase thematic analysis approach (Braun & Clarke, 2006). A coding scheme was developed to identify the feedback opportunities to improve the microlearning modules. The survey results and pilot interview findings were used as the suggested improvements and changes were made accordingly to the microlearning modules for the dissertation study.

Phase 2 - Quasi-experimental study

In Phase 2, the student performance data were analyzed using a repeated measures design. First, a paired *t*-test was conducted to compare the mean scores of the cumulative quiz topics during microlearning topics and the recorded video lecture topics to see if there is any statistically significant difference in terms of student performances. Similarly, another paired *t*-test was conducted on the mean scores in Exam 1 & Exam 2 to see if there are any statistically significant differences in terms of student performance. The course instructor provided the respective course topics for each exam item in exam 1 and exam 2, which were then categorized based on the instructional method (microlearning vs recorded lecture), and the standardized student exam scores were used for the statistical analysis to compare them.

Phase 3 - Students and course instructor perceptions while using microlearning instruction

In Phase 3, To analyze the data from the reflection prompts and the semi-structured interviews, the six-phase thematic analysis (Braun & Clarke, 2006) was used. The interviews were recorded after getting permission from the participants and were stored in Kaltura for transcription. The researcher then reviewed and double-checked the transcribed verbatim for typos and accuracy. As part of validity, these transcripts were member-checked to ensure their accuracy and solicit their opinions on the transcripts' accuracy.

After getting confirmation from the participants on the accuracy of the transcribed verbatim, they were loaded into the NVIVO software for the coding process (see figure 8). All the interviews, reflection prompts, and open-ended survey responses were independently coded by a researcher and a methodology expert in the field.

The researcher and the expert coder became familiar with the data by reading the transcribed verbatim several times. Since the researcher already has research questions, the coding process included intentionally coding the chunks of data that could help answer the research questions. Each meaningful piece of data was compared with the existing codes and grouped to create themes. Thus, creating a coding scheme. After the first cycle coding process is completed for all the interview transcripts, the researcher and the expert coder reviewed the codes together and sorted out their disagreements, and proceeded with the second cycle coding - grouping the codes to identify the categories. Once the second cycle of coding was complete, the researcher invited the second coder for a peer debriefing session to discuss and finalize the categories and identify the overarching themes that could answer the research questions. The codebook was updated and finalized (see Appendix E for the coding scheme and Appendix F for the Categories and subcategories identified from the codes).

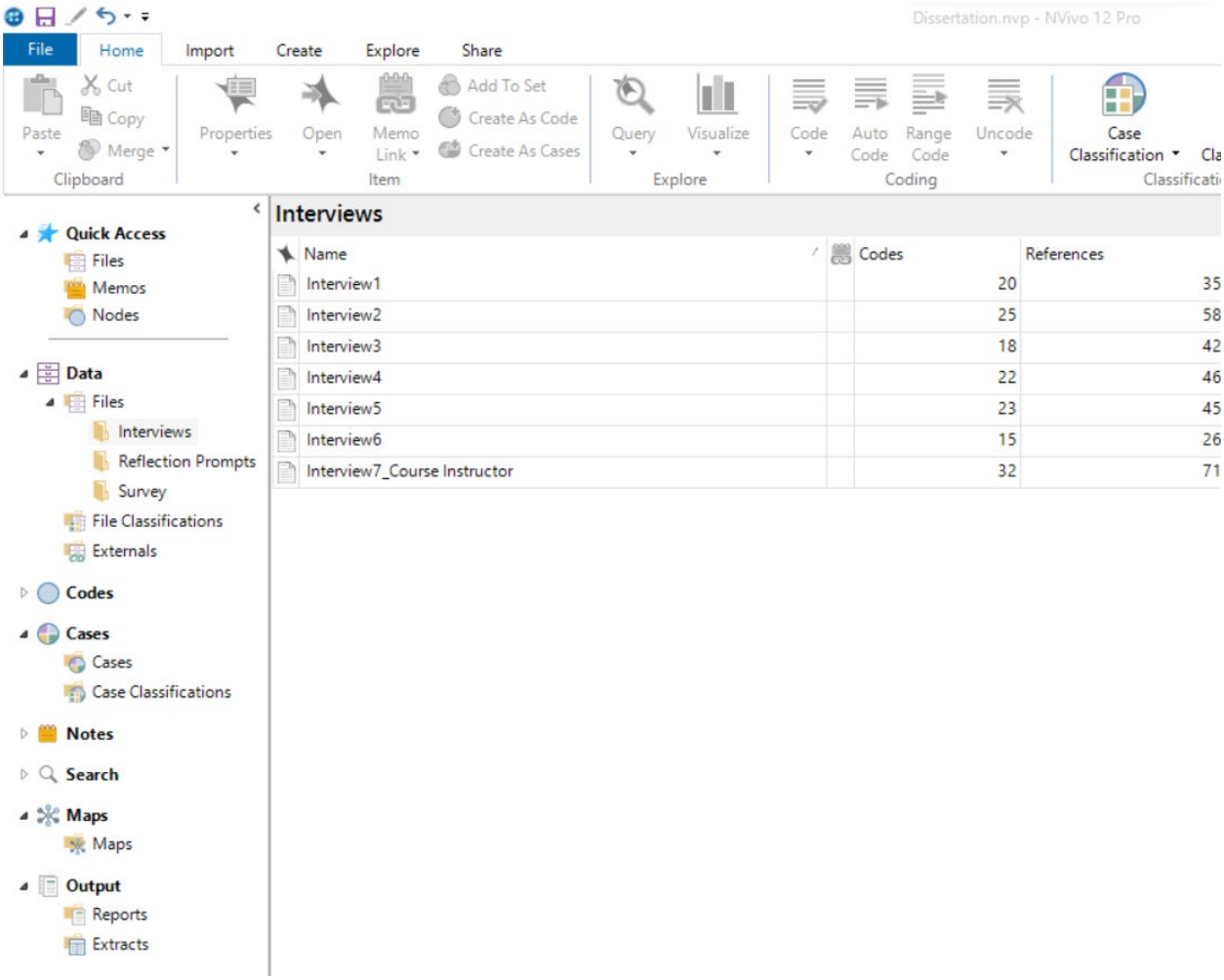


Figure 8. Organization of folders in NVIVO 12 Pro Application

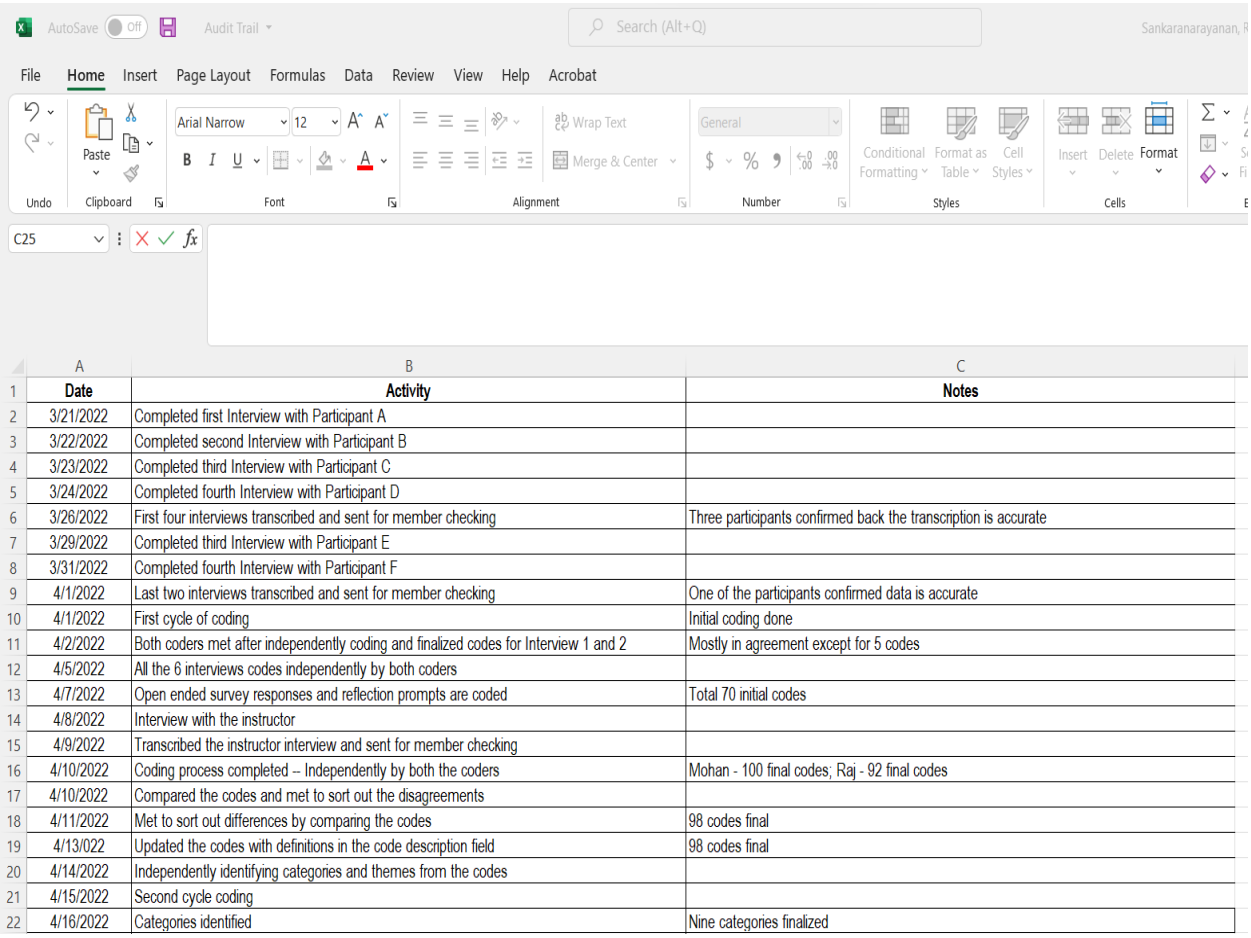
Validity, Reliability, and Trustworthiness

Validity refers to the accuracy of the instrument. To ensure the validity of the survey, an expert review and a pilot study were employed in this study. Reliability refers to the consistency of the instrument. To improve the reliability of the survey, a pilot test and Cronbach alpha reliability test were employed. Trustworthiness refers to the authenticity of the data. As per Lincoln & Guba (1985), trustworthiness has four elements namely credibility, confirmability, dependability, and transferability. The following eight techniques were used to address the study's trustworthiness: (1) Audit Trail, (2) Member checking, (3) Independent coding and

debriefing, (4) Pilot study, (5) Prolonged engagement, (6) Researcher reflexivity, (7) Thick description, and (8) Triangulation were employed.

Audit Trail

The researcher kept the audit trail of the events to reflect on the changes to the data analysis over time (See figure 9). For example, the initial codes are versioned with the date and the changes to the codes after discussion with the second coder are kept in the audit trail so that the changes and reasoning of the codes are tracked for future reference.



	A	B	C
1	**Date**	**Activity**	**Notes**
2	3/21/2022	Completed first Interview with Participant A	
3	3/22/2022	Completed second Interview with Participant B	
4	3/23/2022	Completed third Interview with Participant C	
5	3/24/2022	Completed fourth Interview with Participant D	
6	3/26/2022	First four interviews transcribed and sent for member checking	Three participants confirmed back the transcription is accurate
7	3/29/2022	Completed third Interview with Participant E	
8	3/31/2022	Completed fourth Interview with Participant F	
9	4/1/2022	Last two interviews transcribed and sent for member checking	One of the participants confirmed data is accurate
10	4/1/2022	First cycle of coding	Initial coding done
11	4/2/2022	Both coders met after independently coding and finalized codes for Interview 1 and 2	Mostly in agreement except for 5 codes
12	4/5/2022	All the 6 interviews codes independently by both coders	
13	4/7/2022	Open ended survey responses and reflection prompts are coded	Total 70 initial codes
14	4/8/2022	Interview with the instructor	
15	4/9/2022	Transcribed the instructor interview and sent for member checking	
16	4/10/2022	Coding process completed -- Independently by both the coders	Mohan - 100 final codes; Raj - 92 final codes
17	4/10/2022	Compared the codes and met to sort out the disagreements	
18	4/11/2022	Met to sort out differences by comparing the codes	98 codes final
19	4/13/022	Updated the codes with definitions in the code description field	98 codes final
20	4/14/2022	Independently identifying categories and themes from the codes	
21	4/15/2022	Second cycle coding	
22	4/16/2022	Categories identified	Nine categories finalized

Figure 9. Audit trail

Member checking

Before starting the coding process to ensure the accuracy of the data, the member checks were done with the interview participants before starting the coding process and interpretation of results.

Independent coding and debriefing

To maintain objectivity and to address their own bias while examining the interview transcripts and the coding process, the researcher consulted and discussed with a methodology expert, who coded all the interviews, reflection prompts and open-ended survey responses independently to ensure the study's trustworthiness. In addition, the researcher requested review from two other methodological experts to provide review and critical feedback on the coding process, analysis, interpretation, and description of the study results.

Pilot study

The researcher conducted a pilot study to test the feasibility of the study procedure and to test the instruments of the study. The pilot study also helped the researcher to obtain valuable feedback from the target learners on the microlearning intervention and incorporated the suggested feedback before collecting data in the actual dissertation study.

Prolonged engagement

Prolonged engagement is a means of spending a lot of time with the study participants and the study context to gain an adequate understanding and to establish a trusting relationship between the researcher and the study participants (Zhu, 2019). In this study, the researcher spent two full semesters with the course instructor to understand the course content and the study

participants. During eight full months, the researcher got important insights and understanding about the CS & IT curriculum as a whole apart from the CIT214 course, this study context.

Researcher reflexivity

The case study design requires the researcher to interact with participants to generate, interpret, and co-construct data (Merriam, 2009; Yin, 2014). Therefore, the researcher needs to acknowledge their biases and *subjectivity* and thus take a reflexive stance within the study (Denzin & Lincoln, 2011; Miles et al. 2014; Yin, 2014). One of the integral parts of qualitative inquiry, researchers' reflection memos serve to make sense of the parts of the research project in relation to the whole. These memos help researchers to have conversations with data and could serve as a companion or a precursor to the coding process and data exploration is enhanced through the memoing process (Briks et al. 2008; Mihas, 2021). Document Reflection Memo strategy, “a record of researchers’ initial understanding of a transcript that may be examined later in the project when looking across participants”(Mihas, 2021, p. 246) was used by the researcher to write the reflection memos.

Reflexivity is considered conscious and self-aware (Finlay, 2002). Reflexivity can help in transforming one’s subjectivity into an opportunity to engage in critical elements of data analysis, thus enhancing overall trustworthiness in qualitative research (Zhu, 2019). In this dissertation study, the researcher actively reflected on each step during the research process including data collection and analysis. In addition to that, the researcher provided a positionality statement on the researcher's positional stance.

Thick description

The thick description refers to the detailed description of the study context to increase the credibility and rigor of the qualitative research (Carspecken, 2013). In this dissertation, the study context, the participants, study procedure, data sources, and respective data analyses have been described in detail to improve the trustworthiness of the researcher's interpretation of research findings and conclusions.

Triangulation

Multiple data sources were used in this dissertation study as a means to improve the study's rigor (Yin, 2014). In this dissertation study, two types of triangulation techniques were employed: (1) data triangulation and (2) methods triangulation. The researcher used multiple data points as primary data sources and secondary data sources to answer each of the research questions (see Table 8). In addition to that, for both the research questions, both quantitative and qualitative methods were also used for method triangulation.

Chapter 4: Results

The purpose of this dissertation study is to investigate the differences between student performances while learning through microlearning instruction and recorded video lectures in an online introductory database programming class. In addition, this study also unveils the students' perceptions while using microlearning instruction to understand introductory database programming concepts. It also explores the instructor's perceptions while teaching using microlearning instruction. Ultimately, this study hopes to address the gaps in the microlearning literature through unpacking and exploring the experiences of undergraduate students using microlearning as a viable instructional approach for teaching and learning introductory programming concepts.

In this chapter, the results are presented according to the research questions. First, the difference between the students' performance scores in topic quizzes and assessment exams while using microlearning and recorded video lectures is described. Then, the students' and course instructors' perceptions related to using microlearning for teaching and learning database programming concepts are described based on the survey, student reflections, and semi-structured interview results. Each of the sub-sections includes statistical differences in topic quizzes and exam performances, survey results, and semi-structured interview results. A summary of each research question concludes each of these sub-sections.

Relevant findings across all data sources (Quiz scores, Assessment exam scores, student interviews, reflections, survey questionnaires, and course instructor interviews) are integrated to present a holistic understanding of the data related to each research question.

RQ1: Are there any differences in student performances between the two learning modes: microlearning instruction and recorded video lectures?

The findings for this research question are divided into two parts. The first part discusses the average student quiz performances across all the ten topic quizzes and the second part discusses the students' assessment exam performances while learning using microlearning instruction and recorded video lectures.

Students quiz performance

Thirty out of thirty-three students completed all the ten topic quizzes. To test the hypothesis that the quiz scores of the recorded video lectures-based instruction (M=75.87, SD=16.49) and microlearning instruction (M=80.63, SD=15.43) means are equal, a paired samples t-test was conducted. Before conducting the analysis, the standard statistical assumptions (i.e., normality of quiz scores, independence of scores, scores in continuous range) were checked to make sure all assumptions were met. The null hypothesis of equal resilience means was rejected, $t(29) = 2.214$, p=0.03. Thus, the mean student quiz performances while learning through microlearning instruction was statistically significantly higher than the student quiz performances while learning through the recorded video lectures mean. Cohen's d was estimated at 0.41 which is a small effect based on Cohen's (1992) guidelines. The 95% confidence intervals ranged from 0.36 to 9.17. Table 11 shows the basic descriptive details for students' quiz scores across each instructional method.

Table 11.

Results of differences in students' quiz performance scores

Logistic parameter	Microlearning		Recorded Lectures		*t(30)*	*p*	Cohen's *d*
	M	*SD*	*M*	*SD*			
Quiz Scores	80.63*	15.43	75.87	16.49	2.2144	.0034	0.41

Note. *Denotes significant differences in the mean score of the paired items at the $p < .05$ level.

Students' assessment exams performance

Thirty-one out of thirty-three students enrolled in the course completed both the assessment exams. To test the hypothesis that the assessment exam scores of the recorded video lectures-based instruction (M=87.31, SD=17.29) and microlearning instruction (M=90.53, SD=9.17) means are equal, a paired samples t-test was planned. While checking the standard statistical assumptions, it was found that the assessment exam scores of both groups were negatively skewed and not normally distributed.

In an effort to transform the negatively skewed data and to conduct a parametric test, the following steps were performed. First, two reflection variables were computed using the formula (MAX SCORE + 1 - Recorded Video Lecture) and (MAX SCORE + 1 - Microlearning) from the recorded video lectures and microlearning data in IBM SPSS 28 Application. Second, two log transformation variables were created using the reflection variables - *Reflection_recordedlecture* and *Reflection_Microlearing* variables. Then, the skewness and distribution were explored by plotting the transformed, reflection variables. It was found both the *log10_microlearning* and *log10_recordedlecture* variables were normally distributed and had positive skewness closer to 1. Thus, satisfying the normality assumption.

Finally, a parametric paired samples t-test was conducted. The results indicated that the log-transformed mean scores of the microlearning instruction ($M = 0.80$, $SD = 0.40$) was not significantly different from the log-transformed mean scores of the recorded video lectures ($M = 0.79$; $SD = 0.58$), $t(30) = 0.078$, $p = .469$, indicating there is no significant score differences while learning through two instructional modes (see Table 12).

Table 12.

Results of differences in students' exam performance scores

Logistic parameter	Microlearning		Recorded Lectures		*t(30)*	*p*
	M	*SD*	*M*	*SD*		
Log transformed Exam Scores	0.80	0.40	0.79	0.58	0.078	.469

RQ2: How do students perceive microlearning as a learning approach?

The findings for this research question are divided into two parts. The first part discusses the perceived cognitive load and the motivational aspects reported by students through the microlearning survey administered during the Week 12 of the course and the second part discusses the themes that emerged through the qualitative thematic analysis of the open-ended survey responses, reflection prompts of each topic and semi-structured interviews conducted with the students.

Microlearning perceptions survey findings

The survey results are divided into four parts namely - (1) Extraneous cognitive load, (2) Intrinsic cognitive load, (3) Germane cognitive load, and (4) Motivation. Each of these parts is presented both in tabular format and chart format to make sense of the data. A total of 27 responses were received (81.81% response rate), out of which three of them had missing data for a few of the survey items; hence a total of twenty-four responses were considered for final analysis as presented below. The respondents rated the survey items on a ten-point scale that ranged from 1 - *not at all the case* to 10 - *completely the case* (see Appendix A for the survey instrument).

Extraneous cognitive load

The survey respondents agreed that microlearning is an effective way to learn introductory database programming concepts by ranking the extraneous items lower (M=3.38; SD=2.15). They also stated that the learning content presented through microlearning was not difficult to understand and was presented (See Figure 10). These findings were also supported by the reflection prompts and the interview responses.

Table 13.

Mean and standard deviation values for Extraneous cognitive load (N = 24)

Extraneous cognitive load	*M*	*SD*
It is an ineffective way to learn	3.08	2.41
It is very difficult to understand	3.38	2.20
It was not clearly presented	3.67	2.16

Intrinsic cognitive load

The survey respondents noted that the introductory database programming concepts and the design concepts covered in the course using microlearning instruction were not very complex but not too simple at the same time (*M*=6.36; *SD*=2.26). This suggests that the learning content taught in this course was moderately complex (see Table 14).

Table 14.

Mean and standard deviation values for Intrinsic cognitive load (N = 24)

Intrinsic cognitive load	*M*	*SD*
The SQL commands were very complex	5.96	2.61
Database programming concepts were very complex	6.29	2.58
Database design concepts were very complex	6.83	2.04

Germane cognitive load

The survey respondents agreed that the microlearning approach was helpful for them to understand the introductory database programming concepts and the design concepts covered in the course (*M*=7.74; *SD*=1.96). This finding was also supported by the reflection prompts and the semi-structured interviews.

Table 15.

Mean and standard deviation values for Germane cognitive load (N = 24)

Germane cognitive load	*M*	*SD*
Enhanced my knowledge and understanding of SQL commands	8.13	2.07
Enhanced my knowledge and understanding of Database programming concepts	7.71	2.10
Enhanced my knowledge and understanding of Database design concepts	7.38	2.10

Motivational factors

The survey respondents stated that the microlearning was very interesting and they enjoyed learning through microlearning and generally felt confident about their ability to succeed while using microlearning to learn the introductory programming concepts (*M*=7.53; *SD*= 2.39). This finding was also supported by the reflection prompts and the semi-structured interviews.

Table 16.

Mean and standard deviation values for Motivational factors (N = 24)

Motivational factors	*M*	*SD*
I enjoyed microlearning	7.08	2.93
It made me feel confident in my ability to succeed	7.71	2.48
It is an interesting way to learn	7.88	2.49

Findings from thematic analysis of qualitative data

This second part presents three themes from the qualitative thematic analysis of the data collected from the open-ended survey responses, topic reflection prompts, and six semi-structured interviews with students. A total of 228 minutes of interviews or 995 lines of transcripts were used for the qualitative data analysis.

The qualitative data analysis began using the six-phase thematic approach as outlined by Braun & Clarke (2006). First, I and another expert coder open-coded the relevant data chunks that could be used to answer the research questions by generating concise labels using the coding scheme (see appendix E for the codebook). A total of 112 initial codes were developed. The expert coder and I had three rounds of meetings to compare our independent codes and sorted out our differences, which resulted in 96 final codes (see figure 14 and figure 15). Among these 96 codes, 78 codes were related to the student's perceptions of microlearning as an instructional approach. I summarized these 78 codes into seven categories, which were then further refined into five overarching themes namely: (1) "I prefer microlearning than the recorded lectures": Microlearning vs. Recorded Video lectures, (2) "Microlearning would probably be the best outlet to teach that if you're not going to be in a classroom": Perceived Benefits, (3) "I like the way the microlearning was presented, I really love it.": Effective Instructional Strategy, (4) "It's like a kid's meal - for complex topics, microlearning might be limited": Perceived Challenges, and (5) "Seeing more examples will help me visualize better": Areas for improvement.

These overarching themes and categories were then refined in the following phase to determine if they tell a coherent story about the research question. In the final phase of the data analysis, I finalized these themes and updated the coding scheme so that detailed analyses and information can be derived from the themes. The thematic map is presented in Figure 16. I also

present the narrative from the data extract related to the research question in the below section.

Nodes

Name	Files	References
Effective Instructional Approach	13	78
Clear explanation	2	2
Easy to digest information	4	7
Easy to focus	3	7
Easy to review	6	12
Easy to understand	6	13
Effective	1	1
Holistic understanding	1	1
Instructor prefer microlearning	1	1
Less cognitive load	2	4
Positive feedback	1	1
Rate microlearning usefulness	4	4
Saves instructor time	1	1
Spend more time	1	1
Straight to the point	1	1
Students Prefer microlearning	12	21
Well suited for online instruction	1	1
Instructional Designer Awareness	1	4
Course alignment important	1	1
Designer clear on Learning objectives	1	1
Program alignment important	1	1
Willing to invest	1	1
Instructor attitudes	1	13
Instructor blames self	1	2

Figure 14. Coding nodes within the NVIVO 12 Pro Application

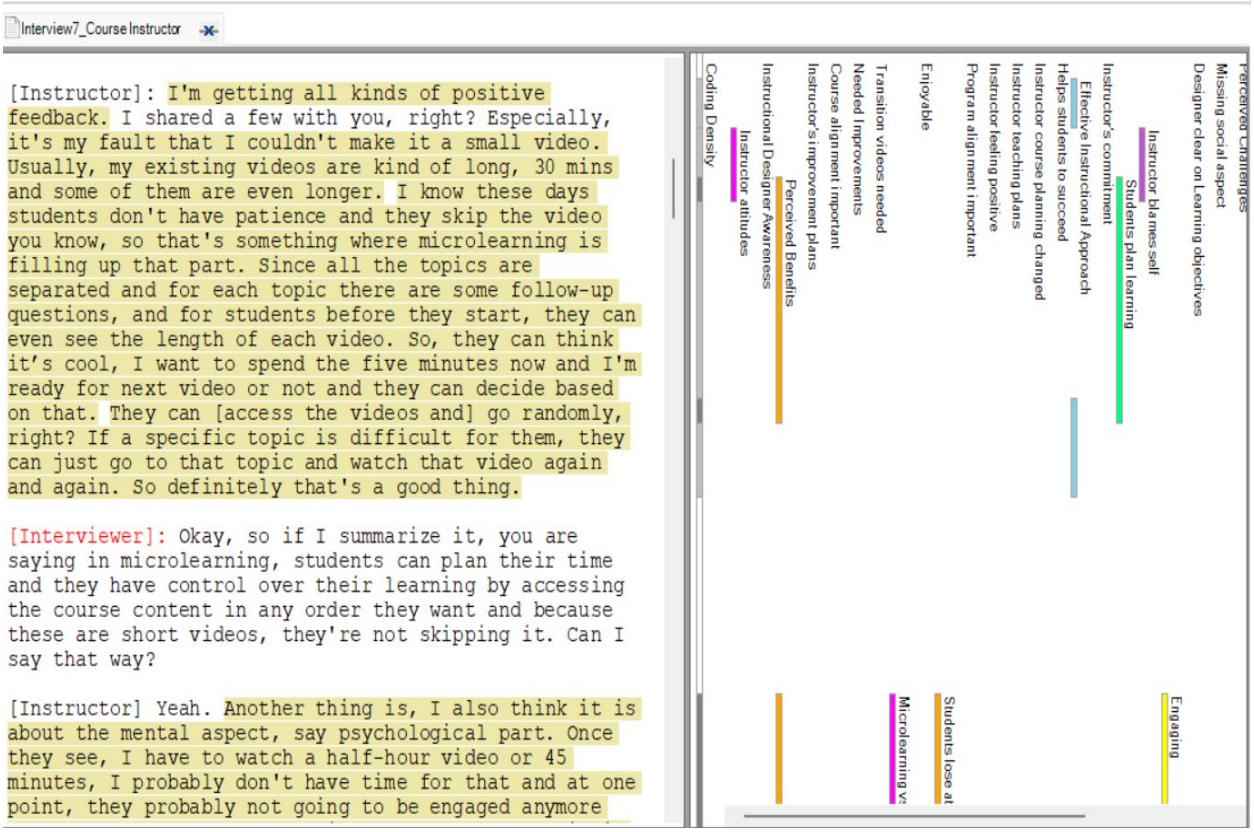


Figure 15. Example of coding stripes to show coding density in NVIVO 12 Pro Application.

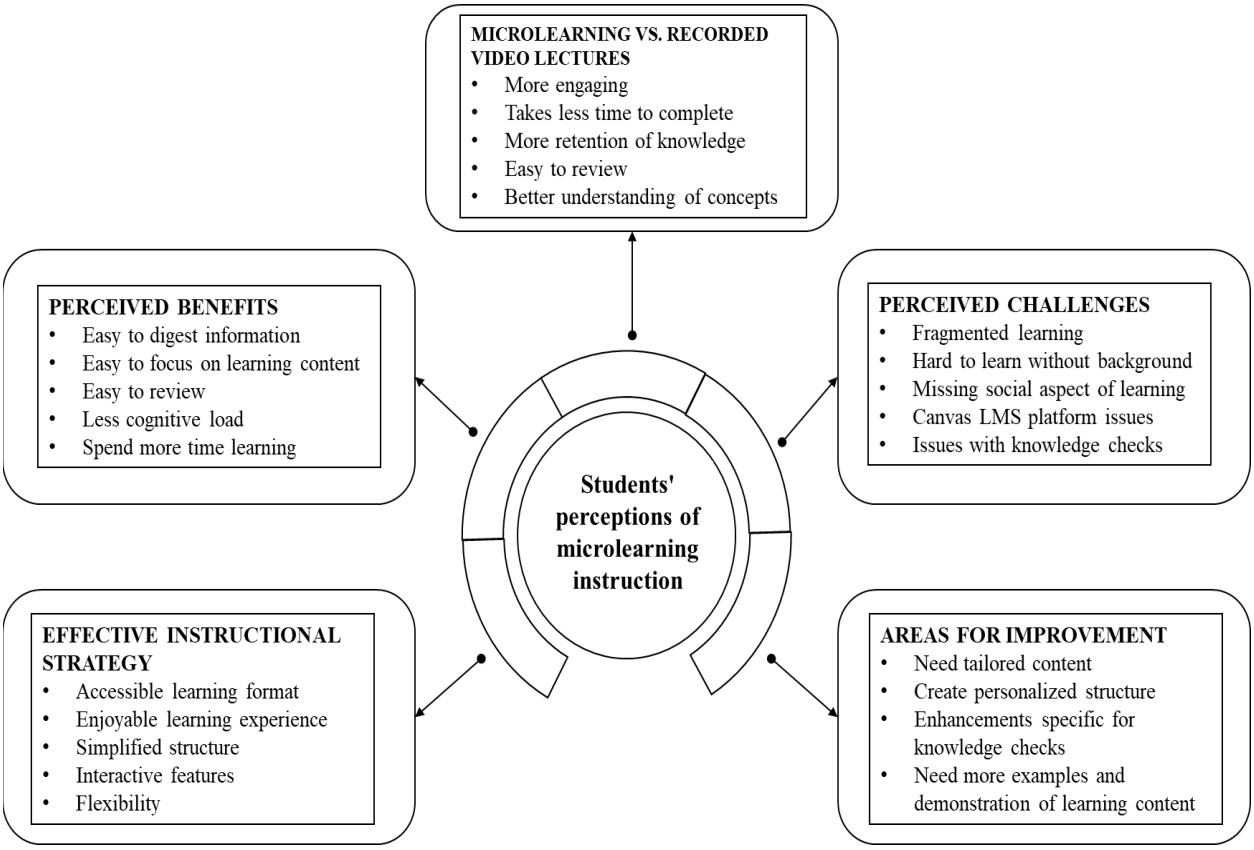


Figure 16. Thematic Map for Students' perceptions of microlearning instruction

Theme 1: ***"I prefer microlearning to the recorded video lectures"***

Many of the participants prefer microlearning compared to recorded video lectures due to various reasons such as microlearning takes short time to complete, microlearning is more engaging, helps them with their attention span, helps retain the learning content more, and they enjoy learning more through microlearning and it helps with some of the limitations of recorded video lectures such as being out of context.

First, some of the participants mentioned that the microlearning modules feel quicker than the recorded video lectures even though they contain the same amount of information while others felt that recorded video lectures contain too much information. For example, Anthony

stated ”*It feels quicker to me than watching a recorded lecture. Technically, it's not a quicker, but it feels quicker because it's easier to digest the information*.” Whereas Chloe stated, “ *I like microlearning because recorded videos seem like having too much information*.” Likewise, another participant reflected in their topic reflection prompts, “*It was interesting to see how the videos were much shorter, but I still felt I learned the same amount of information as usual*.”

Second, the participants stated that interactive features such as knowledge checks make microlearning more engaging than recorded video lectures and help them focus their attention on the learning content.

For example, Chloe stated,

> *“I like it better than recorded videos because you're more likely to pay attention if you know there's going to be a quiz at the end of each video, you are watching. So that's what I really like about it. They helped me remember the lecture more because I'm engaged throughout the whole thing... It allows you to stay focused because you watch one video and they ask you a question about the video you watched, and you answer that”*

Another participant agreed that with recorded video lectures require students to have a sharp attention span to focus:

> “*You are more likely to focus if you have like a sharp span of attention if you can pay attention to something really long. I choose microlearning because I'm more likely to remember what I learned through microlearning than recorded videos”*

Third, participants stated that they prefer microlearning compared to recorded video lectures because they retained more information due to the interactive elements of microlearning. For example, Daniel notes:

> "*Microlearning is more interactive than just your video learning modules. You know, up to this point, most of any type of e-learning I've done has been recorded Videos, which is fine. But I feel like the interaction that you're forced to take part in, in these types of modules requires you to think a little bit more. So, I feel like you've retained the information a little bit better because of that interaction."*

Chloe confirms this by stating,

> *"The recorded videos are not broken down and I forget most of the stuff I watched by the end of the recorded video lectures. But microlearning is like short videos and there is an interesting question after each one of them. So, I remember more"*

With the above point, Felix stated that the knowledge checks and the interactive features in the microlearning act as a refresher for the course and helps to easily review the learning content compared to the recorded video lectures.

> *"I like the fact that in microlearning, it wouldn't let you proceed if you're not done with it. I also like the end section questions at the end of each video that way, it's kind of like give you like a refresher of what you've watched and if you don't understand. you can go back to it. So, I like those two things about microlearning. Basically, that is the major difference I see between the microlearning and the recorded videos. In recorded video I can skip forward the part of the question and continue with the lesson. But in*

microlearning, you must answer in order to proceed, it is good, and it gives you good summary of what you learned."

Fourth, some of the participants stated that they are less encouraged to learn using recorded video lectures whereas almost all of the interview participants stated that they enjoyed learning through microlearning. For example, Chloe stated,

"I like microlearning more than the [recorded] videos. Definitely the weeks with the recorded videos are longer videos. Even just slightly that mindset you have before starting; if you see that there's like a 40- or 45-minute video, just mentally, I would be less prepared and less encouraged to do it. On the other hand, what I see the microlearning was only like 2-to-10-minute videos."

Daniel concurs with Participant C and states that microlearning helps to better understand the learning content because it makes the learners think and reflect on the learning content compared to the recorded video lectures.

"If the students are just watching a [recorded] video going over normalization, the video is just going to constantly be running. And I feel it doesn't stop them and make them actually think about what normal form they just were learning about. And because [in microlearning] you had to stop and think about each step in the normalization process, I really think that helps people understand that."

Bennet stated, " *I definitely thought there are more positives than negatives; even the cons are in rare cases. I enjoyed it[microlearning] more than the lecture videos.*"

Finally, some of the participants said that recorded lectures had some limitations compared to microlearning modules in terms of the learning process. For example, Anthony stated,

> *"[Recorded Lectures] they're nice and all, but sometimes they seem very out of context. It'll show something without anything to back it up. Like it'll show me a random graph and I don't know what to do with the graph."*

Theme 2: *"Microlearning would probably be the best outlet to teach that if you're not going to be in a classroom"*

The participants rated the perceived usefulness of the microlearning approach high to very high because it helped them with a holistic understanding of the learning content. Particularly, one of the participants, Daniel stated that "*I actually think microlearning would probably be the best outlet to teach that if you're not going to be in a classroom.*" There are various reasons why participants mentioned microlearning was an effective online learning strategy: (1) they had an easy time learning the database programming concepts; (2) it was easy to digest information while learning through microlearning; (3) it was easy to focus on the learning content at the given time; (4) It was easy to review the learning content as on when needed; (5) It was easy to understand complex topics; (6) they were able to spend more time in learning; and (7) they experienced less cognitive load while learning through microlearning.

Two out of six participants stated that it was easy to digest the presented information through the microlearning approach. Chole stated that "*Microlearning is just better because each chunk of video has important information needed for each section.*" Eva agreed by saying, "*By Segmenting Ideas into multiple pieces, it is easier to digest this way and because the videos were short, it's easy to scroll each video and find information easily.*"

The participants also stated it is easy to focus while learning through microlearning. Bennet mentioned, "*The videos were more on point as well; microlearning helped me stay focused for a longer period of time*." and Chloe stated, *"it allows you to stay focused because you watch one video and it asks you a question about the video you watched, and you answer that."* Others reflected on the same by saying, "*The short videos were straight to the point and allowed me to stay focused since they were so short.*", "*Smaller bits of information rather than large areas of reading definitely make it easier to focus.",* and *"I was able to stay focused because the videos were broken down into small parts."*

Furthermore, four participants also reflected it is easy to review the learning content through microlearning because they can always go back and rewatch the learning content that is not very clear for them and the structure of microlearning allowed them to look back at the information with ease and it allowed to review the topic multiple times as needed. For instance, Eva mentioned,

> *"Each [micro lesson] is just some few minutes, one minute, two minutes, three minutes at most. So, you don't have to scroll 25 to 40 it guesses what you're looking for. For example, If I don't get the concept for example, what is a candidate key? I can just go to that particular video which is just 2 to 3 minutes long and review the concept without searching for that in a long-recorded video. It is short and treats a particular concept specifically and that concept can be revisited at any point in time. You have the ability for you to be able to play it over and over until you get your concept right."*

Chole agreed with Eva by saying,

"There are sometimes like when I am I doing homework, I want to go back to the way I can just click whichever one I want to review. instead of watching the whole video, it helped me just watch the part of the recorded lecture [which I need]."

Daniel mentioned that he spent more time studying because microlearning helps cover the right material "*in my, in my opinion, it causes you to actually spend even more of your personal time studying because you have to make sure that you've covered all the right material."*

Participants also stated that because it is easier to review the topic through microlearning instruction, four out of six interview participants said it is easy to understand the learning content better and it helps build a strong foundation for the programming concepts. For instance, Bennet mentioned that

"I feel like for the programming concepts actually microlearning would be really helpful. Because if you have different videos that have the lecture when she [course instructor] moved from one slide to another slide like using LIKE and IN [operator] or like an ALTER and MODIFY [command], those are different but they kind of go together. So, if you had like one microlearning part that said ALTER and MODIFY and another one that said LIKE and IN, I think that would be helpful. I'll go back and review it quickly and then I'd be able to understand it better. I think having microlearning for the entire course, I would like better just because I feel like most of this course, even the logical design and the normalization that has different parts like first, second, third [Normal forms], as well as the [SQL] programming having the different terms or different programming concepts and as I explained, I think it can all be divided into little parts with shorter videos."

Daniel mentioned that,

> *"So, I feel like [microlearning] did a really good job slowing down the learning process to where you had to learn about each normal form before you could move on to the next. And if you didn't get those questions right, you obviously would go back and go over the material, at least that's how I would go about doing it and build that foundation for the next piece of the lesson. Because of the way that modules build, I think it, it helps you just built the foundation to build up to heavier concepts."*

Eva said,

> *"The ability to start something, pause it, go back, and continue it is a very good one. Then the ability to repeat a concept, each [micro lesson] is just a few minutes - one minute, two minutes, or three minutes at most. So, you don't have to scroll 25 to 40 minutes with guesses about what you're looking for. For example, If I don't get the concept of what is a candidate key, I can just go to that particular video which is just 2 to 3 minutes, and review the concept without searching for that hour-long long-recorded video. It is short and treats a particular concept and that concept can be revisited at any point in time."*

Finally, the majority of participants noted that, because it is easy to understand and digest the learning content, the microlearning approach helps with reducing the cognitive load. For example, Anthony stated, *"I say microlearning is helpful. I like the [way] quizzes and stuff [are organized] because it breaks it up and kind of gives your brain a much-needed break like every few minutes. it's like easier for my brain to soak it in. I prefer it that way."* Another participant, Eva said, "The videos are not long, so you don't feel you don't feel overwhelmed". Likewise, Chole mentioned, *"I like microlearning better because recorded videos seem like having too*

much information. But microlearning helps us because it breaks it down. You don't have to like process too much information being thrown at you at once."

To sum up, the participants stated microlearning is an effective instructional strategy because it helps them easily digest information, easy to focus on the learning content, easy to review the programming concepts, easy to understand complex concepts, and able to spend more time learning and experienced less cognitive load.

Theme 3: *"I like the way the microlearning was presented, I really love it."*

The participants noted various perceived benefits while learning through the microlearning approach, such as (1) Accessible learning format; (2) Engaging learning format; (3) Enjoyable learning experience; (4) Flexible learning approach that gives learner control that prepares learners to learn different topics ; (4) Better knowledge retention because of simplified learning structure and (5) Helpful learning approach, that takes less time to complete homework and assignments.

Two of the six interview participants and some of the learners reflected that the microlearning approach is very accessible by curriculum is separated by one main idea, so it is easy to locate for review. In other words, it is organized for easy access to the learning content. The majority of participants also mentioned that the microlearning approach is a very engaging and enjoyable learning experience and they would like to have a microlearning approach for all the classes they are taking. For example, Daniel stated, "*I like the way the microlearning was presented, I really love it.*" and Eva stated,

> "*I really enjoyed the microlearning. I like how everything was spaced out into small sections and how after watching a certain number of videos it would give you a question*

to answer to see if you have fully gone through the videos. I would definitely use it for any other class if the option was given."

The participants also stated the microlearning approach is a flexible learning format, which motivates and gives learners control of their learning through various structural aspects. For example, one of the participants reflected that "*bite-sized videos that are easier to complete at any time. An easier way to pick back up where I left off if I need to stop for the time and come*" Likewise, Anthony stated that microlearning helped with readiness to learn, "*It's like I'm ready to learn the next thing. And if I'm not ready, I have the option to re-watch that video."* another participant stated, *"Video Clips helped go more in-depth into the concepts".* One of the interview participants - Bennet said the outline motivated them and get ready to learn,

"*I really liked seeing that outline. It just got me prepared for what I'm going to see and what I'm going to learn. Just like if there's any topic that they say what's discussed last week and I don't remember it, I would go back and do [review] that. Let me give the example: For the database design method, it would have the outline of what we're going to do. For example, revisiting the ER model. So, if I forgot the ER model, I could go back to the week of the ER; even if I don't remember it, I could just watch the recap of the different terms that you would need to know. That was nice and we talked about the database design phases, database design method, the benefits, and then the summary. So that's why I thought it was kind of go in order as like the summary was last and then there was a recap in the beginning. So that's why I would go doing it on order. I thought the structure was well made."*

Participants also mentioned that the simplified structure of microlearning is easy to navigate. One of the participants Anthony stated, *"it's a simple platform - It's not complicated, it's easy to*

navigate." Similar to that, Bennet stated that the progress bar motivated them to complete the topic content.

> *"I really like the progress bar that would show you're into percentage since there were only three or four parts to it, like 20 percent, 40 percent the percentage complete and the little circles that would show completed items [progress bar] would just motivate me more to finish quicker."*

Another major benefit the participants mentioned was knowledge retention. Some of the participants reflected that microlearning modules are straightforward and don't give unnecessary examples, which helps with the retention of knowledge. One of the participants Chole stated that because there is an interesting practice quiz after each microcontent, they can remember the topic more. Likewise, Daniel mentioned that interactive elements instead of simple true/false questions or multiple-choice questions helped them retain information.

> *"I try to go through all of those types of interactions because those exercises do help you. Again, it's all about the retention of the information. The more you have to sit there and think about it, the more information you're going to retain. So, I've found all of that to be extremely useful. It's one thing to answer a true, false, or multiple-choice question – that's really not difficult. But when you have to start interacting and matching, you know, a definition to a concept, you're thinking about it a lot more. So, I feel like that really does help you retain the information."*

Some of the participants stated that the multimodal nature of microlearning - a combination of text and video was helpful and allowed them to learn different topics easily. They also stated that microlearning is helpful to complete assignments and saves homework time. One of the interview participants, Eva noted that "*The purpose of microlearning is not to spend too*

much time, it is just to be able to get the basic concepts and then practice on your own. The concepts were explained clearly, which is the most important point."

Finally, the practice knowledge checks were considered one of the helpful structural elements of microlearning. Almost all the participants attributed practice knowledge checks to playing an important role in their learning through the microlearning approach. Some of the participants stated that the practice knowledge checks challenged their knowledge. while others mentioned that it helped because it gave an opportunity to immediately test themselves and help them analyze if they are ready to move to the next topic and the feedback, they get helps them to understand and test their understanding of the topic. Some other participants mentioned these knowledge checkpoints guided them to complete their homework and other assignments.

Participants also mentioned that (1) Practice knowledge checks act as a refresher; (2) Practice knowledge checks help with exam preparation; (3) Practice knowledge checks increase confidence, and (4) Practice knowledge checks increase learner satisfaction. For instance, one of the interview participants, Felix stated,

> *"The quick knowledge checks help me know if I understood that lesson. It wouldn't let you proceed if you're not done with the first part of it. If we're not done with the complete knowledge check, you can always go back to the question, and it is like a refresher.*"

Daniel stated the practice knowledge checks helped them with exam preparation.

> *"I think one of the big benefits really pertaining to the quizzes - this is asking you relevant questions that are going to prepare you for maybe an exam in the class or final exam, whatever it might be, it's going to ask you questions that are worded very similarly to what you're going to be asked on an exam."*

Some of the participants also stated that the practice knowledge checks increased their confidence. Bennet stated that,

> "*There's this nice interaction and I really like the knowledge checks, because if I got it wrong or if I got it correct, or I guessed or I wasn't confident to answer, I know where to go back in microlearning and go to the parts [I want to know]...I know that I can go back to this part or that part to just quickly watch a two-minute or one minute to get that information if I don't understand it. So, I really liked the knowledge checks, I can check If I understand it, knew it or not, and if I got it correct, I can be with confidence, I know that one.*"

Daniel said the practice knowledge checks increased satisfaction - "*those quizzes, were really what would encourage me to keep going. Because it was almost like that satisfaction you get from finishing something and doing so successfully.*"

To sum up, participants stated many perceived benefits of the microlearning approach such as an engaging learning format, enjoyable learning experience, and flexible learning format. The interactive features, accessibility, simplified structure, and practice knowledge checks make it a helpful learning approach for the students learning introductory programming concepts.

Theme 4: *"It's like a kid's meal - for complex topics microlearning might be limited".*

Even though the participants shared many perceived benefits of microlearning as an instructional approach, they also stated many perceived challenges and areas for improvement. Some of the perceived challenges of the microlearning approach included: (1) Fragmented learning for complex topics; (2) Relevant feedback for practice knowledge checks; (3) Hard to learn without background knowledge for some topics; (4) Missing social aspect of learning such as peer interaction; and (5) Canvas LMS integration not mobile-friendly.

Some participants stated that microlearning might be challenging for some of the complex topics that require foundational knowledge, so they suggested having both learning formats for complex topics such as multiple table queries. For instance, Eva mentioned that,

> *"There are different aspects to consider. Every concept in SQL [programming] can be done with microlearning except for the concept of multiple table queries, because when you start dealing with multiple tables, it is getting complex, and we need details as elaborate as in the recorded video. Same thing with the design [concepts]. So, what I'll suggest is that after doing a microlearning video for that, there should be a correspondent recorded video as a reference resource -- with examples."*

Whereas some other participants stated that, for some topics, they felt the microlearning approach was a bit fragmented and would want more examples to keep the learning content continuous. Bennet noted that,

> *"I feel like the microlessons material was a bit fragmented…. Sometimes I feel like I would want more examples in the content. For example, for the second normal form, a table must be in the first normal form before the second normal form. The first thing teacher would say is, that the table must be in the first normal form to start with; if I don't understand [what is] first normal form, I struggle to understand the second normal form because there was not any detail or examples for first normal form [here]; and an example might be a little bit more helpful. Which I feel like sometimes a longer video would be a little bit needed… [therefore] If it has more detail or if it has an example, that would be more beneficial."*

However, Eva disagreed with Bennet's assertion and mentioned, *"I didn't encounter any fragmented learning in this course. No. It was all flowing from one continuous aspect to the full concept and it was not fragmented."*

Another challenge mentioned by participants was related to the practice knowledge checks. For example, Eva mentioned feedback mechanism can be much more elaborative.

> *"There is something that I think should be in the microlearning that is not there. Which is the feedback mechanism, that is sort of absent. For instance, answering an objective question is not good because [when] I look at the question, it has a maximum of four options. So, if I select the first one, and it is wrong; I select the second one, then there's every chance that they thought, I will get it right before moving on. So, in a way, this is like a trial and error. But if it involves hands-on, maybe given us a relation and say, okay, among this relational, break it down, or which of this relation is a multi-field something. Then you select it. If it's right, then you move on to the next one. But this one can I see that could be added to that microlearning platform. The essence of Learning is for us to be able to know not just answer to the question, but I should know why it says that's right."*

Similarly, Anthony stated, that some of the recap practice knowledge check questions were irrelevant and too simple.

> *"Sometimes the quizzes [practice knowledge checks] felt a little like irrelevant. For example, I'll be learning the fourth normal form but then I'll be asked what an entity is, and I'll be like, I already know. Why are you asking?"*

Some participants mentioned that microlearning modules can be a little hard for some topics without background knowledge. For instance, Daniel noted that,

"My concern would be that they're [microlearning modules] actually not long enough. There's the possibility that more content could have been added and again, I haven't struggled through this class for the microlearning. But if somebody that doesn't have any type of background with the concepts, those lessons might be a little too short for them to grasp on to."

Eva agreed to the above assertion by saying,

"It's like a kid's meal- every short video relates to one particular thing and then it tests your understanding of it…. But I will tell you if it's a complex topic, microlearning might be limited because it is short in duration and [if it is] a complex topic, recorded video lectures might be better because now we can deal with multiple examples on and off."

Whereas for some other participants, if they knew the content already, they like to skip that content and microlearning was not allowing them to do so, which could be time-consuming. Felix mentioned that,

"In recorded video I could feel I can skip forward the part of the question and continue with the lesson. But I didn't like the way the microlearning modules [are structured] which doesn't let you move forward unless you finish one, you cannot move to two. If I already have knowledge about the first part of it, I just want to skip that part and go to the next part. You cannot do that with microlearning. I think for some people it might be time-consuming."

Daniel stated that one other challenge of the microlearning approach and for any e-learning, in general, is the missing social aspect of learning. They stated that,

"One downside, the big downside of microlearning, this also pertains to any type of e-learning environment… is you miss out on that question and answer [social presence,

peer collaboration]. A lot of times, If I'm sitting in an in-person class, I might not have a question, but another student might come up with something that I didn't even think of. And now all of a sudden, I'm listening to the instructor's response and I'm learning more from that. So, in that regard with microlearning and again with eLearning in general, you do miss out on that part of the interaction, which really is kind of a loss to the students."

Finally, some of the participants highlighted an issue with the underlying Canvas LMS platform that is used to deliver the microlearning course content. Anthony stated that,

"I don't know how much you can do about this, but I like completing it [microlearning modules] on my phone. But the website crashes on my phone, it can save my progress, but it crashes sometimes too many times, and I don't know how much you can do about that."

To sum up, some of the perceived challenges related to the microlearning instruction reported by the students included, the microlearning approach being less helpful for complex topics, elaborative feedback for practice knowledge checks, hard to learn using microlearning without background knowledge, missing social aspects of learning and not being mobile-friendly.

Theme 5: *"Seeing more examples will help me visualize better"*

In addition to the perceived challenges, participants identified several areas for improvement in the microlearning design. These included: (1) Need tailored content specific for microlearning; (2) Create personalized structure; (3) Enhancements specific for practice Knowledge check; and (4) Need more examples and demonstrations of learning content.

Some of the participants have reflected that they would like the content specifically created for microlearning modules rather than cut from the hour-long recorded video lectures. One of the participants stated, "*Certain words of the page were cut short, so I had to find the page elsewhere.*" whereas the other one stated they faced that issue, but it was not bad - "*Sometimes I would stop hearing the instructor when there were cuts in the video and I would lose some words she said, but it wasn't really bad*." one of the interview participants, Bennet said,

> *"Creating a short video specifically for microlearning content is really, really helpful, because if you make a long video, the mindset of the person recording as a teacher would probably be like a lecture for 45 minutes, where she has the time to do it rather than microlearning if she makes it to ten-minute video, should be thinking, I have only 10 minutes. I must talk about this unique number for this, but make sure not to make it too short, too long."*

Likewise, Bennet stated a chapter summary would be helpful to quickly recap the previously covered topics.

> *"Sometimes we had the instructor mention, like in the single table that queries [topic], we did this in the last week. So now we're going to show you one that's more specific, for example, if you have a more complex or compound query, if I forgot that I think the practice quiz would have helped me catch up with my knowledge from last week. So, I can remember it."*

Another area for improvement mentioned by participants included needing a more personalized structure where students can pause to think about what is being discussed in the microlearning module. For example, Eva stated,

"One thing I notice about the microlearning... I don't know... Maybe it's the way our professor planned it. If she comes to the particular place that says I want to do this, I believe then the microlearning should wait for a few seconds before moving to the next slide so she can be able to talk to the question. Let's see the question [on the screen] before we go to the solution. So that's another area for improvement. Let the question be on your screen, Let the students try it to answer. It brings the idea to our head...What I'm trying to say in every part of the question on that module needs emphasizing before going to the other microlearning lessons."

Some of the participants stated some areas of improvement related to the practice knowledge checks within microlearning modules such as needing elaborative feedback to point them to the specific content of the module instead of generic feedback whereas others stated that they like the way it is structured, but it would be nice to have more practice questions. Likewise, one of the interview participants Anthony mentioned, that it would be nice to allow open-ended questions as part of the knowledge check questions instead of just multiple-choice questions.

"It might be useful to have like written questions, but those can be pretty hard because if you accidentally capitalize thing and the correct answer doesn't have a capital, it's going to mark it as wrong - which can be frustrating. Yeah, [but if]there's a way to neatly implement written answers that might be pretty useful."

Similarly, Chloe stated, that it would be helpful to have a practice knowledge check summary just like the chapter summary to review the questions and responses.

"I will set at the end of the module be like a review page about all the questions you answered to review. Right now, unless you revisit the page and unless you retake the

quiz, you won't be able to see that again. So, like at the end, I would like a summary of everything [attempted practice knowledge checks] you did."

Finally, some of the participants mentioned that they would love to have more examples, but the timing could not allow it. One of the participants Felix stated, *"Seeing more examples will help me visualize better."* Daniel echoed the same and said, *" I think you could put more [examples] in there. I'm not saying that it's inadequate. I just think that they're helpful. And so, the more of them that are there, that's just more opportunity to help the student now*." Another participant Bennet stated they want to see more examples similar to that of the homework assignments:

"If it has more detail or if it has an example, that would be more beneficial. Sometimes, I feel like I would want more examples in the content. For example, for the second normal form as an example, a table must be in the first normal form before the second normal form. The first thing the teacher would say is, that the table must be in the first normal form to start with; sometimes, if I don't understand the first normal form, I struggled to understand the second normal form because there was not any detail or examples for first normal form; and an example might be a little bit more helpful...

..... The microlearning page was fine, but it would have been better to include more examples of the kinds of problems we're expected to do on the homework. The additional supplemental practice problems were not similar to the homework, either so I was very unsure of my answers."

Some participants also mentioned that a little demonstration would be helpful while discussing the programming concepts. For example, Daniel stated that *"It would be helpful to have a demonstration as things were being presented [writing/typing out the logical design of a database as its being discussed]*"

Therefore, to sum up, the participants mentioned a few areas of improvement for the design and development of the microlearning implementation. These included - creating the learning content specifically for microlearning instruction; needing a more personalized structure where students can pause and think, enhancements related to practice knowledge checks, and adding more examples and demonstrations of learning content. Figure 15 depicts the thematic map for RQ2.

RQ3: How does the course instructor perceive microlearning as an instructional approach?

Findings from thematic analysis of qualitative data

Out of the 96 initial codes developed as part of the first cycle of coding, 18 codes were related to the course instructor's perceptions of microlearning as an instructional approach. I summarized these 18 codes into four categories, which were then further refined into three overarching themes namely: (1) "*I'm seeing that students are enjoying microlearning and making positive comments. I also personally prefer microlearning*": Instructor prefer microlearning, (2) "*it's my fault that I couldn't make it a small video earlier*": Instructor's improvement plans, and (3) *"How I'm going to divide it into the different topic?"*: Instructional designer awareness

Theme 1: "I'm seeing that students are enjoying microlearning and making positive comments. I also personally prefer microlearning."

The course instructor stated that they personally prefer microlearning as an instructional approach because "*more students are committed to this approach.*" When asked about their thoughts on microlearning as an instructional approach, the course instructor mentioned, *"I'm*

seeing that students are enjoying microlearning and making positive comments and I also personally prefer microlearning."

In addition to that, the course instructor also mentioned they feel very positive about microlearning as an instructional strategy to teach introductory database programming concepts because it helps students to be successful.

> *"If we can provide them better learning platform, better learning stuff, and if they do their part, then they're going to be prepared better. Thus, they will use the class time better, and eventually, they're going to be more successful…. Microlearning is helping them to get ready for the class better and they may be able to use the class time more effectively and can get more benefit out of it. Eventually, I say students are going to be successful."*

However, the course instructor also cautioned that even though the platform is very promising, it is not about the microlearning per se but how effectively the learning content is delivered using the microlearning approach.

> *"Overall, I'm feeling positive. I'm feeling better, that I'm giving them better material, and a better platform to learn and students are also enjoying it. Only one thing I can say here is, that it is not Microlearning, but how we distribute the microlearning component, so that how can we add some content to improve, how can we add connecting video, how can we improve the overview, or we can also try to give them some more quizzes, more questions so that they can play with that. We can improve that. It definitely depends on how you're using the platform, but the platform itself is very promising. We just need to use it [in a] more effective way."*

The course instructor also mentioned that their purpose of using the microlearning approach is as a method to deliver the course content and they are committed to teaching the entire course using microlearning going forward - "*Based on my plans for Fall 2022, I'll teach the entire course using microlearning approach. Because I'm seeing the benefit."*

Regarding teaching database programming concepts, the instructor shared that though they feel they could have created short videos, they are confident that they are doing the right thing using microlearning - *"I wish I could spend some time to make more short videos. So, I personally feel better and I'm confident that - okay, at least from my side, I'm doing the right thing."* They also mentioned that in the long run, microlearning helps save their preparation time *"If a student was already prepared well for the class, they're ready for the activity, then it's going to be less work from my side."* For complex programming topics, they plan to use multiple videos with a specific transition video that connects the rest of the videos for a smooth transition.

> *" What we can do in that case is, to cover a single topic, we can put a few videos instead of one. For example, in one video I am going to just explain that theoretical concept behind it, then another two or three short videos to give examples and to show some hands-on... You know... definitely still, we can do each video with one example. In this way, we are covering a complex topic by feeding four small videos, each says three to five-minute videos, then I can create an overview video that connects altogether. So definitely, you can do that."*

To sum up, overall, the course instructor prefers the microlearning instructional approach and feels that it is an effective way to teach introductory programming courses and makes the students succeed in the course. The course instructor also intends to teach all the future courses using the microlearning approach because they see the benefits.

Theme 2: “It's my fault that I couldn't make it a small video earlier.”

The instructor blamed themselves for not making shorter videos for the course earlier because of the time constraints.

> *“it's my fault that I couldn't make it a small video. Usually, my existing videos are kind of long, 30 mins and some of them are even longer... I know that, but still, I couldn't manage time because I'm always overworked and overwhelmed with so many things, that I couldn't manage to give them a small video. And I personally feel bad that it is not the most effective preparation part. So definitely I wish I could spend some time to make more short videos.”*

They also noted that their course planning would change if they used a microlearning approach.

> *“Probably my [course] planning has become different. when I did those recordings previously, I didn't plan that way. I just recorded the video in the normal way I taught the class. So, I just start with the topic, and I just go along with that. But if I do microlearning, definitely I have to plan differently. Say I want to cover a particular topic, then to the point, what should I say? What should be done? Like an activity for that topic and how should I demonstrate and what not. So definitely the planning part going to be different.”*

The course instructor also shared two important improvements they intend to implement with the current microlearning approach. First is implementing discussion posts because the students feel more comfortable sharing their thoughts with peers than reflection prompts provided by the course instructor.

> *“Though I know in my current course, I'm not using any discussion forum or anything, I can still for each week, I can add a discussion forum. Now they're doing the reflection,*

right. That thing, I can do it in a discussion forum -- about what they're thinking or whether they have any question or any concern, that they can talk to each other that way.... we can do some kind of discussion so that they are not going to feel left alone, or they are all by themselves. Often students feel more comfortable with their peers compared to the teacher, right?"

The second enhancement is re-recording some of the videos and planning transition videos to avoid fragmented learning for complex concepts.

"Some students mentioned that some of the transition is not very smooth. So, for those few videos, we can re-record that. And we can add some connecting videos so that makes the transition smoother. We can also add some better overview videos, and some in-depth quiz questions so that they can do that better. In summer, if I can manage some time, I can try to make some sharp transition videos to connect these and that's going to be helpful. Also, I wish to remake some of the videos., re-record them, or at least some part of them."

To sum up, the course instructor being reflective, shared that they did not put in enough time to prepare for microlearning implementation and shared a couple of the improvement opportunities in microlearning implementation namely - re-recording the videos and transition videos to avoid fragmented learning for complex topics and implementing discussion posts for incorporating the social aspect of learning.

Theme 3: "How I'm going to divide it into the different topics?"

The course instructor mentioned some important points that instructional designers should be aware of while designing and implementing microlearning as an instructional approach. These included (1) the Importance of course alignment; (2) the Importance of program

alignment and (3) the Course instructor's buy-in while selecting the authoring tool.

The course instructor stated that every instruction has two types of information namely *must-know information* and *nice-to-know information,* and it is important that the instructional designer is aware and designs the modules in such a way that ensures that the students are learning the course fundamentals of must-know information. Therefore, the instructional designer being clear on course and module-level learning objectives is vital before designing the microlearning module for that topic.

Second, the course instructor said that the design of the microlearning module should relate to the course formal assessment activities planned by the course instructor such as homework, exams, topic quizzes, and projects. Therefore, the specific pathways and specific learning objectives of microlearning content must be well-aligned with the formal assessment items of the course. The course instructor mentioned,

> *"One thing we always need to keep in mind: All the videos, all the class activities students are doing is eventually to make sure they're learning the fundamentals…. We should know what we want students to know for sure. We have to make sure through all the microlearning modules - I am preparing students and then they're doing some activity and then we are doing assessment… The things are aligned properly. That's very important. So you have to keep in mind, "What is the learning objective?", "What I want my students to learn, the bigger goal?" , "What I want my students to know and how I'm going to divide it into the different topics" and "what I want to cover - I do not want to cover everything from the chapter, right?", So that's something very important and is very clear on the learning objectives and pathways. And that pathway should be aligned properly. Whatever I'm delivering, that should be preparing them for doing some activity*

or some practice, so that they can produce something and can apply that in a similar scenario or situation. So that should be very clear."

The course instructor also mentioned that the program alignment or the curriculum alignment is just as important as the course alignment discussed above. In other words, the instructional designer should be aware of how the microlearning design relates to the course sequence in the program. For example, the students taking this course (CIT 214) will also take other core courses and an advanced database programming course (CIT441) in the CS & IT curriculum. The instructional designer should be aware of the course sequence of the program as well.

Finally, the course instructor stated that they are *willing to invest, and* buying the license for the microlearning authoring tool is a minor thing compared to the benefit the platform offers. Instructional designers need to get the course instructor's buy-in while choosing the right authoring tool to design and implement the microlearning approach because of the cost involved. For example, the articulate rise educator license costs $500 annually for a single user. The thematic map for research question 3 is shown in figure 17.

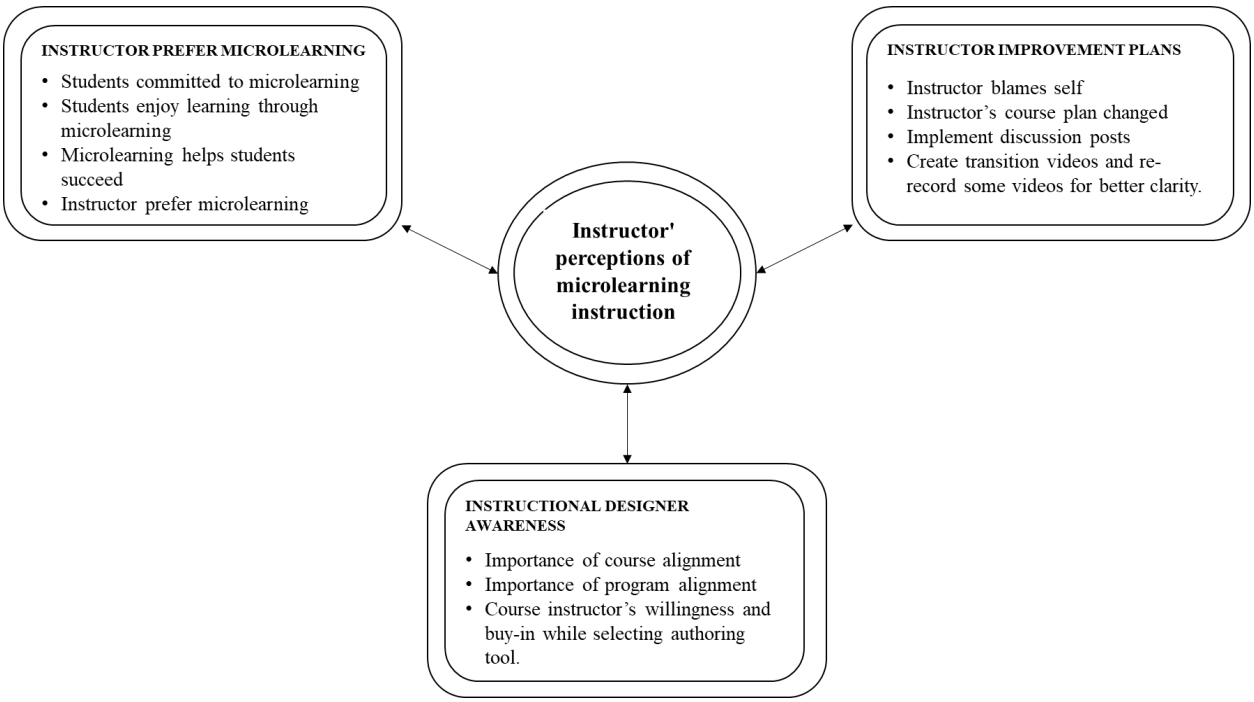


Figure 17. Thematic Map for Instructor's perceptions of microlearning instruction

Chapter 5: Discussion

In this chapter, first I summarize the study based on research questions and my interpretation of the study results concerning these research questions. Then, I provide the study limitations and present the implications of this study for research and practice. Finally, I will conclude with future research directions.

Summary of the Study

The purpose of this dissertation study is to inform educators and instructional designers on the influence of the microlearning instructional approach to facilitate student learning outcomes and to put these considerations into designing and developing microlearning content to maximize the student learning outcomes. The aim of this study is to investigate if microlearning is a viable instructional approach for teaching and learning introductory programming concepts by comparing the student performances using two instructional approaches namely, recorded video lectures and microlearning. In addition to that, the perceptions of the course instructor and students are sought while using microlearning for teaching and learning introductory database programming concepts. To that end, three research questions guided this study - (RQ1) Are there any differences in student performances between the two learning modes: microlearning instruction and recorded video lectures? (RQ2) How do undergraduate students perceive microlearning as an instructional approach? and (RQ3) How does the course instructor perceive microlearning as an instructional approach? Chapter 3 details the research methodology and Chapter 4 outlines the detailed study results.

In this discussion section, for each of the research questions, I will use my assertions with the help of the theoretical framework and the study results to discuss if microlearning is a viable

instructional strategy for teaching and learning introductory database programming concepts.

Differences in student performances between the two learning modes: microlearning instruction and recorded video lectures?

The findings from this study revealed that microlearning is a viable instructional approach for teaching and learning introductory programming concepts. To answer the first research question regarding the differences in student performances between two learning modes, I analyzed the student performance data from quizzes and assessment exams by converting each item to percentages to standardize the scores. Then, I calculated the cumulative average of quiz scores and exam scores for each student for both the learning modes. After that, using two paired *t-tests* (one for quizzes and one for assessment exams), I analyzed if there are any statistically significant differences between these two means of the learning modes.

The findings revealed that the students scored significantly higher in the quizzes while learning using the microlearning approach than recorded video lecture instruction. As in line with many educational interventions, the effect size was small (Cohen's d =0.40). All students scored higher overall in the assessment exams compared to quizzes. However, somewhat surprisingly, the students' performance in the assessment exams while learning using microlearning intervention was not significantly higher compared to the recorded video lecture instruction. Though there could be many reasons for this, one possible explanation could be the comparable complexity level of the exam questions from the quizzes reduced the anxiety level in students, which resulted in negligible differences and overall better performance in scores for both learning modes. The results are in line with the previous studies found in the literature (Nikou & Economides, 2018; Yin et al., 2021).

The findings from the qualitative analysis and some of the instructional design principles based on the cognitive-affective theory of learning with media could help explain these quantitative results. For example, almost all the interview participants and many of the survey respondents stated that they prefer the microlearning instructional approach to recorded video lectures because it is more engaging and helps with their attention span. Interactive elements such as practice knowledge checks are the big contributors to the student preferences of microlearning over recorded video lectures. As per the *Guided Activity* and *Feedback* principles of the cognitive-affective theory of learning with media, learners learn better when there are some interactions in the learning content and through explanatory feedback because they prompt and guide the students to engage in the selection, organization, and integration of new information thereby managing essential processing and fostering generative processing of learning content (Moreno & Mayer, 2007). Additionally, this finding is in-line with the other studies that have shown microlearning can improve student learning performance (e.g., Nikou & Economides, 2018). In their extensive literature review, Wang and colleagues note that human attention span has become shorter in the last two decades due to the pervasiveness of bite-sized content in our daily lives and microlearning helps manage attention span by gradually building up knowledge over time (Wang et al. 2020). Similarly, Triana and colleagues stated that through the microlearning approach, students get an opportunity to practice similar quiz items and receive feedback immediately and this interaction, due to the spacing effect, improves their cognitive imprint, resulting in effective knowledge acquisition and long-term retention of knowledge than the same material delivered together without any interaction (Triana et al. 2021).

Some of the interview participants and survey respondents also stated they enjoy learning through microlearning compared to recorded video lectures because they are more focused and

engaged throughout the microlearning approach. One of the participants stated that, because they knew there would be a question at the end about the video they just watched, it motivated them to stay focused. This finding is very much in line with the previous literature that shows microlearning increases learner satisfaction (e.g., Bruck et al. 2012) and improves learner attitudes (e.g., Inker et al. 2020). Bruck and colleagues found that microlearning resulted in high usage levels and increased satisfaction among learners (Bruck et al. 2012). Likewise, Inker et al. (2020) reported that microlearning increases satisfaction and results in improved learner attitudes in their study findings.

Another interesting difference between microlearning and recorded video lectures reported by the participants included the psychological or mental aspect of getting themselves prepared to learn. One of the interviewees stated that the mindset they have watching a 45-minute to one-hour recorded video vs. two to ten minutes of multiple videos makes a difference in terms of preparation and encouragement. The course instructor also stated this psychological aspect is a big difference between the two learning modes. This could be because of the spacing effect as demonstrated by the Ebbinghaus where the learning content spaced in time tends to produce stronger performances than massed learning content.

Finally, the findings from this dissertation study are similar to the recent study findings reported by Yin and colleagues, which showed no significant difference between the traditional and microlearning modes. However, the authors reported students indicated stronger intrinsic motivation in the microlearning approach compared to the traditional approach (Yin et al., 2021).

Students' perceptions of microlearning as a learning approach

As discussed earlier, in order to analyze the students' perceptions while using microlearning as a learning approach, I collected data from multiple sources such as microlearning perception surveys, student reflections, and student semi-structured interviews. First, I used descriptive statistics to analyze the survey data and for the reflections and interviews, I used Braun and Clarke's (2006)'s six-phase thematic approach.

Student's perceived Cognitive load while using microlearning instruction

The study findings have shown that (1) the survey respondents experienced less extraneous cognitive load because microlearning was not difficult to understand as it was clearly presented to the learners; (2) they experienced moderate intrinsic cognitive load because the learning content was neither too easy nor too complex; and (3) they perceived high germane cognitive load because microlearning helped them understand both the programming and database design concepts.

As per Cognitive load theory (CLT), the learning tasks induce information processing load which affects students' cognitive ability to process new information and to construct knowledge in their long-term memory (Sweller et al., 2019). As discussed earlier, learners experience three types of cognitive load while processing instruction namely, *intrinsic cognitive load*, which can be only altered by changing the learning content or the learner's knowledge level; *extraneous cognitive load*, which refers to how the instruction is presented to the learners and *germane cognitive load*, which is the effort required to learn (Sweller et al., 2019). Therefore, as per the cognitive load theory, it would be safe to assume the survey respondents

perceived the microlearning intervention to be an effective and efficient individualized learning approach (e.g., Ayres & VanGog, 2009).

Along those same lines, the main three instructional goals of any effective multimedia instruction as per the cognitive theory of multimedia learning, are to (1) *reduce extraneous processing*, by avoiding multimedia content that doesn't support the instructional goal; (2) *manage essential processing*, by promoting learning processes aimed at helping learners to understand the complex learning content; and (3) *fostering generative processing*, by motivating learners to make sense of presented information through continued participation (Mayer, 2017). Based on the above study findings, based on the cognitive theory of multimedia learning, it can be safe to assume that the microlearning approach is an effective multimedia learning environment as perceived by the learners.

Qualitative analyses of the student interviews and reflections also confirm the above assertion. For instance, few of the interview participants stated that they experienced less cognitive load while learning through microlearning. One of the participants stated that microlearning is helpful because it breaks up the course content and kind of gives their brain a much-needed break every few minutes. Whereas another participant noted, that because the videos are not long, they don't feel overwhelmed, and it was easier to process than too much information being thrown at them at once. This finding is in line with the previous literature that suggests that microlearning avoids cognitive overload because the learning content is designed in a manner that is cognizant of the human cognitive architecture, thus reducing cognitive fatigue that results from the long lessons (Alqurashi, 2017; Bruck et al. 2012; Yin et al., 2021). On the similar veins, as argued by Inker and colleagues this finding confirms that the microlearning approach is more effective because, it alleviates cognitive loads and aids in forming schema

structures in long-term memory than massed learning, as suggested in spaced learning theory by Ebbinghaus (Ebbinghaus, 1913 as cited in Inker et al., 2020). This finding also confirms the claim that the microlearning intervention offers the perfect platform for the implementation using Mayer's (2005) cognitive theory of multimedia learning principles, such as the *segmentation*: breaking down the learning content into more digestible chunks (Grevtseva et al., 2017). One of the interview participants Eva agreed by saying, "By Segmenting Ideas into multiple pieces, it is easier to digest this way and because the videos were short, it is easy to scroll each video and find information easily."

Students were more motivated while learning using microlearning instruction

Previous research has shown that learners with higher motivation could handle complex learning tasks persistently and easily (Lin et al., 2021). In microlearning instruction, learners are more satisfied, they enjoy their learning process, perceive higher motivation, and higher self-directed learning behavior is observed, which results in enhanced student performance (Nikou & Economides, 2018; Nikou, 2019). Moreover, as per the Cognitive Affective Theory of Learning with Media, the motivational aspects of multimedia instruction help learners with their generative processing by increasing their cognitive engagement of learners, which leads to better learning outcomes (Leutner, 2014; Mayer & Estrella, 2014).

In this study, the survey respondents reported that they are more motivated to learn using the microlearning approach. These results were also very much supported by the qualitative data analysis of the interviews and reflections. The respondents stated that there are many motivational aspects associated with the microlearning intervention that helped them learn the content better. For example, one of the participants reflected that they enjoyed learning through

microlearning because they like the way the learning content was spaced out and they would use it for any other class if the option was given. Likewise, one of the interview participants also mentioned that structural features such as the progress bar motivated them to finish the microlearning content quicker. Another respondent stated that the practice knowledge check questions increased their confidence and helped with better preparation for their exams and homework. Whereas another interview participant noted that the interactive elements of microlearning were encouraging to keep them going and they liked the satisfaction they got while completing each microlearning module successfully. This finding is also in-line with the other studies found in the literature, which reported the motivational effect of microlearning on student learning performance (e.g., Nikou & Economides, 2018). Therefore, it could be safely assumed that students perceived the microlearning intervention to be an engaging way of learning based on the cognitive-affective theory of learning with media and the related literature that supports the educational effects of the microlearning approach.

Students were attentive while learning using the microlearning approach

In addition to the cognitive overload and motivational aspects, the human attention span also plays a major role in the learning process, and if the attention span increases, cognitive overload also increases, which might hamper the learning process (Javorcik & Polasek, 2019). The qualitative analysis of student reflections, open-ended survey questions, and semi-structured interviews showed that microlearning prevents attention span issues by keeping learners engaged and helping them focus on the learning content at the given point of time, thus it was easy to digest complex information presented to them. As stated by one of the participants, because of the interactive features and the practice knowledge check questions, they "*will specifically ask*

questions on the content just learned" and that expectation helps them focus. Whereas another participant mentioned that it is easier for them to focus because the microlearning content is straight to the point and short.

Students perceived microlearning as an effective online learning strategy

In addition to the benefits, students perceive microlearning to be an effective learning strategy especially if they are learning online. For example, one of the participants Daniel stated that "*I actually think microlearning would probably be the best outlet to teach that if you're not going to be in a classroom.*" Here are some of the reasons why students perceived microlearning to be an effective online learning strategy.

1. Helped with a holistic understanding of the learning content
2. Structural and interactive features helped them with learning complex concepts
3. Easy to review the learning content on a needy basis
4. Helped with a deep understanding of complex learning concepts
5. Accessible learning platform
6. A flexible learning approach that gave control to their learning process
7. Helped with better knowledge retention through interactive learning
8. Took less time to complete learn content, homework, and assignments
9. Helpful Interactive features and practical knowledge checks

As suggested by Khong and Kabilan (2020), the cognitive theories of learning could help explain why and how microlearning is perceived as an effective instructional strategy by the students. Specifically, these cognitive theories of learning (CLT, CTML, and CATLM) could shed some light on how microlearning responds to the two major learning challenges: (1) The

structural design features help with overflow and complexity of learning content; and (2) Conducive and flexible learning environment and one that adapts to learners' preferences (Khong & Kabilan, 2020).

The learner-centered principles towards designing multimedia environments through CTML (Mayer, 2014), the motivational aspects suggested by Sweller's CLT (Sweller et al., 2019) and CATLM (Moreno & Mayer, 2007) to improve learner performance offered a more nuanced and effective online instructional approach for learning introductory database programming concepts (Khong & Kabilan, 2020).

In addition to that, as noted by one of the participants, the multimodal nature of microlearning with the combination of text and video was helpful and allowed them to learn different topics easily. As technology enhances the multimodal learning environment, one might concur that microlearning instruction activates both visual and verbal channels and facilitates integrative cognitive processing of learning content (Mayer & Moreno, 2007). This successful integration and cognitive processing in turn make the learners feel confident and competent to meet the learning challenges of the complex learning content.

Moreover, when the required motivation is present, the learners will actively process the information even if the learning content is complex; however, if the learners are not motivated enough, even though cognitive resources are available the learners may not engage in active processing of information. In other words, in this study, the students were motivated enough and that helped mediate their learning process by increasing their cognitive engagement" (Moreno & Mayer, 2007).

The participants also mentioned that the microlearning approach is effective because it is flexible, and it gives them control of their learning process. As per the *self-management* principle

of CLT, by giving the learner control to apply the cognitive load theory principles themselves to the learning content, their cognitive load is decreased resulting in effective learning (Sweller, 2011). Similarly, as per the *pacing* principle of CATLM, Learners learn better when they have control of their learning process. The findings of this study show that the microlearning approach has provided the flexibility and the features to control their learning process (such as a progress bar).

The findings of this study also support the other instructional design principles suggested by the CATLM such as *Guided activity* (learners learn better when they interact with learning content), *Reflection* (learners learn better when they reflect upon their learning while learning the content), *Feedback* (learners learn better through explanatory feedback), and *Pre-training* (learns to learn better when they receive focused pre-training or activation of their prior knowledge) (Mayer & Moreno, 2007).

One of this study's findings is that microlearning helps with knowledge retention was in line with the previous studies seen in the microlearning literature (e.g., Giurgiu, 2017; Mohammed et al., 2018). As suggested by a few researchers, these findings also confirm the claim that the microlearning instruction results in effective retention of knowledge because of increased learners' autonomy, that is, they have control of what and when they are learning the content (Aldosemani, 2019; Donahue, 2016; Emerson & Berge, 2018; Kovacs, 2015).

Another important contribution of this study is that it provided more empirical evidence on the influence of the microlearning approach on complex topics such as database programming and design concepts, thus it could help explain why microlearning could be an effective online instructional strategy. For example, Emerson and Berge (2018) argue that microlearning may not be the best tool for students learning complex skills and it could be best used only for

reinforcement of factual information (p. 127). In other words, the microlearning approach is assumed to be a good strategy mostly for lower-order thinking skills such as remembering and understanding cognitive levels as seen in the literature. However, in this study, the learners used microlearning instruction for incorporating higher-order thinking skills such as application, analyzing, and problem-solving skills through assessment exams and their homework assignments as opposed to the shallow knowledge gain as discussed in the literature.

Students perceived a few challenges while using microlearning instruction

Even though students perceived numerous benefits while using microlearning instruction to learn introductory database concepts, they also reported a few challenges. Some of the perceived challenges included:

1. Fragmented learning for some complex topics
2. Relevant feedback is needed for some practice knowledge checks
3. Cannot skip a few topics that are already known
4. Hard to learn without background knowledge of some topics.
5. Missing social aspects of learning such as peer interaction and
6. Canvas LMS integration is not mobile-friendly.

In addition to the perceived challenges, the study participants also identified many areas for improvement in the microlearning design. These included:

7. Need tailored content specific for microlearning
8. Creating personalized structure for some topics
9. Allowing open-ended responses in practice Knowledge check and
10. Need more examples and demonstrations of learning content.

This study revealed a few limitations of the microlearning approach. First, a few of the participants also noted that *"microlearning is like a kid's meal",* hence microlearning approach might be limited and can be a little hard for some topics without background knowledge. This is because they are too short to fully grasp the complexity of the topic and in this situation recorded video lectures may be helpful. Providing both the learning modes might be helpful for them to select based on the sub-topics. These findings confirm the previous microlearning literature on the limitations of the microlearning instructional approach. For instance, few researchers have noted that learning complex skills using microlearning might result in fragmented knowledge because of learning in short segments in short periods (Emerson & Berge, 2018; Lim et al. 2019). The findings from this study didn't fully confirm this assertion; however, some of the participants stated that some complex topics like single table queries needed more foundational details and elaborated explanations to understand them completely. Whereas few other participants disagreed with this. One of the participants, Eva noted they didn't encounter any fragmented learning in this course, and it was all flowing from one continuous aspect to the full concept; it was not fragmented but agreed with others that feedback for practice knowledge checks could be more elaborative. She stated that in addition to elaborative feedback, routing them to the appropriate micro-content would be helpful.

The study findings also revealed another potential limitation of microlearning as found in advanced learners compared to novices. One of the participants stated that asking practice knowledge quiz related to the previous topic and a previous foundational concept is unnecessary and they already knew the answer. Moreover, some other participants stated that they couldn't skip some micro-content that they already knew, which is time-consuming. This finding could be

attributed to the *expertise reversal effect* of cognitive load theory, which states that the relative effectiveness of the instructional approach reverses with the change in expertise levels in learners (Sweller, 2011). In addition to that, a few other participants suggested that having an outline for practice knowledge checks could be as helpful as the topic outline. Both these concepts directly relate to the CATLM's feedback and reflection principles for effective multimedia instructional design (Mayer & Moreno, 2007).

Another big downside of microlearning stated by participants was "*missing social aspects and peer-to-peer interaction*". One of the participants mentioned that, if they are in an in-person class, they might not have a question, but another student might come up with something that I didn't even think of; suddenly, by listening to the instructor's response they are learning more. They do miss out on that part of the interaction, "*which really is kind of a loss to the students.*" in microlearning instruction. This finding is very much in alignment with the previous studies. For example, while investigating the effect of microlearning on mechanical engineering content, Wang et al. (2017) found that microlearning significantly improved learning outcomes; however, there was very limited interaction between student to student and student the instructor but increased interaction between student and content.

Finally, some of the participants complained that the canvas website crashed many times when they tried to use their mobile devices to study using microlearning instructions. While this is not a limitation of the microlearning design per se, this was not discussed in the literature. There could be a couple of reasons for the canvas website crash such as LTI integration issues between the Articulate Rise authoring application and/or the exported SCROM file format, but the infrastructure issue needs to be addressed to provide learner-centered design.

It is also worth noting some of the areas of improvement shared by the participants.

These were not projected as limitations but more like *nice to have* features. These findings are not found in the previous microlearning literature. Nevertheless, these findings have some implications for microlearning instructional design. First, participants noted that it would be helpful to have the videos created specifically for microlearning instruction rather than segmenting it from the recorded video lectures. Because, while recording long video lectures, the mindset of the instructor recording would probably be like a lecture for 45 minutes, whereas for microlearning, for a three to ten-minute video, they would be thinking, I have only 10 minutes. *"I must talk to the point and make sure not to make it too short, too long."*

The second area of improvement suggested by participants was creating a more personalized structure, where students can pause to think about what is being discussed during the microlearning instruction. However, the participants also stated that not all the topics needed to be emphasized. Doing a learner analysis might be helpful to identify which topic needs more emphasis so that it would be helpful for the students.

The third area of improvement suggested by participants included allowing open-ended responses like the topic quizzes and exams in the practice knowledge checks instead of just the multiple-choice questions. The participants said they are also aware of the practical difficulties of implementing this approach because it is hard to provide feedback for open-ended responses.

Finally, some of the participants mentioned that they would love to have more examples similar to the homework assignments and demonstration of the concepts but understood that the timing could not allow it. They stated that detailed examples and demonstrations would help them with completing the homework assignments and help them with their exam preparation. These suggestions are helpful to understand the student perceptions in terms of instructional design.

The course instructor's perceptions of microlearning as an instructional approach

To analyze the course instructor's perceptions while using microlearning as an instructional approach, I collected qualitative data using a semi-structured interview with the course instructor. Then, I used Braun and Clarke (2006)'s six-phase thematic approach to uncover the themes that could answer the research question - How do the course instructor perceive microlearning as an instructional approach? as outlined in Chapter 4.

As research indicates the instructor's online presence has important implications for students' overall learning experiences (e.g., Richardson et al., 2016), the findings from this research question add valuable contributions to the literature to understand the instructor's perceptions while teaching introductory database programming concepts using microlearning instruction. The qualitative analysis of the course instructor interview revealed the instructor's preference for microlearning, the instructor's improvement plans, and some important implications for instructional designers for designing and developing microlearning content.

First, the course instructor stated that they personally prefer microlearning because students are committed to it and enjoy learning using the microlearning approach. In addition to that, the course instructor also mentioned that microlearning helps students to be successful and is going to teach Fall 2022 entirely using the microlearning approach. This clearly shows the course instructor's commitment to the microlearning approach.

Second, the course instructor blamed themselves for creating long videos because of time constraints and mentioned that their course planning probably needs to change to incorporate the microlearning approach. So, this means, that to teach using microlearning the instructor has to plan more time upfront. This finding contradicts the literature that states microlearning videos are faster and easy to create (Donahue, 2016; Lim et al. 2019). However, once the videos are

created, they could be easily reused for multiple classes. So, in the long run, the amount of time invested could be less.

Third, the course instructor stated that for complex topics, microlearning could be appropriate but it might need transition videos that link the concepts thereby avoiding fragmented learning. Therefore, this finding confirms the claim that microlearning instruction might result in fragmented learning (Emerson & Berge, 2018; Lim et al. 2019) but could be easily avoided through effective design.

Fourth, being reflective, the course instructor shared their plans for implementing discussion posts for each topic in canvas LMS, because the students feel more comfortable sharing their thoughts with peers than the reflection prompts provided by the course instructor. As the literature suggests, the interaction between students and the lack of feedback is an important reason for lower student retention in online courses (Richardson et al., 2015).

Finally, the course instructor shared two important aspects that instructional designers should consider when designing and implementing microlearning instruction. First, they should ensure the overall course alignment is achieved by designing each topic's microlearning module learning objectives to match the respective interactive activities, the topic learning content, and the topic assessment plan. This helps students understand the must-know information rather than nice-to-know information. Second, the instructional designer should also keep the course aligned with the overall program-level outcomes. Because the students will enroll in advanced level courses after this course, they should have the necessary skill set to succeed in the program.

To sum up, the findings from this study revealed that the microlearning approach is a viable instructional approach for teaching and learning introductory database programming concepts. The students perceived many benefits of the microlearning approach such as less

cognitive load, simplified learning structure, and easy-to-understand complex topics. Some of the limitations included fragmented learning for complex topics, missing social aspects and peer interactions, and enhancements related to interactive elements. The course instructor perceived microlearning to be a promising instructional approach that helps students to be successful in the course and has plans to use this instructional method for their future courses. In the next section, I will discuss the study's implications for research and practice

Study Limitations

There are several limitations to this study. First, the major limitation of this study is that it was conducted as a single case study, within a single online classroom. Second, I collected the students' self-reported data through reflections, a survey, and interviews and there could be a possibility of self-presentation bias (Kopcha & Sullivan, 2007). I have employed data and methods triangulation to mitigate this limitation. Third, I included only one-course instructor's perceptions of the microlearning instructional approach. Therefore, the study findings might not be representative of all the instructors who teach introductory database programming courses. Fourth, the survey instrument I used to capture students' cognitive load perceptions was adapted from an instrument that measures cognitive load in traditional educational settings (Leppink et al. 2013). I have conducted a pilot study to test the feasibility of the instrument for this online class. While the modified instrument holds the key psychometric properties, it needs further research validation before use. If there are additional research studies that test the validity of this instrument in similar settings, it might add further proof to the reliability and validity of the modified instrument used here. Finally, given the nature of the research design, it may be difficult to generalize the study results across multiple contexts. I have provided detailed

descriptions of methods so that they could help with the transferability of the study findings.

Implication for Practice

The findings from this study have many implications for practice, especially for the CS & IT course instructors and instructional designers who design and implement microlearning instruction.

Implications for CS&IT course instructors

Create instructional videos specifically for microlearning: The findings from this study revealed that both students and the course instructor preferred microlearning as a viable instructional approach (Aldosemani, 2019; Donahue, 2016; Emerson & Berge, 2018; Khong & Kabilan, 2020; Kovacs, 2015). Having said that, they also highlighted the importance of creating the instructional content specific to the microlearning approach instead of segmenting from long recorded video lectures, so that it doesn't result in fragmented learning of complex topics and creates less confusion for students.

Include social aspects of learning: The findings from this study also revealed an important missing aspect of the microlearning approach, the social aspect of learning from peers (Emerson & Berge, 2018; Lim et al., 2019). The course instructors can avert this issue by implementing discussion posts within the microlearning modules, where students can reflect on the learning content for the topic, interact with their peers and take advantage of the social aspects of the learning.

Mimic practice knowledge check questions like the assessment exams: The findings from this study have shown that the students are taking the practice knowledge checks very seriously. Therefore, it is important to have the practice knowledge check questions mimic the

questions being used in the homework and the assessment exams so that it helps with knowledge transfer. The course instructors can help students by allowing multiple formats of practice questions such as open-ended questions instead of just multiple-choice questions.

Provide elaborative feedback for practice knowledge checks: Given that many students thought that the elaborative feedback is critical for students' successful preparation for exams, assignments, and homework; the course instructors should use various strategies to provide elaborative feedback. This is vital to avoid student retention issues especially if it is an online course (e.g., Richardson et al. 2015). For example, while designing a microlearning module the course instructors and instructional designers can help the students by linking the course content to the feedback, providing optional learning materials, and emphasizing the important points in the learning content.

Implications for Instructional designers

Achieving course alignment is the key: The finding from this study revealed the importance of course alignment while designing and delivering microlearning instruction. Instructional designers working with the course instructors should be aware of how the topic learning objectives are aligned with the instructional content and the interactivity elements of microlearning along with the assessment items. The instructional designers must understand the *must-know* information and design microlearning content around that information.

Understanding the importance of program or curriculum alignment: The course instructor underscored the importance of understanding the program level outcomes in addition to the course level objectives. Therefore, instructional designers designing and implementing microlearning instruction should be aware of the student's program of studies or program plan.

Getting the course instructors' buy-in is most important: Implementing microlearning involves cost as the authoring tool needs to be purchased. It is vital to get the course instructor on board with financial decisions because of the necessary approvals required. To my knowledge, there are no OER authorizing platforms available for creating microlearning instruction yet.

Implications for Future Research

The findings from this study have many implications for future research, especially for the theory and methodology.

Implications for theory

No clear unequivocal theoretical framework: Even though the microlearning approach is very popular in the corporate settings, many scholars have pointed out that there is no clear unequivocal support in the literature regarding the theoretical basis for the microlearning approach (e.g., Khong & Kabilan, 2020). Some of the reasons for this could be that microlearning is a relatively new but emerging trend in higher education (Leong et al. 2020). As an evolving field of educational/instructional technology, there are multiple conversations and multiple theoretical frameworks that have guided and supported microlearning as an instructional approach. Future studies should explore this and provide more empirical evidence on the theoretical underpinning of the appropriate theoretical frameworks suitable for microlearning instructional approaches.

Influence of interactive features on cognitive load: The findings from this study have revealed that interactive features were one of the main reasons why participants perceived microlearning to be an effective online instructional approach. However, it is not clear if we add more interactive features that would result in a higher extraneous cognitive load. As Sweller and

colleagues suggest, if an instruction requires more cognitive resources to deal with extraneous cognitive load, then learners will have a lower cognitive capacity to deal with intrinsic cognitive load, which likely will result in unsuccessful learning (Sweller et al. 2019). The future research could examine the impact of interactive features on the learner's cognitive load while using microlearning instruction.

Impact of microlearning approach and Learning efficacy: The study findings have shown that learners are more engaged and motivated while learning through the microlearning approach. Future studies could investigate the other key constructs such as learning efficacy (Honebein & Honebein, 2015) of the microlearning approach in experimental settings with more participants and more study contexts.

Emerging learning technologies integration: Both the students and the course instructor perceived microlearning as an effective online instructional strategy. Future research could also explore more on this area, especially with the integration of the microlearning approach with emerging learning technologies such as AR/VR (e.g., Leela et al. 2019), Learning Analytics, and other immersive learning environments like chatbots (e.g., Yin et al. 2021).

Methodological Implications

Impact of different kinds of microlearning on student learning outcomes: This study has predominantly used a single type of microlearning – an instructional video-based microlearning format. There are many modes and delivery formats of microlearning content such as (1) *Image-based microlearning content* including infographics, process diagrams, memes, and animated GIFs; (2) *Audio-based microlearning content* including short narratives and podcasts; and (3) *Video-based microlearning content* including video flashcards, screencasts,

microlearning vlogs, demonstration videos, and time-lapse videos. Future research can investigate the impact of different types of microlearning content on student learning outcomes.

Multiple case studies and contexts: One of the major limitations of this study is that this study was conducted in a single online classroom. Future research might collect data from multiple classes with other learning modes such as in-person and hybrid classrooms. Second, this study explored if microlearning is a viable instructional approach for an introductory database programming classroom. It might be helpful if future studies could examine if the study findings can be replicated in other subject areas. Finally, it would be valuable to do a comparison study on the impact of microlearning intervention in online, hybrid, and in-person classes.

Conclusion

This dissertation study explored the influence of the microlearning instructional approach by comparing the differences in students' exam and quiz performances between recorded video lecture instruction and the microlearning instructional approach in an introductory database programming online course. Findings of this study revealed that students scored significantly higher in quizzes and scored slightly, although not significantly, higher in the exams on the microlearning topics compared to the recorded video lecture topics. Overall, the study findings suggested that student performances are influenced by the microlearning approach. The qualitative data analysis revealed that students preferred the microlearning instructional approach over the recorded video lectures because it (1) helped with a holistic understanding of the learning content; (2) Structural and interactive features allowing them to easily learn complex topics; (3) Easy to review the learning content on a needy basis; (4) Helped with a deep understanding of complex learning concepts; (5) Accessible learning platform; (6) A flexible

learning approach that gave control to their learning process; (7) Helped with better knowledge retention through interactive learning; (8) Took less time to complete learn content, homework, and assignments; (9) Helpful Interactive features and practical knowledge checks and (10) Engaging and enjoyable learning experience. The results have also shown that microlearning is an effective instructional strategy, especially for online classrooms and it helped reduce the cognitive overload in the students. Having said that, some of the students also reported a few challenges while using the microlearning approach such as (1) Fragmented learning for some complex topics; (2) Elaborative feedback is needed for some practice knowledge checks; (3) Cannot skip a few topics that are already known; (4) Hard to learn without background knowledge of some topics; (5) Missing social aspects of learning such as peer interaction and (6) Canvas LMS integration is not mobile-friendly. The semi-structured interview with the course instructor and the corresponding interview data analysis revealed that the course instructor also personally prefers microlearning because it increases student satisfaction and helps students to be successful in the course. At each step of the research process, I constantly reflected on my position as a researcher and future educator. Through this reflection process, I learned it is not only the method and the platform that enables students to be successful but also the instructional strategy and the overall course alignment that helps the students to be successful.

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Appendix A Microlearning perceptions Questionnaire

Adopted from (Inker et al., 2020; Leppink et al., 2013).

Part 1: Select an option between (0) Not at all the case to (10) Completely the case.

1. The SQL programming topics covered in the microlearning modules were very complex.
2. The database design topics covered in the microlearning modules were very complex.
3. The database concepts and SQL commands covered in the microlearning modules were very complex.
4. The instructions and/or explanations in the microlearning modules were not very clear.
5. The instructions and/or explanations in the microlearning modules were, in terms of learning, very ineffective.
6. The instructions and/or explanations in the microlearning modules were very difficult to understand.
7. The microlearning modules enhanced my understanding of the SQL programming topics covered.
8. The microlearning modules enhanced my knowledge and understanding of database design topics.
9. The microlearning modules enhanced my knowledge and understanding of the database concepts and SQL commands.
10. Viewing the microlearning lectures made me feel confident in my ability to succeed on Exams.
11. I enjoyed viewing the microlearning lectures as opposed to the recorded video lecture.
12. I think microlearning is an interesting way to learn database programming concepts.

Part 2: Additional details

13. Please select all the desirable microlearning features you have used to learn introductory database programming concepts

    a. Short Lessons
    b. Video Clips
    c. Interactive features (Flip cards, List items, practice knowledge checks, etc.)
    d. Is there anything else you would like to add (please specify)?

    _____

14. Can you please share three specific points on how microlearning modules affected the way you understand database programming concepts?

    a. _____

    b. _____

    c. _____

15. Can we contact you to get a little more detail about your experience using microlearning? If yes, please share your email address.

Appendix B Pilot Interview Protocol

Notes to the interviewee:

- Thank you for your participation. Your input will be valuable to this research and in helping us with improving the microlearning content for the next semester.
- Confidentiality of responses is guaranteed
- Approximate length of interview: 30 minutes, four major questions

Purpose of the research:

To test the feasibility of microlearning intervention and improve it for the future semester. Your input would be a huge help to make changes to the design and learning content.

Questions:

1. Could you please talk about your experiences using microlearning modules?

   - Have you previously taken any microlearning courses?
   - How was your experience using microlearning courses for the first half of the course?
   - Do you want to share any specific week's content?

2. Can you talk about some of the challenges you faced using microlearning modules?

   - What are some of the areas that could be improved?
   - Where there any other challenges related to accessing the content?
   - Did this experience meet your expectations?
   - What is your previous learning experience in this type of environment?

3. Can you talk about some of the aspects you liked using microlearning modules?

   - Is there a specific week's content you liked?
   - Do you think we need to add more types of interaction?
   - What do you think about the design of microlearning content?

4. What factors most helped/hindered your learning using microlearning?

   - Why?
   - How?
   - Here is a list of potential factors that may help you…
   - How was your overall experience using microlearning?
   - What modules did you feel were complete or not complete? Why?

Appendix C Interview Protocol

(Adapted from Carspecken, 2013)

Notes to the interviewee:

Thank you for your participation. Your input will be valuable to this research and in helping us understand learner experiences while using microlearning modules. Confidentiality of responses is guaranteed. Approximate length of interview: 30 minutes, four major questions

Purpose of the research:

The purpose is to understand what learners experienced while using microlearning content and how microlearning might have influenced their understanding of database concepts. Is microlearning a viable instructional strategy for teaching and learning introductory database programming concepts?

Domain One: Experiences while using the microlearning modules

Lead-off question

" [Show one of the microlearning modules and ask] Could you please talk about your experiences while using this or any microlearning modules? Describe as if you are trying to talk about the feasibility of using this module or any microlearning module to your friend."

[Covet categories: usability of microlearning approach; participants' beliefs while using microlearning content for learning database programming concepts; motivation; participants view microlearning as an instructional method for understanding database programming concepts]

Possible follow-up questions

1. What was your experience like while using the microlearning modules?
2. What motivated you to participate?
3. What kinds of things did you learn about database programming using the microlearning approach?
4. Do you want to share anything specific about the week's content or any microlearning week's content in general?
5. If you had a recorded video lecture for this week, would it be the same or different?

Domain Two: Perceived usefulness of microlearning modules

Lead-off question

" [Show one of the microlearning modules and ask] Could you please talk about some of the useful/beneficial features while using this or any microlearning modules? Describe as if you are trying to explain this to a friend who is planning to use it for the first time"

[Covet categories: Advantages of using microlearning approach; Positive design aspects; participants' beliefs while using microlearning content for learning database programming concepts; contributing factors; participants' view on microlearning as an instructional method for understanding database programming concepts]

Possible follow-up questions

1. How do you rate the helpfulness of microlearning modules and why? (1=not helpful; 2=a little helpful; 3=somewhat helpful; 4=quite helpful; 5=extremely helpful)
2. I see, do you want to share what worked about the microlearning modules on this week's content?
3. What are the useful design aspects of using this microlearning module or some other microlearning module?
4. Do you want to tell me if you had a recorded video lecture for this week, would it be the same or different?
5. What are your other thoughts about microlearning as an instructional approach?

Domain Three: Limitations of microlearning modules

Lead-off question

" [Show one of the microlearning modules and ask] Could you please talk about some of the issues or concerns while using this or any microlearning modules? Describe as if you are trying to explain this to a friend who is planning to use it for the first time"

[Covet categories: Limitations of using microlearning approach; negative design aspects; contributing factors; participants' beliefs while using microlearning content for learning database programming concepts; participants view microlearning as an instructional method for understanding database programming concepts]

Possible follow-up questions

1. Do you want to share what did not work about the microlearning modules on this week's content?

2. What are the negative aspects of using this microlearning module or some other microlearning module?
3. What are the factors you think have contributed negatively to your understanding of the database concepts?
4. Do you want to tell me if you had a recorded video lecture for this week, would the experience be the same or different?
5. What are your other thoughts about microlearning as an instructional approach?

Domain Four: Summary / Recommendations

1. How could microlearning modules be improved?

Appendix D Informed Consent Statement

Protocol # 10081

INDIANA UNIVERSITY INFORMED CONSENT STATEMENT FOR
Exploring the influence of the microlearning instructional approach on Introductory Database programming concepts

You are invited to participate in a research study exploring the influence of the microlearning approach on introductory database programming concepts. You were selected as a possible subject because you are a student in that specific class. Please read this form and ask any questions you may have before agreeing to be in the study. The study is being conducted by Rajagopal Sankaranarayanan from Instructional Systems Technology at Indiana University. The principal investigator is Prof. Kwon Kyungbin who is Associate Professor in the same department. This research is unfunded.

STUDY PURPOSE The main purpose of this study is to explore the influence of microlearning as an instructional approach to facilitate undergraduate students' understanding of introductory database programming concepts.

NUMBER OF PEOPLE TAKING PART IN THE STUDY If you agree to participate, you will be one of 32 subjects who will be participating in this research.

PROCEDURES FOR THE STUDY If you agree to be in the study, you will do the following things:

During Week 10, you will be asked to complete an electronic survey consisting of ten questions in a ten-point rating scale ranging from (1) Not at all the case to (10) completely the case and three additional questions consisting of a multiple-choice question and two open-ended questions. This survey will not take more than 10 minutes to complete. If you feel uncomfortable with the items of the survey, you can stop filling it out.

In addition, if you are interested you could participate in an interview to share your experiences while using the microlearning content. If you decide to participate in the interview, you could win one of the two $25 amazon gift cards which are randomly drawn. Your participation is entirely voluntary.

RISKS OF TAKING PART IN THE STUDY There is a potential loss of confidentiality, but efforts will be made to keep your personal information confidential. We cannot guarantee absolute confidentiality. Your personal information may be disclosed if required by law. Your identity will be held in confidence in reports in which the study may be published and databases in which results may be stored. The researchers only will access the recording files, and we will store the data on external hard drives; we will use them for education purposes, and the files will be destroyed by deleting these files and formatting the external drive.

BENEFITS OF TAKING PART IN THE STUDY There may be no direct benefits. Your participation in this study will provide the researcher with valuable insights to understand the

influence of microlearning approaches to teach introductory programming concepts. Specifically, it would help in designing microlearning modules as an instructional strategy for introductory programming online courses.

CONFIDENTIALITY Efforts will be made to keep your personal information confidential. We cannot guarantee absolute confidentiality. Your personal information may be disclosed if required by law. Your identity will be held in confidence in reports in which the study may be published and databases in which results may be stored. The researcher only will access the recording files, and we will store the data on the external hard drive; we will use them for education purposes, and the files will be destroyed by deleting these files and formatting the external drive.

Organizations that may inspect and/or copy your research records for quality assurance and data analysis include groups such as the study investigator and his/her research associates, the Indiana University Institutional Review Board, or its designees, and (as allowed by law) state or federal agencies, who may need to access your research records.

PAYMENT If you decide to participate in the voluntary interview, you may be able to win one of the two $25 Amazon gift cards, which are randomly drawn. There is a 1 in 16 chance to receive this.

CONTACTS FOR QUESTIONS OR PROBLEMS For questions about the study, contact Prof. Kyungbin Kwon at kwonkyu@indiana.edu or (812) 856-8460.

For questions about your rights as a research participant or to discuss problems, complaints, or concerns about a research study, or to obtain information, or offer input, contact the IU Human Subjects Office at (812) 856-4242 or by email at irb@iu.edu

VOLUNTARY NATURE OF THIS STUDY Taking part in this study is voluntary. You may choose not to take part or may leave the study at any time. Leaving the study will not result in any penalty or loss of benefits to which you are entitled.

Appendix E - Codebook

Code name	*Code description*
Effective Instructional Approach	
Effective	Microlearning is an effective way to learn the concepts
Easy to understand	Microlearning content is easy to understand
Easy to review	Easy to review content in microlearning
Easy to focus	Easy to focus using microlearning
Easy to digest information	Microlearning has easy-to-digest information
Less cognitive load	Students experienced less cognitive load in microlearning
Positive feedback	Positive feedback from students using microlearning
Easy to take notes	It is easier to take notes while learning through microlearning
Rate microlearning usefulness	Rate microlearning usefulness
Spend more time	Students spend more time learning while learning through microlearning
Students Prefer microlearning	Students Prefer microlearning
Well suited for online instruction	When not meeting in class, microlearning is probably the best outlet to teach the course
Holistic understanding	Microlearning helps with a complete understanding of a topic through micro-content and interactive features

Instructional Designer Awareness

Course alignment important	Learning objectives should match learning content, learning activities, and learning assessments. This course alignment is important for microlearning design.
Designer clear on Learning objectives	Designers should be clear about learning objectives to design the microlearning content
Program alignment important	Program alignment is important for microlearning design
Willing to invest	Instructor willing to invest in microlearning platform

Instructor's Attitudes

Instructor blames self	Instructor blames self for creating long recorded lecture videos
Instructor course planning changed	Instructor course planning changed after using microlearning
Instructor feeling positive	Instructors feel positive about using microlearning in their class
Instructor teaching plans	Instructor's teaching plan for complex programming concepts using microlearning
Instructor's commitment	Instructor's commitment to microlearning
Instructor's improvement plans	Instructor's improvement plans using microlearning
Instructor's purpose	Instructor's purpose for using microlearning
Instructors prefer microlearning	Instructors personally prefer microlearning
Saves instructor time	Microlearning saves instructor time
Students more committed	Students more committed to microlearning

Preparation takes time	Microlearning preparation takes time (Instructor)
Microlearning vs. Recorded video lectures	
Forget information_recorded video lectures	Forget most of the information by end of watching recorded video lectures
Hard to think	Students feel it's hard to think while learning through long videos
Less encouraging_Recorded Videos	Recorded video lectures are less encouraging and overwhelming
Long videos boring	Students feel long videos are boring
Out of context_Recorded Video	Recorded video lectures are out of context
The same amount of information	Short videos but the same amount of information
Simplified version	Microlearning is a simplified version of the recorded video lectures
Students lose attention	Students' attention span lost in longer videos
Needed improvements for Microlearning	
Chapter summary needed	Chapter summary needed in microlearning modules
Implement discussion posts	Need discussion posts for students in microlearning to promote the social aspect
More examples needed	More examples are needed for microlearning
More quizzes needed	More quizzes are needed in microlearning
Need demonstration	Demonstration of concepts would be helpful in microlearning

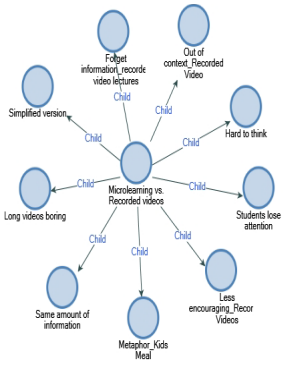
Need personalized structure	Personalized learning structure needed (what a learner needs to know minus what they already know)
Need Quiz recap	Quiz recap needed in microlearning
Need tailored content	Learning content to be tailored for Microlearning
Pause to think	Students need to think about the concept while the topic is being discussed
Open-ended responses	Allow open-ended responses for Quizzes in microlearning
Transition videos needed	Transition videos are needed in microlearning to avoid fragmented learning
Student's perceived benefits	
Engaging	Microlearning is engaging
Enjoyable	Microlearning is an enjoyable learning experience
Helped with depth knowledge	Microlearning helped go more in-depth into the concepts
Helpful to build the foundation	Microlearning is helpful to build foundational knowledge
Helpful to complete assignments	Microlearning is helpful to complete assignments
Helps students to succeed	Microlearning helps students to be successful
Increase attention	Microlearning increases students' attention to content
Knowledge retention	Easy to retain and remember the content in microlearning
Learn different topics	Easy to learn different topics in microlearning
Makes learners think	Microlearning makes learners think

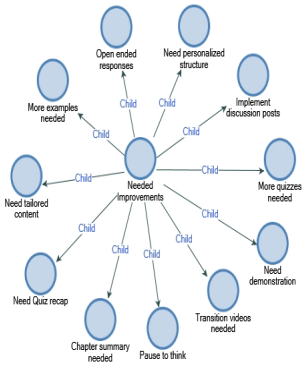
Students plan to learn	Microlearning is helpful for students to plan their learning time
Less time to complete	Microlearning takes less time to complete
No fragmented learning	No fragmented learning in microlearning
Students ready to learn	Ready to learn while using microlearning
Saves homework time	Saves time spent completing homework
Student perceptions of Quizzes	
The quiz acts as a refresher	Quizzes act as a refresher in microlearning
Quiz feedback	Quiz feedback needs to be improved in microlearning
Quizzes are helpful	Quizzes are helpful in microlearning
Quizzes encourage students	Quizzes encourage students to learn in microlearning
Quizzes help exam preparation	Quizzes help with exam preparation in microlearning
Quizzes help homework	Quizzes help with homework in microlearning
Quizzes help retain information	Quizzes help retain information in microlearning
Quizzes increase learner satisfaction	Quizzes increase learner satisfaction in microlearning
Quizzes increase confidence	Quizzes increase confidence in microlearning
Immediate quiz	Students can immediately test their topic knowledge through quizzes
Test knowledge	Quizzes tested student's knowledge
Students analyze readiness	Students use quizzes to analyze readiness to learn
Student perceptions of structural features	
Easy to navigate	Navigating content is easy in microlearning

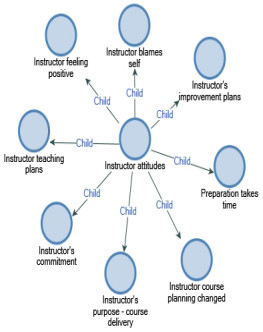
Accessible	The topics are easily accessible and easy to find because the content is separated by the main idea
Clear explanation	The learning content is explained clearly in microlearning
Easy to complete	Microlearning is easy to complete
Flexible	Microlearning is flexible
Learner control	Leaners can plan their learning process
Organized for easy access	Microlearning is organized for easy access
Outline prepares to learn	Outline prepares students to learn in microlearning
Simplified structure	Microlearning has a simplified structure
Multimodal	Microlearning has a combination of video and texts
Straight to the point	Microlearning is straight to the point
Progress bar motivates learners	Progress bar motivates students to learn in microlearning
Interactive features helpful	Interactive features are helpful in microlearning
Managing everything	Managing the learning process in microlearning
Student's perceived challenges	
Hard to learn without a background	Learning through microlearning may be hard to learn for someone without background knowledge
Bit fragmented	Some of the content is disorganized and are missing continuity
Cannot skip content	Even if learners know about a topic, they cannot skip the learning content and move forward in microlearning

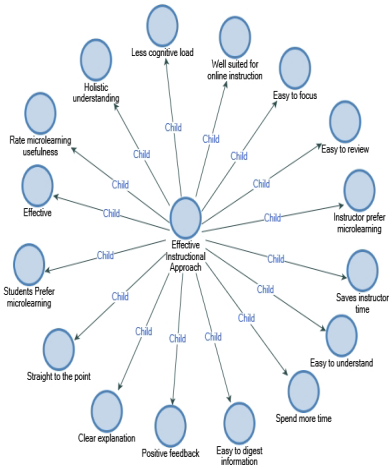
Some quizzes irrelevant	Some of the quizzes are not relevant to microlearning
Missing social aspect	Missing social aspects and learning from peers in microlearning
Not helpful for complex concepts	Microlearning is not helpful to learn complex programming concepts
Not mobile-friendly	Canvas website crashes on the phone while using microlearning
Metaphor_Kids Meal	Metaphor_Kids Meal

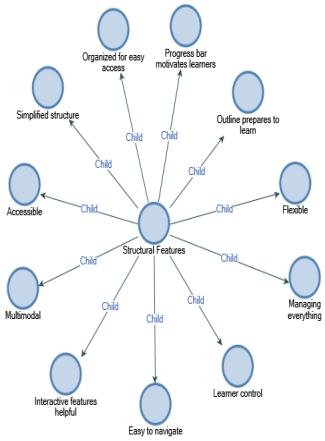
Appendix F - Categories/ Sub-Themes

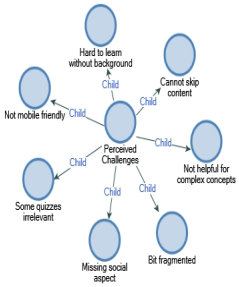


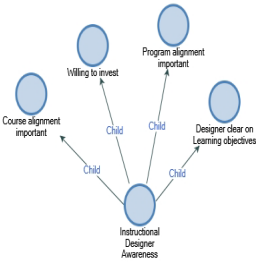


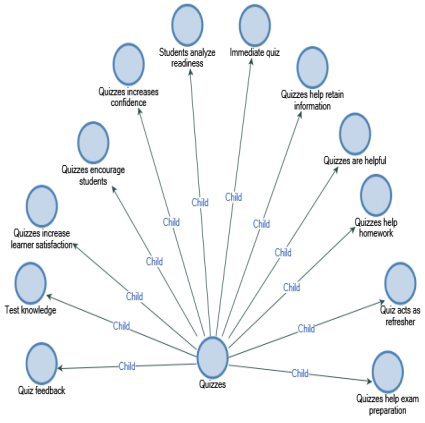


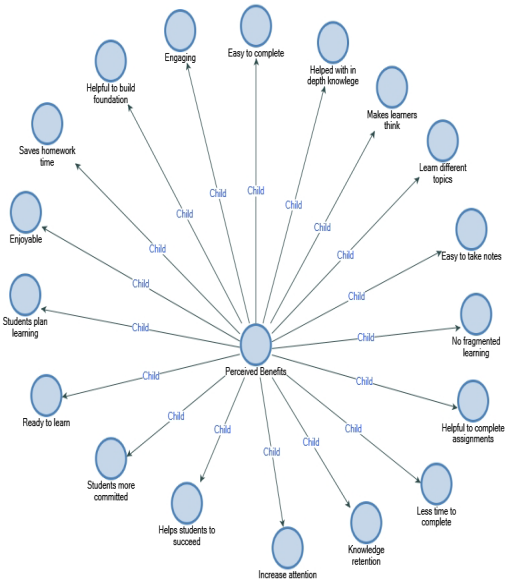












Rajagopal Sankaranarayanan CV

rsankar@iu.edu

Education

PhD	Indiana University, Instructional Systems Technology **Dissertation**: "Influence of microlearning instructional approach on introductory database programming concepts" *Committee Chair*: Dr. Kyungbin Kwon	Jun 2022
MSEd	Indiana University, Instructional Systems Technology **Advisor**: Dr. Kyungbin Kwon	Oct 2021
MS	Illinois State University, Technology **Advisor**: Dr. Klaus Schmidt	May 2017
BTech	Anna University, Information Technology **Graduated with Distinction**	Apr 2005

Honors and Awards

Curriculum Enhancement Grant	2022
Center for Integration of Research, Teaching & Learning (CIRTL) Associate	2021
J K Kemp Fellowship	2021
Larson Award	2021
Indiana University Emissary Award	2021
Graduate & Professional Student Government, Travel Award	2020
AECT Organization Training and Performance Convention Scholarship	2020
L.C. & Sharon Larson Award	2020
Graduate Teaching Apprenticeship Program, College Teaching Associate	2020
Global Learning Fellowship	2019
Faculty Doctoral Fellowship, Instructional Systems Technology	2018
Proffit Doctoral Fellowship, School of Education	2017
Outstanding performance Award	2009
Bravo Award	2007

Research Experience

Design Precedent Research Group 2018 - 2022

PI: Prof. Elizabeth Boling

- Presented in 2019, 2020, and 2021 AECT Conferences.
- Conducted literature reviews and practitioner interviews.
- Analyzed the interview transcripts and written proposals.

Online Design Research Group 2020 - 2021
PI: Dr. Faridah Pawan

- Conducted literature review on Learning presence construct
- Presented the work at AERA and AECT conferences
- Published paper in Online Learning Journal.

Computer-supported collaborative learning Research Group 2019 - 2020
PI: Dr. Kyungbin Kwon

- Conducted literature review on group awareness tools.
- Published paper in Interactive Learning Environment Journal

Teaching Experience

R521: Instructional Design and Development (Online) Aug 2021 - Dec 2021
Teaching Assistant, Instructional Systems Technology

- Providing critical feedback for students' ID projects and discussion posts.
- Monitoring student progress
- Mentoring graduate students
- Managing the Canvas course site

Teaching for Learning: Approaches & Strategies for the classroom Aug 2021
Facilitator, Center for Innovative Teaching and Learning

- Facilitated and trained newly appointed Associate Instructors (AIs) on Bloom's Taxonomy and writing learning objectives.
- Was attended by 150 participants across different schools at Indiana University.

R690: Research Methods related to IST (Online) Aug 2021 - Dec 2021
Teaching Assistant, Instructional Systems Technology

- Managing the Canvas course site.
- Moderating class discussions
- Interviewing experts and mentoring graduate students

R521: Instructional Design and Development (In-person) Jan 2020 - May 2020
Teaching Assistant, Instructional Systems Technology

- Monitoring student progress
- Mentoring graduate students
- Collating peer review feedback for each week

R551: Learning in Organizations (Online) May 2019 - Jul 2019
Teaching Assistant, Instructional Systems Technology

- Grading discussion posts
- Moderating student discussion posts
- Managing the Canvas course site

R685: HRD in Organizations (Online) Jan 2019 - May 2019
Teaching Assistant, Instructional Systems Technology

- Grading discussion posts
- Moderating student discussion posts
- Managing the Canvas course site

R511: IST Foundations (Online & In-person) Aug 2018 - Dec 2018
Teaching Assistant, Instructional Systems Technology

- Grading discussion posts
- Moderating student discussion posts
- Consolidating students' course evaluations.

R621: Needs Assessment (Online & In-person) Jan 2018 - May 2018
Teaching Assistant, Instructional Systems Technology

- Grading discussion posts
- Moderating student discussion posts
- Consolidating students' course evaluations.

Publications

Book Chapter

Phillips, T., Lachheb, A., **Sankaranarayanan, R.,** & Abramenka-Lachheb. V. (2021). Learninganalytics as a tool for reflection on instructional design practices. In J. Stefaniak, S. Conklin., B. Oyarzun, & R. Reese. (Eds.), *A Practitioner's Guide to Instructional Design in HigherEducation*. EdTech Books. https://edtechbooks.org/id_highered/learning_analytics_aG.

Journal Publications

Sankaranarayanan, R., Kwon, K., & Cho, Y. (2021). Exploring the differences between individuals and groups during the problem-solving process: The collective working-memoryeffect and the role of collaborative interactions. *Journal of Interactive Learning Research*, *32*(1), 43-66. https://www.learntechlib.org/primary/p/217515/.

Pawan, F., **Sankaranarayanan, R.**, Myers, R., & Miao, D. (2021). Learning presence and the reconceptualization of language and literacy teachers' online professional development. *Online Learning, 25*(4), 49-73. http://dx.doi.org/10.24059/olj.v25i4.2888.

Abramenka-Lachheb, V., Lachheb, A., Leung, J., **Sankaranarayanan, R.,** & Seo, G.Z. (2021). Instructional designers' use of informal learning: How can we all support each other in timesof crisis? *Journal of Applied Instructional Design, 10*(3). https://dx.doi.org/10.51869/103/valaljlrsgs.

Journal Articles in *Review*

Sankaranarayanan, R., Kwon, K., & Mithun, S. (2022, *Under Review*). The impact of a microlearning instructional approach in an online introductory database programming classroom. *Tech Trends.*

Sankaranarayanan, R., Leong, J., Abramenka-Lachheb. V., Seo, G.Z., & Lachheb, A. (2022, *Under Review*). Microlearning in diverse contexts: A bibliometric analysis. *Tech Trends.*

Boling, E., Lachheb, A., Abramenka-Lachheb. V., Basdogan, M., **Sankaranarayanan, R.,** &Chartrand, G. (2022, *Under Review*). Factoring power and positionality into research on instructional design interventions. *Journal of Formative Design in Learning.*

Journal Articles in *preparation*

Sankaranarayanan, R., Yang. M, & Kwon, K. "*Influence of microlearning instructional approach on the introductory database programming concepts: An exploratory case study.*"

Leung, J., Abramenka-Lachheb, V., **Sankaranarayanan, R.,** Lachheb, A. & Seo, G.Z., "*Instructional designers' use of informal learning in the time of covid crisis: A follow up study.*"

Boling, E., Lachheb, A., Basdogan, M., Meize, G., **Sankaranarayanan, R.**, Nadir, H., Abramenka-Lachheb, V., Alghamdi, K., Bhattacharya, P., Kadirova, D., & Chartrand, G. *"Precedent Knowledge in Design."*

Conference Presentations

Sankaranarayanan, R., Collier, J., Arslan, O., Phillips, T., Alvarado-Albertorio, F., Bal, I. A., Dolowitz, A., Duha, M. S. U., Marcelle, P., Michela, E., & Shaffer, E. L. (*2021, November*). *Bibliometric analysis of peer-reviewed literature on microlearning from 2005 to 2021* [Concurrent session]. AECT21 International Convention, Association for Educational Communications & Technology, Chicago, IL, United States.

Shaffer, E. L., Alvarado-Albertorio, F., Arslan, O., Bal, I. A., Connell, M., Duha, M. S. U., Michela, E., Collier, J., Dolowitz, A., Marcelle, P., & **Sankaranarayanan, R.** (*2021, November). A micro-team with a macro-idea: Designing videos in a virtual space.* [Panel Session]. AECT21 International Convention, Association for Educational Communications & Technology, Chicago, IL, United States.

Alvarado-Albertorio, F., Arslan, O., Bal, I. A., Duha, M. S. U., Michela, E., Shaffer, E. L., Collier, J., Connell, M., Dolowitz, A., Marcelle, P., & **Sankaranarayanan, R.** (*2021, November). GSA microlearning initiative team framework discussion and 2021 resource debut.* [Innovate! session]. AECT21 International Convention, Association for Educational Communications & Technology, Chicago, IL, United States.

Bal, I. A., Alvarado-Albertorio, F., Arslan, O., Collier, J., Connell, M., Duha, M. S. U., Marcelle, P., Michela, E., Shaffer, E. L., Dolowitz, A., & **Sankaranarayanan, R.** *(2021, November). Do you want to build microlearning? Design with a microlearning team!* [Innovate! session]. AECT21 International Convention, Association for Educational Communications & Technology, Chicago, IL, United States.

Bal, I. A., Duha, M. S. U., Alvarado-Albertorio, F., Arslan, O., Collier, J., Connell, M., Marcelle, P., Michela, E., Shaffer, E. L., Dolowitz, A., & **Sankaranarayanan, R.** *(2021, November). Testing 1, 2, 3: Creating a checklist for designing microlearning video resources through DBR.* [Roundtable session]. AECT21 International Convention, Association for Educational Communications & Technology, Chicago, IL, United States.

Pawan, F., Zakaria, F., **Sankaranarayanan, R.,** & Miao, D., (*2021, April). Learning Presence: Doctoral Students' Engagement Patterns in Online Discussions and Reflections on Language and Literacy*. [Poster session]. AERA21 Annual Meeting, American Educational Research Association, Virtual Online.

Pawan. F., **Sankaranarayanan, R.**, & Zakaria, F. *(2021, March). Inquiring into patterns of Learning presence in an online doctoral seminar course.* [Concurrent Paper Session]. 21st IST Conference, Bloomington, IN.

Sankaranarayanan, R., Kwon, K., & Cho, Y. *(2020, November) The collective working-memory effect and the role of collaborative interactions.* [Special Session]. AECT20 International Convention, Association for Educational Communications & Technology, Virtual Online.

Pawan, F., Zakaria, F., **Sankaranarayanan, R.,** & Hung, R., *(2020, November). Inquiring into patterns of "learning presence" amongst online doctoral students.* [Poster Session]. AECT20 International Convention, Association for Educational Communications & Technology, Virtual Online.

Boling, E., Meize, G., Alsaif, M., Lachheb, A., Basdogan, M., Nadir, H., Abramenka-Lachheb, V., Alghamdi, K., Bhattacharya, P., **Sankaranarayanan, R.,** Kadirova, D., & Chartrand, G. *(2020, November). Practicing designers' experiences of building and using precedent knowledge.* [Concurrent session]. AECT20 International Convention, Association for Educational Communications & Technology, Virtual Online.

Sankaranarayanan, R., Kwon, K., & Cho, Y. *(2020, March). Exploring differences between individuals and groups during the problem-solving process: The collective working-memory effect and the role of collaborative interactions.* [Concurrent Paper Session]. 21st IST Conference, Bloomington, IN.

Park, J. J., **Sankaranarayanan, R.,** & Cho, Y. *(2018, October). Informal Learning in the Workplace: An Integrative Review.* [Roundtable session]. AECT18 International Convention, Association for Educational Communications & Technology, Kansas City, MO.

Professional Affiliations

- ***Association of Educational Communications and Technology***, 2019 – Present
  Vice President for communications & Board Member – Organizational Training & Performance Division.

- ***Association for the Advancement of Computing in Education***, 2020 – Present

- ***International Society for Performance Improvement***, 2020 – Present

- ***American Educational Research Association,*** 2018 – 2021
  Proposal Reviewer – Instructional Technology SIG.

Professional Service

Service to the Instructional Systems Technology

Proposal Selection Team Co-leader, 21st IST Conference	Aug 2021
Treasurer and Board Member, Graduates of Instructional Systems Technology	Aug 2018 / 20
Registration Team leader, 19th IST Conference	Aug 2019
Hospitality Team co-leader, 18th IST Conference	Aug 2018

Service to the Indiana University

Recruitment Emissary, University Graduate School	Aug 2021
Associate Instructor Orientation, Center for Innovative Teaching & Learning	Jul 2021
Committee Member, Learning and Teaching with Technology Committee	Aug 2020
Facilitator, Doctoral Students Writing Group	Aug 2019
Representative, Preparing Future Faculty Conference	Aug 2018

Service to the Instructional Design Research Community

Peer Reviewer, Online Learning Journal	May 2022
Peer Reviewer, Journal of Applied Instructional Design	May 2022
Reviewer, TechTrends	May 2022
Proposal Reviewer, OTP Division, AECT 2022 Annual Convention	Nov 2022
Peer Reviewer, Journal of Applied Instructional Design	Dec 2021
Proposal Reviewer, OTP Division, AECT 2021 Annual Convention	Nov 2021
Proposal Reviewer, Instructional Technology SIG, AERA Conference	Feb 2021
Proposal Reviewer, RTP Division, AECT 2020 Annual Convention	Nov 2020
Beta Tester, Mixed Methods International Research Association	Dec 2019

Languages

Tamil: Native Language
English: Advanced Reading and Writing

Instructional Design Skills

Instructional Design:
Needs Analysis, Microlearning Design, Iterative Design, Business Communications, Program Evaluation and Assessment, Data Visualization, Instructional Theories/Models.

LMS:
Canvas, Moodle

Authoring tools:
Articulate Rise, Adobe Premiere Pro, Audacity, Piktochart, Canva, 7taps

Project Management*:*
Slack, Trello, MS Project, Monday