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Identifying Self-Regulation Strategies Students Use When Cognitive Load Occurs

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IDENTIFYING SELF-REGULATION STRATEGIES STUDENTS USE WHEN COGNITIVE LOAD OCCURS

by

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ABSTRACT

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When the amount of information to process exceeds students' capacity to do so, that indicates a problem in the learning environment that will hinder students' successful learning. This study investigates the self-regulated learning strategies that students use to overcome excessive cognitive load when they feel overwhelmed. This study bridges the two theories, cognitive load theory and self-regulation, to identify self-regulation strategies that students use when cognitive load occurs. Individual interviews were employed for data collection and thematic analysis was used in data analysis. Findings showed that cognitive strategies and resource management strategies are two common strategies that students employed when medium and low levels of cognitive load occur. It was also found that students' self-regulation strategies differ from one another even when students report the same levels of cognitive load. The findings also provide guidelines to

support students' learning when cognitive load occurs in the learning environments. Furthermore, it is suggested to examine the relationship between each identified self-regulation strategy and levels of cognitive load for further research.

(92 pages)

PUBLIC ABSTRACT

Identifying Self-Regulation Strategies Students Use When Cognitive Load Occurs

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When the amount of information to process exceeds students' capacity to do so, that indicates a problem in the learning environment that will hinder students' successful learning. This study found that students use a variety of strategies to help them manage their own learning when they felt overwhelmed by the amount of information they needed to process. Further, these strategies differed from those typically expected of students when they are not overwhelmed.

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Chapter I: Introduction

Many students report feeling overwhelmed, stressed, or scared in the college environment (Martinez, Lewis, & Marquez, 2020). Students often feel overwhelmed by all they must do in college, and 49.7 percent of the students reported academics as the most frequent factor based on American College Health Association data (ACHA, 2019).

Cognitive load is defined as the effect of learning that might be influenced by the degree of instructional information that is processed in learners' working memory in the learning environments (Sweller, 2019). Cognitive load theory has been investigated by researchers within the last three decades in educational fields to better support student learning from instruction. Research has focused on reducing the extraneous information in instructional materials or combining text and pictures to reduce the unnecessary information occupying working memory, which helps learners to more easily understand and retain the content (Chandler & Sweller, 1991). Moreover, research indicates that it is easier for learners to gradually reduce the load and solve problems through providing scaffolding such as using worked examples (Paas & van Merrienboer, 1994; Saw, 2017). Further, research suggests reducing load in working memory by eliminating redundant materials in instructional design could also facilitate learning (Kalyuga & Sweller, 2014).

However, manipulating aspects of instructional design cannot universally resolve the problem of learners' cognitive load due to differences between learners' characteristics

that include aspects of prior knowledge, emotion, or motivation (Sweller, 2019). Thus, it is important to optimize cognitive load depending on learners' different degrees of capacities and abilities in learning (Boekaerts, 2017; de Bruin & van Merrienboer, 2017). Even providing the same information to learners, behaviors or efforts might be different and reflect different individual levels of cognitive load. Research suggests that learners could manage their learning when cognitive load occurs to ensure they learn the material they need (Eitel, Endres, & Renkl, 2020). Thus, learners themselves are able to effectively manage their experience of load in the learning process by employing strategies or behaviors under the conditions of cognitive load.

Self-regulated learning (SRL) refers to a process where learners manage the internal and external resources to achieve personal goals in academic settings (Zimmerman, 2002). When learners encounter difficult tasks or information in learning, it is especially important to employ SRL strategies that facilitate learning success. However, little is known about how SRL may affect or be affected by different levels of cognitive load.

This study investigates what kinds of self-regulation strategies students use when different levels of cognitive load occur. To fill the gap in understanding how the specific SRL strategies support students, this study employs Zimmerman's (2000) SRL model to investigate strategies in the forethought, performance, and self-reflection phases under the conditions of cognitive load.

Since this study aims to focus on identifying specific SRL strategies students use under the different levels of cognitive load, the differences and similarities of SRL strategies between the students with different cognitive load scores should be investigated. The following research question is used to guide this study:

What kinds of self-regulation strategies do undergraduate students report using under different levels of cognitive load?

Chapter II: Literature Review

Overview

This study aims to identify the self-regulation strategies students use when cognitive load occurs. In this chapter, I review previous literature related to two theories, cognitive load theory and self-regulation, in order to examine the SRL strategies that students use while managing cognitive load. The first section discusses the concept of cognitive load theory and the existing problems when it occurs. The second section introduces the definitions of self-regulation and its importance in supporting students learning in academic settings. The third section reviews extant literature that bridges cognitive load and self-regulation.

Cognitive Load Theory

Cognitive load theory explains that information received from instruction can be processed in learners' working memory and influence the effectiveness of learning (Sweller, 1988). Because working memory is limited in its capacity, information that exceeds that capacity will not be retained in long-term memory for future use (van Merrienboer & Sweller, 2005). In contrast, learners can learn more efficiently if the materials or tasks do not reach learners' capacity limits.

As one of the predictors of cognitive load, mental effort is defined as "the amount of controlled processing in which the individual is engaged" (Paas & van Merrienboer, 1994; p. 420). Learners' investment of mental effort in learning tasks plays an important role in successful performance. Numerous studies demonstrate that mental effort is positively related to task performance (Camp et al., 2001; Paas & van Merrienboer, 1993; Paas et al., 2005). Thus, learners who invested more mental effort into tasks result in a higher scores on performance assessments.

According to the characteristics of task demands, Chandler and Sweller (1991) distinguished three types of cognitive load: intrinsic load, extraneous load, and germane load. However, germane cognitive load was eliminated from the theory due to its problematic differentiation from intrinsic cognitive load (Sweller, 2010).

Intrinsic load represents the natural complexity of learning information imposed on working memory. This type of cognitive load is mainly determined by the levels of element interactivity and prior knowledge of learners (Ayres, 2006; Sweller & Chandler, 1994; Sweller, 2010). Ayres (2006) showed that when there are many elements that are not isolated occurrences within a learning task, the learners experience a higher level of cognitive load, because the capacity of working memory is insufficient to manage much interaction among elements. One way to solve such a problem is to reduce element interactivity in order to reduce cognitive load (van Merrienboer et al., 2006). In addition, the effects of element interactivity can be reduced if learners have high levels of prior

knowledge (Sweller, 2010). Thus, learners' cognitive load would not be high if they are able to understand complex information in learning materials.

Extraneous load refers to unnecessary or irrelevant information presentation or learning methods in instructional materials imposed on learners' working memory (Chandler & Sweller, 1991). It could lead to negative effects when learners allocate needed working memory resources inefficiently by attending to redundant information (Sweller, 1994). For example, Ayres and Sweller (2005) examined extraneous load by using the split-attention effect in the instructional design. They demonstrated that extraneous load would increase when learners' attention is dispersed by the separate pictures and words compared with an integrated one. Thus, it is worth noting that extraneous load may impair learners to some extent and aspects in the learning environments.

Since working memory is limited for both novices and expert learners, it is essential to avoid excessive burden imposed on learners in order to learn effectively. When instructional materials are more appropriate for learners to process in working memory, it may better facilitate learning. However, cognitive load might occur and increase when various types of complex information or difficulty occupy the learners' working memory, thus reducing the quality and quantity of information retention in long-term memory (Lewis, 2016; Sweller, 1999; Mayer & Moreno, 2003). When it increases, information processing will be slow because of information that exceeds the capacity of learners'

working memory to process (Sweller, 1989). Moreover, cognitive overload even has detrimental effects on students who experienced it (Sweller, 1988). Thus, it is important to note that cognitive load needs to be overcome in order to support and improve students' learning. However, little is known about strategies that are able to compensate and support learners when cognitive load occurs.

Self-Regulated Learning

Since the 1960s, several models of self-regulation have been developed by researchers from different perspectives (Boekaerts, 1991; Efklides, 2011; Pintrich, 2000; Winne & Hadwin, 1998; Zimmerman, 2000). This study employs Zimmerman's three phases of SRL model to guide the interview questions to investigate which strategies students use before, during, and after learning when cognitive load occurs.

From a social cognitive theory perspective, self-regulated learning is described as the processes that learners use to monitor and control their cognitions, affect, and behaviors towards attaining their goals in learning settings (Pintrich, 2000; Schunk & Zimmerman, 1994; Zimmerman, 2000). Bandura (1986) assumed that learners' behaviors are determined by a reciprocal relationship between personal, behavioral, and environmental influences. Researchers proposed that self-regulatory activities include self-observation,

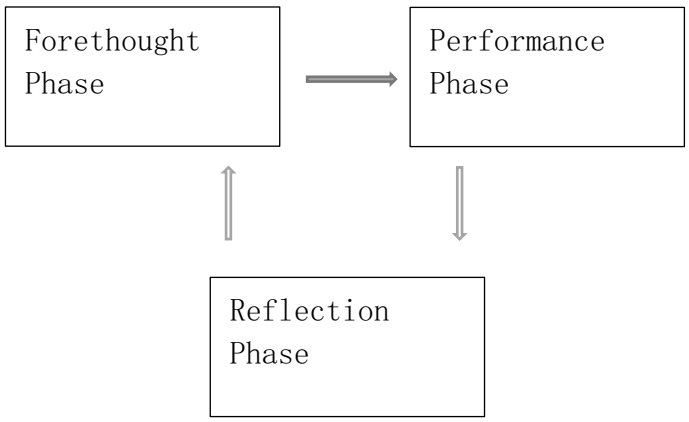
self-judgment, and self-reaction, which can be used to monitor the internalization changes between the three influences (Bandura, 1986; Zimmerman, 1989).

Zimmerman (1998; 2000; 2002) proposed a structure of three phases of SRL that learners might use: forethought phase, performance phase, and self-reflection phase (see Figure 1). The forethought phase refers to the self-regulation processes that occur before learners invest efforts to learn, which involves task analysis and self-motivation beliefs as two major aspects (Zimmerman, 2000). Specifically, it is worth noting that planning activities and motivation processes are critical components of this phase if learners expect to attain academic success. The performance phase refers to the processes that occur during the learning execution, which mainly include self-control and self-observation as two important aspects (Zimmerman, 2000). Self-control can be identified as learners using self-instruction, attention focusing, or task strategies when tasks are implemented. As a form of self-observation, self-monitoring is defined as "mental tracking of one's performance processes and outcomes" (Zimmerman & Moylan, 2009, p.303). The self-reflection phase, which includes self-reaction and self-judgment, as the two forms of this phase can be seen as the process that learners review their performance after implementing learning tasks. As a form of self-reaction, adaptive reactions refer to learners adjusting their activities to perform better if they note that negative impacts exist on their learning (Zimmerman, 2000). In addition, Zimmerman also suggests that

learners' processes in reflection might influence the following forethought phase for the next cycle of SRL (see Figure 1).

Figure 1

Zimmerman's three phases of self-regulation



Cognitive strategies and metacognitive strategies are two strategies that are highly correlated with students' academic achievement. Specifically, cognitive strategies refer to the mental processes that students use to achieve their goals in learning (Zimmerman, 2000). Typically, cognitive strategies include paraphrasing, summarizing, or outlining, which can be used by learners when they solve tasks (Pintrich, 1990). Metacognitive strategies refer to students' reflecting, monitoring, and regulating the cognitive processes, which can be seen as second-order cognitions to facilitate students' overall learning (Hacker et al., 2009). Apart from some self-regulation strategies focused on learners' cognitive activities, resource management strategies are also common strategies in the

learning environments, which focus on managing internal and external resources such as help-seeking or study time (Pintrich, 1990; Zimmerman & Martinez-Pons, 1986).

To optimize the self-regulatory phases and processes, SRL strategies should be employed by learners when they engage in learning. As behaviors to help learners gain information or knowledge, SRL strategies have a significant impact on improving the academic achievement and performance of learners (Bielaczyc et al., 1995; Dignath et al., 2008; Komarraju & Nadler, 2013). Bielaczyc and colleagues (1995) examined the effect of self-regulation strategies training by providing students with monitoring strategies training. They found that the students who received strategies gained knowledge more than those with no training. Similarly, Zimmerman and Martinez-Pons (1986) showed that students in high achievement groups were able to use strategies of seeking information or organizing and transforming better than students in low achievement groups. Researchers have further described the effects of specific SRL strategies on learners' academic achievement (Virtanen & Nevgi, 2010; Komarraju & Nadler, 2013). For example, Komarraju and Nadler (2013) found that cognitive strategies such as rehearsal strategies and resource management strategies such as time management strategies are positively correlated with grade point average. Although some SRL strategies have been found to correlate with academic performance, there is still a paucity of studies related to which specific SRL strategies that students use are effective to learners when cognitive load occurs.

Bridging CLT And SRL

To gain more insights into the two theories, it is essential to demonstrate the efficacy of bridging between CLT and SRL initially (Baars et al., 2017; Dong et al., 2020). From a metacognitive strategies perspective, previous studies have examined the relationship between cognitive load and self-regulation in the effort monitoring and regulation (EMR) framework (Baars et al., 2018; 2020; Dong et al., 2020). Research employed mental effort as the predictor of measuring learners' cognitive load within the EMR framework (Nelson & Narens, 1990). Metacognitive strategies such as learners' judgments of their learning, feeling of knowledge, and confidence in retrieved answers were included in the monitoring component. According to this, Baars and colleagues (2018) found that cognitive load negatively correlated with the judgment of learning when children perform complex problem-solving tasks. The result showed that students' ability to the judgment of learning was low when they invested more mental effort in the tasks. Similarly, Blissett and colleagues (2018) also investigated the relationship between mental effort and monitoring judgment in terms of students' learning. They found a negative relationship between mental effort and monitoring accuracy by asking students how sure they were of their diagnosis. Moreover, they also found that the certainty of participants was lower when their mental effort is higher. The findings demonstrated that there is a relationship between the cognitive load and SRL so it is feasible to investigate the two

theories deeply. However, apart from the mental effort, it is necessary to demonstrate other aspects of cognitive load in order to ensure the reliability of efficacy between the two theories.

Taub and colleagues (2014) employed prior knowledge, which presents the indicator of cognitive load, to predict the SRL strategies students use in learning environments. The results showed that students with high prior knowledge engage in more SRL strategies than those with low prior knowledge. Besides the metacognitive strategies mentioned above, resource management strategies such as help-seeking have been provided to learners during their participation in the research study. To further identify the self-regulation strategies that students use, Dong and colleagues (2020) measured the students' levels of cognitive load by distributing a survey on cognitive load and help-seeking. They found that students' levels of cognitive load influenced their ability to use specific self-regulation strategies. Specifically, Dong and colleagues indicated that students with low prior knowledge, which implies a high intrinsic cognitive load, were unable to use help-seeking strategies. In contrast, students with high prior knowledge are more actively engaged in help-seeking strategies. Although the researchers have attempted to demonstrate the relationship between the two theories, most studies shed light on demonstrating the correlation between CLT and SRL by providing specific survey items from a quantitative research approach.

Due to the extant research focused on bridging CLT and SRL, little is known about the various SRL strategies employed by students when cognitive load occurs. To investigate students' SRL strategies, researchers have suggested that including SRL prompts in journal writing can be used to optimize cognitive load (Nückles et al., 2020). Including writing prompts can assist learners in planning remedial strategies to reduce the information processing load on students' working memory (Nückles et al., 2020). Specifically, they proposed SRL prompt questions such as "for each comprehension difficulty: Try to plan a remedial action and conduct it. Please describe what you did and how your understanding changed" to have students write their answers by using the journal writing approach to affect students' cognitive load (Nückles et al., 2020, p. 1094). Based on such SRL prompts, students' load in working memory might be reduced and thoughts or strategies might be revealed through the process of writing. However, although such SRL scaffolding activities are designed to optimize information processing load, it may lead to an increase in the extraneous load when implementing journal writing.

In line with avoiding the extraneous load from learning activities as well as being able to improve learning outcomes, it is critical to explore the self-regulation strategies students use to support their learning when cognitive load occurs. As described above, previous studies not only tested the efficiency relationship between the CLT and SRL but also provided some specific SRL strategies to optimize cognitive load. However, there is

little known about exactly what kinds of strategies are selected by students themselves to manage under high or low cognitive load conditions in the learning environments. Considering the paucity of research on student selection of SRL strategies, it is important to use qualitative methods to investigate the experiences of students when cognitive load occurs. In this study, I investigated SRL strategies utilized by students experiencing different levels of cognitive during the forethought, performance, and self-evaluation phases.

Chapter III: Methodology

Research Design And Rationale

The goal of this study is to explore the SRL strategies of students who have different levels of cognitive load in an undergraduate setting. Specifically, it aims to uncover the SRL strategies that students use when cognitive load occurs at relatively medium and low levels, respectively to identify strategies under different levels of cognitive load. Thus, it is essential to employ qualitative research to achieve this purpose since it allows researchers to understand the participants' various perspectives in natural settings (Creswell, 2013). This study aims to gain insights into how students conceptualize the SRL strategies they use from participants' experiences and responses. The various SRL strategies students use under conditions of different levels of cognitive load were identified and characterized through analyzing interview content.

Grounded theory (Strauss & Corbin, 1990) was used to guide this study. It is defined as an approach to collecting and analyzing data that represents the voices of participants in order to generate explanations for the phenomenon (Strauss, 1987). However, in contrast to Glaser's approach to grounded theory, the approach to coding in the current study follows Strauss's approach in which existing theory informs the interpretation of collected data while remaining open to emergent aspects of the phenomenon under study (Heath & Cowley, 2004). Specifically, Strauss and Corbin (1990, 1998) suggested that

the existing theoretical framework could be used to identify and understand complex phenomena by iterating through a process of (1) engaging the data, (2) deduction based on existing theory, (3) validation, (4) revisiting data, and (5) inductive elaboration. Thus, I started to look at data based on the established Zimmerman's (2000, 2002) self-regulated learning framework at the beginning and then patterns and themes emerged during the coding process.

Data Collection Method

Research Context

The 3-credit course is offered by the Department of Management Information System every Fall and Spring semester at a university. During the Fall of 2021, sections of this course were provided via web broadcast as well as asynchronous online lectures through the Canvas Learning Management System. The learning objective of this course was to tackle real-world problems by using fundamental programming skills, such as Excel, SQL, and Python. Students who participated in this course needed to do readings, quizzes, homework assignments, and exams. All learning activities in each module were completed by students individually. The programming class sometimes might be difficult for students to learn so cognitive load might occur in this instructional context.

Participants

Participants in this study were undergraduate students who enrolled in a three-credit Information System course in the Fall semester of 2021. The instructor of this class disseminated a 2-item cognitive load survey to approximately 100 students in the class after class each week. Each student in class responded to the surveys. Of these, this study successfully recruited three students who had different cognitive load scores to represent different levels after taking cognitive load surveys for 14 weeks for participation (see Appendix A). Because this study aims to identify SRL strategies from different levels of cognitive load students, the students with different cognitive load scores were purposefully selected "for the most proper utilization of available resources" in only one class (Alkassim & Tran, 2016, p. 2). Since the students had received the same instructional materials in the same class, this study selected the participants with different levels of cognitive load scores in this class to investigate the strategies they employed.

Semi-Structured Interview

To investigate students' SRL strategies when cognitive load occurs, I conducted semi-structured interviews with the participants using an interview protocol after I received approval from the Institutional Review Board. See Appendix B for the interview questions and protocol. Semi-structured interviewing combines the traits of structured and unstructured interview categories, which take place by asking a few prepared

interview questions and with improvised questions that were not prepared beforehand (Barriball & While, 1994). Considering the goal of this study, I asked about SRL strategies students use under the forethought, performance, and self-reflection phases when cognitive load occurs. Each individual interview lasted approximately 30 minutes and was conducted only once. All interviews were audio-recorded and later transcribed.

Procedures

During the Fall of 2021, a 2-item cognitive load survey link was electronically disseminated to students in the Information System class each week. The survey provided a Likert scale from 1= very low cognitive load to 9 = very high cognitive load and asked the students to respond to each of two items relating to perceived complexity and difficulty, respectively (see Appendix A). I recruited one medium cognitive load and two low cognitive load students to participate in interviews based on scores of students' responses to cognitive load survey questions for 14 weeks. The instructor of this class contacted the students, informed them about the purpose of this study, and sent a recruitment sheet to the class. After the students agreed to participate in the interview, I emailed them an online informed consent form before starting the interview. The form provided participants with full disclosure of the nature of the study. It outlined the purpose, procedures, risks, confidentiality, compensation as well as benefits of this study.

Participants were also told that their participation in the study was voluntary in nature and that they could leave the study at any time without penalty. Since the instructional methods for the course were web broadcast and asynchronous sections, the interviews were conducted electronically via Zoom in order to bring more convenience for the students to participate no matter their location. During the 30-minute interview, I asked interview questions that were designed to investigate what kinds of strategies students use to manage cognitive load during three phases of self-regulation learning: forethought, performance, and self-regulation phase. After the interviews were completed, I then transcribed them by listening to the audio back and forth in order to correct the transcripts and familiarize myself with the data.

Data Analysis

Qualitative data analysis was used to answer the research question for this study (Creswell, 2013). In the data analysis process, I looked at data based on the pre-existing framework and augmented relevant categories with emergent themes (Strauss & Corbin, 1990). After reading through the transcripts and becoming familiar with the entire content in transcripts, I conducted open coding through creating codes based on the transcripts and then developed a codebook (Glaser & Strauss, 1967; Saldaña, 2009). The codes,

definitions, and quotes were identified and listed (see Appendix C). After open coding, the sub-categories of students' SRL strategies were identified.

To ensure the accuracy of codes, I employed the constant comparison data method, which refers to constantly comparing the data, data and codes, or codes and codes that can be used to improve the accuracy of existing findings (Thornberg & Charmaz, 2013). Thus, I constantly compared and refined the definitions and explanations of each theme by reviewing the codebook back and forth to make sure the definitions were attached to the codes. Then, I constructed the themes based on the existing sub-categories. Themes are provided in Appendix C. Next, I compared and matched categories between the pre-existing framework and my inductive codes (see Table 7, 8, 9) and looked at the similarities and differences of categories and themes between the students under conditions of different levels of cognitive load.

Trustworthiness

In this study, I employed strategies to increase the trustworthiness and rigor to establish the validity and reliability of research findings. The terminology of validity refers to the precision in findings that reflect the data (Long & Johnson, 2000). To ensure precision and avoid personal bias in presenting participants' perspectives from the interview transcripts, I employed the two strategies (Miles & Huberman, 1994). First, I

checked the emergent themes by looking through the data back and forth to provide an accurate indication of participants' perspectives and gain clear and transparent findings. In addition, I sent the deidentified transcripts and codebook to a colleague in our department and discussed the results of the initial coding to ensure the reliability of the findings (Lincoln & Guba, 1985).

Ethics

In a qualitative study, the researcher and participant relationship, the researcher's subjective interpretation of data, and the design itself are types of ethical problems that might be ethical issues (Ramos, 1989). In this study, participants had the autonomy to choose what they would like or not to answer in the interview in order to protect their rights. Although the participants were voluntarily participating in this study, related issues might occur when they participated in the study. When the participant had a paused during the interview, I stopped asking the question in order to minimize ethical issues and achieve the ethical standard in conducting the study (Kvale, 1996).

Chapter IV: Results

The results of this study are described in this chapter. The first section reports the participants' cognitive load scores. The second and third section reports the themes of students' SRL strategies under medium and low levels of cognitive load. Specifically, the second section mentions similarities and differences between the students with different levels of cognitive load in the forethought, performance, and reflection phases. The third section describes the differences and similarities between SRL strategies students use under the same level of cognitive load in the forethought, performance, and reflection phase. Below are the results of each section with the themes and quotes for this study.

Cognitive Load Scores

Based on the results of the cognitive load survey, the average cognitive load scores of each participant across the semester were 4.5, 4.1, and 3.8 out of 9, respectively. Among the percentile of cognitive load scores in the entire class, 4.75 is the 50^{th} percentile and 3.91 is the 25^{th} percentile (see Figure 2). According to this, student 1 had a medium cognitive load score, and student 2 and student 3 had low cognitive load scores. It should also be noted that not all participants completed all surveys, and computed means do not account for time points from which data are missing.

Although the mean levels of cognitive load were identified, the students experienced the fluctuation of cognitive load in this class. From the available data, each participant found different modules to be relatively easy or difficult with all three participants demonstrating fluctuating cognitive load values across modules (see Figure 3). Participant 2 had the highest cognitive load and the gap in scores between the highest and lowest. Both participant 1 and participant 3 had the lowest scores with huge fluctuations across classes as well. Thus, all participants had fluctuations of cognitive load over 14 weeks. All three participants reported substantial difficulty with learning programming and calculation but relative ease in learning concept knowledge. When the participants found modules hard, they described flowcharting, data analysis, or programming-related issues related to the need for generating specific outputs of SQL and Python programming, creating charts, or calculating equations. When the participants found modules easy, they identified learning objectives including modules on information technology industry infrastructure, the basic information of how all the systems connect, or internet security. Although cognitive load occurred in easy modules, it was easier for the participants to process and understand, because concepts were simpler to learn than complex skills like programming-related issues.

Figure 2

Results of cognitive load score for entire course

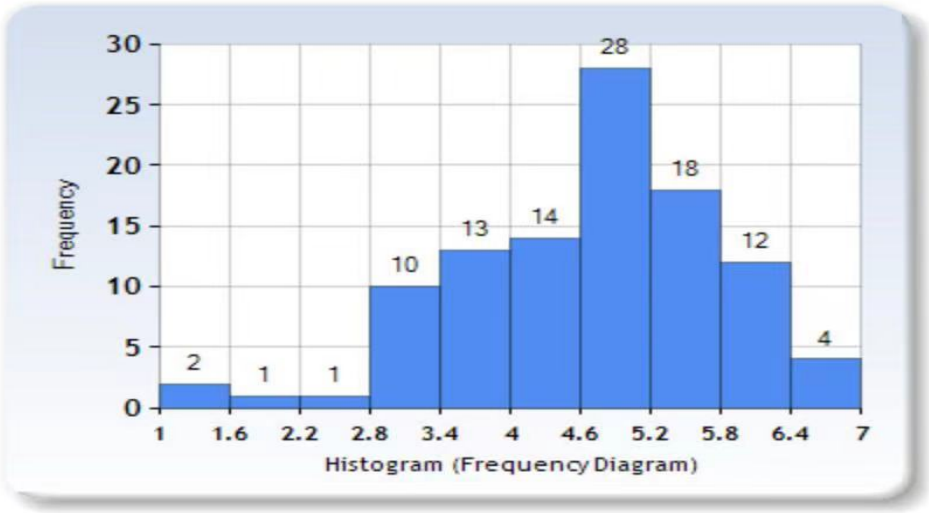
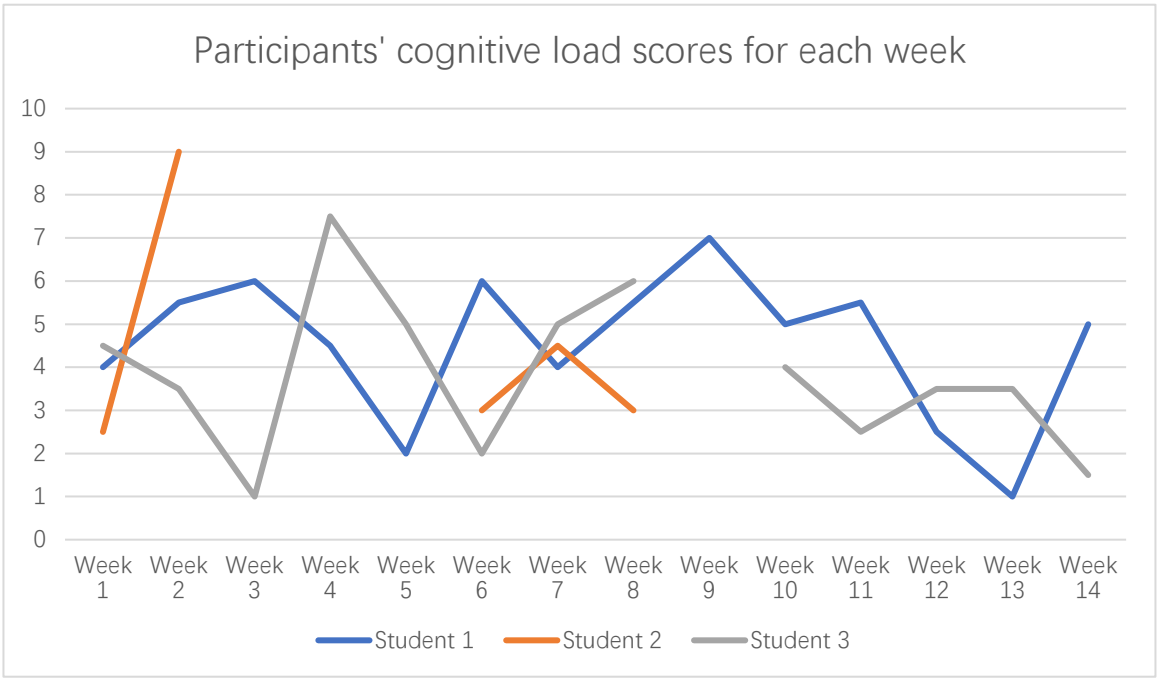


Figure 3

Participants' cognitive load scores for each week



SRL Strategies Student Use Under Medium and Low Levels of Cognitive Load

Forethought Phase

This theme focuses on the students' SRL strategies to prepare when cognitive load occurs before putting effort into learning content. As noted above, student 1 had a medium cognitive load score and student 3 had a low cognitive load score. For the students with medium and low levels of cognitive load scores, cognitive strategies and resource management strategies were employed in hard and easy modules that they determined (see Table 1).

Cognitive strategies, which focused on learners' mental activities to manage their learning, that the two levels of cognitive load students employed were similar in this forethought phase. In hard modules, the students mentioned that cognitive strategies were employed to overcome their cognitive load. Two students described skimming the tasks as a strategy to prepare before learning when they were worried about high levels of load. This point was consistent with task analysis within Zimmerman's SRL model because the participants analyzed learning tasks in the forethought phase. The quotes explained how the students used time management as a strategy.

> "Before learning each module, I would just make sure to be prepared for it and kind of read the information beforehand so that way it's easier to process." (S1)

> "For each module just make sure you study it before she was introduced it. It makes it a lot easier to manage and bring it down to me at least." (S1)

> "I would just read all of the materials that the teacher put down… I would read 'to start here', I would read the assignments, modules, just like to see what I was getting into it." (S3)

In addition to using cognitive strategies in hard modules, the student with a medium cognitive load score and the student with a low cognitive load score also focused on resource management strategies, which means learners utilize resources to achieve their need for easy modules before learning. Based on the two students mentioned, it is important to note that good time management could make the learning easier and facilitate their learning in easy modules. Although this strategy seems essential for learners to employ while experiencing high cognitive load, it suggests that Zimmerman's SRL model should add time management as a strategy in the forethought phase, because it is important for students to use when cognitive load occurs. The resource management strategies that the students mentioned were time management strategies:

> "It's usually just like make sure to complete this at this time. So I'm not like stacking up all my assignments at one place because I'm like, oh, it's easy, I can just wait. But I think making sure you have good time management with it. I think it makes the class a lot easier." (S1)

> "In easier modules, I think what helped me the most was putting in more time before I actually got to the assignment before the deadline basically. So I put in more time a few days before somethings was due to understand it." (S3)

Table 1

The medium and low cognitive load students' strategies in forethought phase

	Theme	Sub-theme (S1 Medium cognitive load)	Sub-theme (S3 Low cognitive load)
Hard/Easy modules	Cognitive strategies	Skim learning tasks	Skim learning tasks
Easy modules	Resource management strategies	Arrange time	Arrange time

Performance Phase

This theme concerns students' SRL strategies to overcome cognitive load during learning. In the performance phase, SRL strategies that students use also focused on cognitive strategies and resource management strategies to overcome cognitive load (see Table 2).

For hard modules, the students with medium and low cognitive load score both employed cognitive strategies during learning. The student with a medium cognitive load score focused on note-taking to reduce the load. When students took notes, learning materials could be remembered and then cognitive load might be reduced. However, the student with a low cognitive load score mentioned highlighting the difficult materials instead of focusing on taking notes for the lectures. Based on the quote the student mentioned, the students explained that highlighting content allowed them to pay attention to better support learning when a high cognitive load occurs. The two strategies were

consistent with the pre-existing framework, because the participants employed note-taking and highlighting content to guide themselves to overcome high cognitive load. In addition, the student with a low cognitive load score mentioned more targeted strategies, such as reading content multiple times and writing down difficult content, than the student with a medium cognitive load score.

> "I think once you read it, then you just take little notes. I feel like that helps to relieve some of the pressure off of you. Because once you take those notes right, it's very easy to get a high percentage on the quiz. As long as you're just taking good notes and you're actually fully reading, it helps you a lot when you're overwhelmed." (S1)

> "I read the textbook and I would just take care of things that I felt important. I like things in the textbook. Sometimes if I was struggling with concepts, I would go back through the chapter and just highlight things that I outlined are important or things that I found difficult, I would highlight those. Or, just read through it again. I read through maybe one, two, or three times depending on how hard it was." (S3)

> "I would write down all the things that were hard for me to remember, equations that I couldn't memorize." (S3)

Even in hard modules, the student with a low cognitive load score showed motivation in learning because they were interested in the learning materials. However, motivation from the student with a medium cognitive load was not as strong as the student with a low cognitive load score. Zimmerman's SRL framework mentions that self-motivation in the forethought phase means that students have expectations before

learning instead of having motivation or being willing to spend more time learning in the performance phase.

> "I like it so I still put a lot of more timing into it. While it is not necessarily easier, I just like doing it more. Because I enjoy it, I put four times as much time into it as I did in the others. So I did a lot better in that one." (S3)

> "I'm doing [*major*] currently as my major. And I believe that this is very important because it takes the data and it's not just like a list that you have." (S1)

For hard modules, the students with medium and low cognitive load scores also employed resource management strategies to overcome cognitive load. The students mentioned that help-seeking was a strategy because others' help could reduce cognitive load and better understand the stuff they felt loaded. The person that student with a medium cognitive load solicited for help was distinguished from the person that student with a low cognitive load score solicited. The student with a medium cognitive load score solicited the study group for help and the low cognitive load score student reached out to the student-teacher in this class. It seems like that reaching out to others allowed the students to get the answer and then reduce their load. This strategy was consistent with Zimmerman's framework, because both of them mentioned that they solicited help from others to better support their learning. The quotes explained the reason why the students reached out to their study group and then occasionally the teacher.

> “I would go to my study group and we would bounce ideas back and forth off each other to help us to get moving. And then once I have like this little pieces that I was missing. I'm able to more fully understand that subject. So I feel like having other people to kind of bounce those ideas off helps a lot.” (S1)

> “In the harder modules, sometimes I would reach out to the student-teacher. Sometimes, if the first module was hard for me, I didn’t do very well on the assignment, I thought I did but I didn’t. So I asked her to come back and look through with me and explained what I was doing wrong so that I can do well on the exam. That was something I did in the harder ones.” (S3)

For easy modules, students also focused on cognitive strategies and resource management strategies to overcome the cognitive load. The student with a medium cognitive load focused on note-taking, which was the same strategy as the modules the students felt were hard: “Just taking little notes and making sure that you take it slowly” (S1).

SRL strategies that students used to overcome cognitive load included resource management strategies in easy modules. As same as the strategies students employed in hard modules, the students with a medium cognitive load score and a low cognitive load score also employed soliciting help from others such as reaching out to the teacher or the student-teacher.

> “If I don't understand something, I usually go to my teacher or go to another student. I'll be like, can you clarify this? And that usually helps clear it up.” (S1)

> “I did ask the student-teacher.” (S3)

For easy modules, the student with a low cognitive load score mentioned that a resource management strategy, searching the Internet, was used when cognitive load occurs to facilitate learning because it helped students to reduce the load in their minds. This strategy departed from Zimmerman's SRL model, because it focused on students themselves soliciting other resources to learn.

> "In the assignments, if I couldn't understand something, I would like to search the internet and take care of what was wrong." (S3)

Student 3 employed help-seeking strategies as well. Compared with the hesitation to reach out because of procrastination in hard modules, the student did not hesitate and clearly knew what kinds of questions they needed to ask when they reached out to others in easy modules. Reaching out to others seems helpful for students to reduce cognitive load because they had the answers to their questions. This strategy was consistent with help-seeking within Zimmerman's framework, because both of them identified that soliciting help from other people was a strategy for the students. The quotes explained how the students employed this strategy.

> "I started a week before the deadline. And then I would work on it for a couple of hours each day. And when I got stumped, I called my teacher or I would email her or emailed my student teacher again. Because I feel like they have time to answer my questions cause it wasn't the day of the deadline. If I had a problem, they were able to answer it." (S3)

> "I guess because of the hard modules I didn't really understand. I understand a lot less than in hard modules. When I asked for help, I didn't really understand

the answers. If I asked questions in the easy modules, I knew exactly what questions to ask and knew when they give me the answer." (S3)

"I would put them off until it was really close to the deadline and it would be really late at night. And I didn't feel like I can reach out that late at night. And so that is the main reason I wouldn't reach out to her. Just that it was the bad timing. And I knew that it was right before the deadline so she get a ton of the emails. So I didn't email because I knew she had already really had work." (S3)

Table 2

The medium and low cognitive load students' strategies in performance phase

	Theme	Sub-theme (S1 Medium cognitive load)	Sub-theme (S3 Low cognitive load)
Hard modules	Cognitive strategies	Take notes	Highlight the content
	Resource management strategies	Reach out to study group	Reach out to teacher
Easy modules	Resource management strategies	Reach out to teacher	Reach out to teacher
			Search the internet
	Cognitive strategies	Take notes	

Reflection Phase

The reflection phase concerns the SRL strategies student use when cognitive load occurs after learning. This theme described the similarities and differences in the reflection in hard and easy modules between the student with a medium cognitive load

score and a low cognitive load score. Compared to the student with a medium cognitive load score who mentioned that the person did reflection based on the survey questions sent by the research team, the student with low cognitive load did not engage in reflection based on the survey.

> "And then at the end of it, she'll have these little exit tickets. So it was like did you set goals, did you do your reading, all this kind of stuff just kind of helps you reflect back to see did I actually put in the work. And when I did those reflections, I always try to improve from those." (S1)

The student with a medium cognitive load score focused looked back and checked the learning. "If you had a hard time understanding it, make sure to go back and do the reading if you didn't do that before." (S1) The student with a low cognitive load score looked back at the materials to reflect as well, "look back on the assignments that I did" (S3). However, the student with a low cognitive load score had more independently specific thinking and reflection than the student with a medium cognitive load score.

> "If I didn't do the reading one section, I would make sure to do it in the next and take really good notes and stuff. And it helps me a lot because looking back at it." (S1)

> "I guess I would do that with most things, if I struggled on something before I would read the book more thoroughly rather than skim through it." (S3)

For easy modules, the two levels of cognitive load students both reflected that time management was a problem that needed to be overcome when cognitive load occurs (see Table 3). The student with a medium cognitive load reflected that procrastination needed

to be overcome. However, the low cognitive load student reflected that how to put more time into learning rather than overcome procrastination. This is not included in Zimmerman's SRL framework because the pre-existing framework focused on comparing the previous performance or behaviors during reflection. The quotes showed different actions and explained the thoughts of the students on this reflection.

> "I think when it's easier, I have a tendency to wait on it. I'll wait until like the day is due or the day before that. Not like stressing out because I realized oh, it's easy. I have time and I don't need to do it right away. Like I said before, as long as I set to complete certain things on certain days. It doesn't become overwhelming and make me crunched my time and then…I guess." (S1)

> "I wish that I would spend more time in studying. I think I did a lot of time into practice in the easy modules. And in reflection, I could put more time in maintain study." (S3)

Table 3

The medium and low cognitive load students' strategies in reflection phase

	Theme	Sub-theme (S1 Medium cognitive load)	Sub-theme (S3 Low cognitive load)
Hard modules	Cognitive strategies	Reflection based on survey questions	Reflection by oneself
Hard modules	Cognitive strategies	Check previous learning	Check previous learning
Easy modules	Cognitive strategies	Procrastination problem	Put more time

Different Strategies Under the Same Level of Cognitive Load

As noted above, the cognitive load score of student 2 was 4.1 and the cognitive load score of student 3 was 3.8. It is apparent that the two students had low cognitive load scores and the difference value between them was not obvious. Under the situation of a similar cognitive load score, the two students had different kinds of strategies to overcome the cognitive load. Student 3 not only reported resource management strategies but also focused on cognitive strategies. However, student 2 only mentioned resource management strategies were used to overcome cognitive load.

Forethought phase

The forethought phase in this section focused on the SRL strategies for students under the same levels of cognitive load scores before students learning. As described in the last section, student 3 focused on cognitive strategies such as skimming the tasks and resource management strategies such as arranging the time before learning. Although student 2 and student 3 had similar cognitive load scores, student 2 only employed resource management strategies before learning (see Table 4). Specifically, the student employed setting up a computer as the strategy to overcome the cognitive load. That was different from the other low cognitive load student. In addition, this strategy was not included in Zimmerman's framework, because this focused on resource management strategies instead of cognitive strategies such as goal setting and strategic planning.

> "I put more effort into making sure I had my computer set up before classes began." (S2)

Table 4

The two low cognitive load students' strategies in forethought phase

	Theme	Sub-theme (S2 Low cognitive load)	Sub-theme (S3 Low cognitive load)
Hard modules	Cognitive strategies	Nothing	Skim learning tasks
Easy modules	Resource management strategies	Set up computer	Arrange tasks

Performance phase

The performance phase concerns the SRL strategies students use to overcome the cognitive load during learning. Compared with student 3 who used cognitive strategies such as highlighting the content and soliciting help for hard modules, resource management strategies such as reaching out to the teacher and student-teacher and searching the internet for easy modules, student 2 only employed resources management strategies to overcome cognitive load (see Table 5). This strategy was consistent with the help-seeking within Zimmerman's framework, because both of them described soliciting help from others in self-regulation. During learning, student 2 used the help-seeking strategy to overcome cognitive load in hard modules.

> "I think I asked zoom meeting recitation leaders for some help and we were able to get me caught up I believe." (S2)

For easy modules, student 2 also focused on resource management strategies, which included time management and taking a break to better support students learning when cognitive load occurs. Based on the quotes, taking a break seems important for the students to reduce much information entering their minds immediately. This strategy was consistent with Zimmerman's SRL model, because the student is distracted from the current learning environment in order to have a willingness to keep attention better on learning.

> "It was just there were times that I didn't manage my time very well. So I didn't get those done as quickly as I should have." (S2)

> "If that did happen, I would like to organize my room or something. Just get my mind off of it for a little and kind of reset" (S2)

Table 5

The two low cognitive load students' strategies in performance phase

	Theme	Sub-theme (S2 Low cognitive load)	Sub-theme (S3 Low cognitive load)
Hard modules	Cognitive strategies	Nothing	Highlight the content
	Resource management strategies	Reach out to teacher	Reach out to teacher

Easy modules	Resource management strategies	Take a break	Reach out to teacher
		Arrange time	Search the internet

Reflection Phase

This theme focuses on reflection between the students under the same levels of cognitive load after learning. It is apparent that student 2 had no reflection after learning based on the student's response. However, student 3 had specific reflections as mentioned in the last section (see Table 6). Based on Zimmerman's SRL framework, it is important for learners to have self-reflection to better learning. However, the student did not choose reflection after learning, which was different from Zimmerman's SRL model.

"I never really took specific time outside of class to reflect." (S2)

In addition, Zimmerman's SRL strategies and my inductive codes in the forethought phase (see Table 7), performance phase (see Table 8), and reflection phase (see Table 9) were also compared in tables.

Table 6

The two low cognitive load students' strategies in reflection phase

	Theme	Sub-theme (S1 Medium cognitive load)	Sub-theme (S3 Low cognitive load)
Hard modules	Cognitive strategies	No reflection	Reflection by oneself
Easy modules	Cognitive strategies	No reflection	Put more time

Table 7

Comparison of Zimmerman's SRL strategies and inductive codes in forethought phase

Zimmerman's SRL	My codes	Comparison
Task Analysis	Skim learning tasks	They are the same thing because both of them described that students focused on analyzing learning activities before learning.
Strategic planning	Arrange time	They have matched because of the students who planned to use time management strategies before learning.
Goal setting	Nothing	Not match. The student did nothing before learning does not match with Zimmerman's SRL model because the model includes strategies that could be used to better learning. However, the student did not use strategies.
Self-efficacy	Set up computer	Not match. This strategy departed from the pre-existing framework because there was no strategies related to setting up computers.
Outcome expectations	/	/
Intrinsic interest/value	/	/

Learning goal orientation	/	/

As shown in the table, it is obvious that the similarities and differences between the pre-existing self-regulation categories and codes from the inductive approach. In the forethought phase, the similarities between Zimmerman's SRL categories and my codes were task analysis because task analysis focused on using a set of steps to analyze the learning activities. The participants mentioned that arrange their time to study when cognitive load occurs because the students planned to use time management strategies before learning. The pre-existing framework mentioned goal setting, outcome expectations, and intrinsic interest learning goal orientation were also developed in my codes. For example, the student mentioned that doing nothing means no strategy was employed to support learning. However, Zimmerman's SRL model includes the strategies that could be used to better support students learning. Therefore, the pre-existing category did not match my codes.

Table 8

Comparsion of Zimmerman's SRL strategies and inductive codes in performance phase

Zimmerman's SRL	My codes	Comparison
Imagery	Notes-taking	Not match. Because imagery means learners use their imagination to remember related information and teach themselves

		while notes-taking only means taking notes of information.
Self-instruction	Highlighting the content	Not match. Because self-instruction means students self-instruct using their ability to teach themselves and highlighting the content means highlighting the information in content to remember related information.
Help-seeking	Reach out to teacher/ study group	They are similar because reaching out to the teacher or study group belonging to help-seeking.
Attention focusing	Take a break	This strategy is consistent with the pre-existing framework because taking a break means students would like to distract from the learning environment and pay more attention to better learning later.
Self-recording	Search the internet	Not match. Because self-recording means that learners record their learning time or something during learning, which is not the same meaning of search the internet
Self-experimentation	/	Not match

In performance phase, the similarities between the pre-existing framework and my codes were help-seeking strategies and attention focusing. Help-seeking refers to the learners soliciting help from others, which is included in my codebook and Zimmerman's SRL framework. In addition, attention focusing means that learners pay more attention in order to better learn and taking a break also means that students would like to distract

from the learning environment and pay more attention to learning. The differences between inductive coding and Zimmerman's SRL were the categories such as task strategy, self-record and self-experimental did not mention the participants when cognitive load occurs during learning. In addition, self-instruction and imagery, means that learners use their imagination to remember related information and teach themselves. However, in this study, note-taking and highlighting the content means that take notes information and highlighting the content of information.

Table 9

Comparsion of Zimmerman's SRL strategies and inductive codes in reflection phase

Zimmerman's SRL	My codes	Comparison
Self-evaluation	Reflection based on survey questions	Not match. Because pre-existing framework focused on one's previous performance or behaviors that influence learning while reflection based did not focuse on that.
Causal attribution	Procrastination problem	Not match. Causal attribution means one's beliefs about the cause of errors or success while procrastination only reflected the problem occurs when cognitive load is not a standard of failure or success.
Self-satisfaction	Reflection by oneself	Not match. The participants did not mention self-satisfaction after learning. Zimmerman's self-evaluation means that the person compares the performance with a standard,

		such as one's prior performance, or another person's performance. Although the student mentioned that the person did a reflection on oneself, the student didn't compare the performance with a standard.
Adaptive/defensive	Put more time	Not match. The participants did not mention withdrawing from learning when cognitive load occurs. In contrast, the participants were willing to put more time into learning.

In reflection phase, there were differences between pre-existing framework and my coding because Zimmerman's SRL model focused on someone compares previous performance or behaviors that influence learning while my codes found that the students did reflection-based regularly when cognitive load occurs. In addition, the difference between the two categories was the existing framework showed that defensive or adaptive, which means students have the willingness to avoid learning when having difficulty in learning. In contrast, the students focused on spending more time into study when cognitive load occurs in this study.

Chapter V: Discussion

This chapter illustrates participants' self-regulation strategies when cognitive load reaches medium and low levels based on the results described in the previous chapter. The first section explains the self-regulation strategies used by students who had cognitive load. and its similarities and differences employed by medium and low levels of cognitive load students. The second section describes the similarities and differences between self-regulation strategies that students who had the same level of cognitive load employed.

SRL Strategies Under Medium and Low Levels Of Cognitive Load

The themes below are divided into three phases: before, during, and after learning in order to describe SRL strategies students use when cognitive load occurs. The similarities and differences between the medium and low cognitive load students are discussed in each theme.

Forethought Phase

In the forethought phase, the SRL strategies were employed when students felt loaded after noticing the modules were hard before putting effort into learning. The

students had a low cognitive load in easy modules and high cognitive load in hard modules in learning they engaged with.

The two students mentioned resource management strategies they employed when cognitive load occurs in easy modules. Although both of the students reported time management-related issues that occurred before learning, it is obvious that the differences between the two levels of cognitive load students exist. The student with a medium cognitive load reported that a time management strategy was needed to be used to overcome the cognitive load before putting effort into the content.

Procrastination was a problem for the medium cognitive load student due to the student's tendency to wait when the content was easy. Thus, the student employed a time management strategy to subjectively arrange time in order to effectively learn (Koch & Kleinmann, 2002). Compared with the medium cognitive load student, the low cognitive load student mentioned that it was doable to arrange time appropriately in advance before learning easy modules. From this perspective, the student with a low cognitive load could plan their studying better than the medium cognitive load student.

One of the reasons that might lead to this situation is the student's interest in content because the student had a low cognitive load score mentioned this. In this sense, compared with the student with a medium cognitive load score, students' interest might reduce the cognitive load for a low cognitive load student. Once the student has more interest in the content, the student is more willing to engage in the content and process

the information to working memory so as to reduce cognitive load. This finding is in line with the previous research that showed that the same content might be easier for the student with interest than the student with no interest. Thus, the low cognitive load student with interest had a lower cognitive load than the medium cognitive load student who does not show interest in the content (Milyavskaya et al., 2018).

The student who had a low cognitive load score mentioned that the strategy of arranging the time to overcome cognitive load was not to be used in hard modules. In contrast, the student focused on cognitive strategies before engaging with the learning. Compared with the easy modules, knowledge of the content seems more difficult for the students to process into working memory in hard modules. Under this situation, only managing resources may not be effective in learning if cognitive activities cannot be employed. Thus, it might be one of the reasons why the student planned for the class by employing cognitive strategies such as skimming the tasks instead of employing resource management strategies for hard modules. This finding in line with previous research showed that cognitive strategies positively related with the content permanent store into working memory (Costley, 2020).

Performance Phase

The second section aims to investigate the SRL strategies students use to overcome cognitive load during learning. The results showed that cognitive strategies and resource

management strategies were frequent themes that the two students employed when cognitive load occurs.

Resource Management Strategies

As mentioned in the results section, help-seeking was a strategy that all participants employed when cognitive load occurred in the performance phase. In self-regulation, students were aware that they could solicit help after the stage question was generated (Karabenick &Berger, 2019). It is doable to gain understandable answers when students solicit help effectively in solving the problem (Webb & Mastergeorge, 2003). Help-seeking is associated with students' academic performance (Horowitz et al., 2013) and students' abilities to confront future challenges and difficulties. Thus, cognitive load could be overcome by students through using help-seeking strategies in the learning environments. No matter the students with medium or low levels of cognitive load, all three participants mentioned that this strategy was employed to reduce the cognitive load during learning.

Although the students under the two cognitive load levels reported the help-seeking strategies, the differences between the medium and low cognitive load students exist when they employed this strategy to manage cognitive load. For hard modules, the medium cognitive load student might have less ability in SRL strategies than the student with low cognitive load. The student with a medium cognitive load score mentioned

soliciting ideas from the others in the group in order to move forward when cognitive load occurs. However, the low cognitive load student reported reaching out to the teacher for help in hard modules. The sources of help-seeking include informal and formal help from peers and instructors if learners solicit help (Karabenick &Knapp, 1988). The student with more cognitive load solicited help from peers because they could provide ideas or hints while the student with low cognitive load solicited help from the teacher who provided professional help to the student. Since professional help might be more effective than informal help, students who prefer the teachers' help might reduce more load than students who prefer peers' help. This is in line with the previous research that showed that support from peers is not significantly related to academic achievement (Chen, 2005). Thus, soliciting help from peers might not be able to effectively reduce the cognitive load for the medium cognitive load student in an academic setting.

Cognitive Strategies

In hard modules, students with a low cognitive load score employed highlighting the difficult content and the student with a medium cognitive load score focused on note taking as a strategy to reduce the cognitive load. When cognitive load occurs, it is useful to employ notetaking to help students process and comprehend the information through the ways into their working memory (Jansen et al., 2017). If students focus on taking notes of content as a strategy, easy or difficult and necessary or unnecessary information

that occupies learners' memory might be covered in notes. Under this condition, irrelevant information in content would occupy learners' working memory. Thus, the medium cognitive load student might have more load than the low cognitive load student because of this strategy.

The student focused more on difficult content when employing the highlighting strategy. Since the students employed this strategy, it avoided unnecessary information into working memory. Thus, students only need to pay more attention to the necessary information instead of focusing on information that is already known when highlighting the content. The low cognitive load student described highlighting difficult content as a strategy to overcome cognitive load in hard modules. This finding is in line with the previous research that showed that highlighting can be seen as an effective strategy that students use when cognitive load has been increased (Roodenrys et al., 2012).

In addition to reaching out to the teacher, the student with a low cognitive load score was also employed to search the internet when cognitive load occurs. The difference between the hard modules and easy modules was that searching the internet is to seek resources by students themselves instead of seeking others' help. It is easy for students to search the information on the internet when the content were easy for students to process. At the same time, searching the internet can be seen as an important strategy employed by college students when they need to seek academic information (Selwyn, 2008).

Through searching on the internet, academic knowledge would be increased and reduce the cognitive load for students at the same time.

Reflection Phase

This section aims to discuss SRL strategies that medium and low cognitive load students use based on the results in the reflection phase. This phase involves the processes that occur after the performance or the effects of how learners respond to the performance.

In easy modules, the two students reflected that personal conditions affect learning in the reflection phase when cognitive load occurs. The medium level student mentioned procrastination in reflection when cognitive load occurs in learning. The tendency to wait can be seen as the personal condition that affects medium cognitive load student's learning when cognitive load occurs. In contrast, the student with low cognitive load manages time well when cognitive load occurs for easy modules. It seems like the student with more cognitive load had less tendency and ability to manage the learning than the student who had a less cognitive load. This finding is in line with the prior work which showed that chronic procrastinators regulate their performance speed ineffectively when high cognitive load occurs (Ferrari, 2001).

One of the differences between the student with a medium and low cognitive load is that the latter had a better reflection than the former. The student with a low cognitive load score reflected more strategies that might be helpful for learning in the future than the medium cognitive load student. Once a student is not only limited in retrospect but does prospect for reflection, the student not only thinks about the error in the previous learning but also considers how to do better in the future. In this way, the student with a low cognitive load reduced the load in the learning environment, which also might be a reason why the student had low cognitive load.

In the reflection phase, the student with a medium cognitive load score did reflected based on the SRL survey questions. The survey provided to the class included only a few questions in terms of goal setting in self-regulated learning. In addition to investigating scores, the survey questions were also used as a prompt by the student to do reflection and check themselves. However, a few questions in this survey only provided hints in limited aspects to help students reflect on learning. As mentioned above, the student with a low cognitive load score had a good reflection because the student did the reflection independently instead of relying on the limited prompts provided by the survey. If the student does not rely on the survey to do reflection, it might be able to broaden the insights into more aspects so as to reduce more cognitive load. Thus, compared with the medium cognitive load student, the low cognitive load student reflected more and deeply in the reflection phase.

SRL Strategies Under the Same Level of Cognitive Load

As mentioned in the cognitive load scores section, students 2 and 3 were under the same level of cognitive load because their cognitive load scores were around the 25th percentile of the entire class. Although the two students were under the same level, most of the strategies that student 3 mentioned tend to cognitive strategies and student 2 reported tended to resource management strategies. Due to the SRL strategies of student 3 that were discussed above, this section focuses on interpreting the strategies of student 2 and the differences between student 3.

Forethought Phase

As mentioned above, student 3 not only used resource management strategies but also focused on cognitive strategies in the forethought phase when cognitive load occurs. However, student 2 focused more on resource management strategies to overcome cognitive load. The cognitive strategies focused on learners' mental activities in self-regulation to overcome the cognitive load in the learning environments. The resource management strategies focus on utilizing resources to achieve the need instead of emphasizing students' cognitive activities. Compared with the strategies of student 3, student 2 only focused on setting up the computer before putting effort into learning to

overcome cognitive load. Once the student employed this strategy, unnecessary and additional extraneous issues would be avoided to occupy learners' working memory. Due to learners' working memory capacity being limited, this resource management strategy might be able to be used by learners in order to avoid irrelevant load and put the necessary information into working memory. Compared with student 3, student 2 lacked mental cognitive activities when cognitive load occurs before engaging in learning. Although the two students were at the same levels of cognitive load, the abilities of SRL strategies might not be under the same level. It is obvious that student 3 had better and more strategies than student 2 based on what was discussed above.

Performance Phase

In the performance phase, the similarity between student 2 and student 3 is that student 3 showed not only the resource management strategies but also cognitive strategies while student 2 only showed the resource management strategies when cognitive load occurs. Student 2 reported that taking a break is a strategy to reduce cognitive load during learning in easy modules. If learners felt loaded, it is demonstrated that the capacity of learners' working memory was not enough to process the information. When the information is not very hard for learners to understand in easy

modules, taking a break might be able to reduce learners' attention to other aspects so that learners could focus more on learning after a break.

The similarity between the two students under the same level of cognitive load is that both of the students employed help-seeking strategies. The reason that the student employed this strategy was discussed in the section above.

Reflection Phase

Compared with the personal situation that student 3 reflected, student 2 mentioned no reflection has been employed when cognitive load occurs in the reflection phase. Even under the same level of cognitive load, student 2 focused more on resource management strategies, and student 3 focused on either cognitive strategies or resource management strategies when cognitive load occurs. The different reflection between the two students might be because of the differences in cognitive strategies and resource management strategies. Cognitive activities play an important role in managing the difficulties in learning when cognitive strategies are employed by learners. However, learners focus on managing internal or external resources when they employ resource management strategies. Under this condition, the reflection phase focused more on students using the time to think about their behaviors in learning when cognitive load occurs. Hence, this might be the reason why student 2 had no reflection when cognitive load occurs.

Limitations

Although the study provides a few implications, some limitations should be mentioned. In order to investigate SRL strategies students use under conditions of cognitive load, this study recruited three students with medium and low cognitive load scores. The first limitation is that high levels of cognitive load participants were not included in this study. If students have a high cognitive load, it is possible that students are not able to solve the problem by themselves or that instructional design has problems, thus providing self-regulation might not fundamentally solve problems for high cognitive load students.

The second limitation is that the sample size of the study is small so that all of the strategies under different levels of cognitive load might not be identified. Future studies could interview a large sample of students in order to integrate the more SRL strategies that students use under different levels of cognitive load. Further, not all participants who completed cognitive load surveys did so every week, leading to missing data that may have obscured other trends or skewed estimated cognitive load means.

The third limitation of the study is that the participants were recruited from only one class, which might lead to the students' SRL strategies bias toward the students in other majors. This study only identified students' SRL strategies to overcome cognitive load in

one class. Future research could investigate students' self-regulation strategies in kinds of instructional contexts under various conditions of cognitive load.

Implications

This study provides implications from a theoretical perspective and a practical perspective when investigating CLT and SRL. From a theoretical perspective, this study drives insights into a particular way to bridge cognitive load theory and self-regulation through identifying self-regulation strategies students use to reduce cognitive load. As mentioned above, previous research related to the two theories focused more on demonstrating the efficacy of bridging cognitive load and self-regulation (Seufert, 2020). This study deeply bridges the cognitive load and self-regulation topic through interviewing the students' specific strategies when cognitive load occurs. The results showed that the interview was an effective way to investigate the specific SRL strategies students use when cognitive load occurs. The results also revealed that cognitive strategies and resource management strategies might be the frequent SRL strategies that students under the medium and low cognitive load levels employed to overcome cognitive load. Thus, both cognitive strategies and resource management strategies could support learners under the different levels of cognitive load.

In addition, this study contributed new themes to Zimmerman's framework. When cognitive load occurs, medium and low load students were more willing to arrange their time to study before learning in easy modules, which is not included in the pre-existing SRL model in the forethought phase. During learning, the medium and low cognitive load students chose to take notes and highlight the content, which was not included in Zimmerman's SRL model. In reflection phase, low cognitive load students reflected that they could put more time into the study, which is different than the defensive in Zimmerman's SRL model. The findings are important for the students when cognitive load occurs in the learning environment. Thus, this study suggests that the new themes from inductive coding could be added to the pre-existing framework, because learning under conditions of higher cognitive load seem to be associated with a different structure of SRL than typical behaviors reported by Zimmerman.

From a practical perspective, this study provides insight for instructors and students' SRL strategies to overcome cognitive load in academic settings. The results showed that students in medium and low levels of cognitive load employed cognitive strategies and resource management strategies when cognitive load occurs. For further research, the identified SRL strategies can be used as variables to investigate which strategies are effective to optimize cognitive load to better support students' learning.

Conclusions

The goal of the study aimed to investigate the SRL strategies students employed in different levels of cognitive load occur in undergraduate students. Specifically, this study revealed the similarities and differences of SRL strategies between students with medium and low cognitive load and the differences between two low cognitive load students before, during, and after learning. The results showed that the cognitive strategies and resource management strategies are two frequent strategies students use to support learning when cognitive load occurs. In addition, the low cognitive load student has better self-regulation than the medium cognitive load student. Although the students are under the same levels of cognitive load, there are different types of SRL strategies used by the students. Compared with previous research related to CLT and SRL, this study focused on identifying students' specific SRL strategies when cognitive load occurs. Moreover, this study explored SRL strategies students use to overcome cognitive load before, during, and after learning three phases. The study could provide a foundation to further research to investigate the relationship between identified SRL strategies and different levels of cognitive load to better support students' learning.

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Appendices

Appendix A

Survey Items

Cognitive Load Survey Items (adapted from Paas, 1992)

Measured on a 9-point Likert scale ranging from 1 (Very Low Mental Effort) to 9(Very High Mental Effort).

1. How complex was the material in this module?
2. How easy or difficult did you find this module?

Appendix B

Interview Protocol

Hello, (participant's name). Thank you for your participation. My name is Linyu Luo, a master's student at Utah State University conducting my thesis work at this point.

Before starting the interview, I would like to mention a few things again from the informed consent you signed. The interview will take approximately 30 minutes. I will ask you a few questions in terms of what strategies do you use to manage your own learning when you feel overwhelmed.

As mentioned in the informed consent, I would like to get your permission to record and transcribe the interview in order to verify the information accurately. All information in the interview will be confidential. The purpose of this interview is to identify strategies you use as data. I will maintain your identity and personal information will not be revealed in any publication.

This is a minimal risk research study. That means that the risks of participating are no more likely or serious than those you encounter in everyday activities. The benefits of strategies might expose the strategies you use who feel loaded after being identified while there is no direct benefit for you at this point. But the study has been designed to understand more strategies that students use to manage the load to support learning.

Your participation in this research is completely voluntary. If you feel uncomfortable during the interview, I will stop asking or recording based on your needs.

Do you have any questions or concerns before we start the interview? We will get started if you don't have any questions.

1. Walkthrough questions: Could you please pull up the canvas? Could you please tell me where /how you felt things are hard? Could you please tell me where /how you felt things are easy?
2. Forethought phase: What did you do to manage it when you feel overwhelmed before learning in hard modules? What did you do to manage it when you feel overwhelmed before learning in easy modules?
3. Performance phase: When doing the readings, quizzes, assignments, what did you do when you felt overwhelmed in hard modules? When doing the readings, quizzes, assignments, what did you do when you felt overwhelmed in easy modules?
4. Reflection phase: When you felt overwhelmed in hard modules, what did you do on reflection after learning? When you felt overwhelmed in easy modules, what did you do on reflection after learning?

That's all the questions that I have for you. Is there anything else that you would like to share with me?

Thank you so much for your participation. Do you have any concerns or questions about the interview? If you have any concerns or questions after the interview, please feel free to contact me.

Appendix C

Coding Definitions

Title / Name		Definition
Question 1a – Manage cognitive load in the forethought phase for hard modules		Interview question "What did you do to manage it when you felt overwhelmed before learning hard modules?"
Strategy – Skim the tasks	Cognitive strategies	Identifying skim the learning tasks that they would engaged with as a strategy when the students worried about load they engaged with to prepare. S1 "Before learning each module, I would just make sure to be prepared for it and kind of read the information beforehand so that way it's easier to process." S1"For each module just make sure you study it before she was introduced it. It makes it a lot easier to manage and bring it down to me at least." S3 "I would just read all of the materials that the instructor put down… I would read "to start here", I would read the assignments, modules, just like to see what I was getting into it"
Strategy – Nothing	Cognitive strategies	Didn't do anything when the student felt overwhelmed before learning. S2 "I don't know there was anything I did specifically when I was overwhelmed before learning"
Strategy – Set up computer	Resource management strategies	Identifying set up computer as a strategy when felt overwhelmed before learning. S2 "I put more effort into making sure I had my computer set up before classes began"
Question 1b – Manage cognitive load in the performance phase for hard modules		Interview question "When doing the readings, quizzes, assignments, what did you do when you felt overwhelmed in the hard modules?"
Strategy – Take notes	Cognitive strategies	Identifying take notes of learning materials as a strategy to reduce cognitive load in hard modules

		during learning. S1 "I feel like that helps to relieve some of the pressure off of you because once you take those notes right, it's very easy to get high percent on the quiz. As long as you're just taking good notes and you're actually fully reading it helps you a lot when you're overwhelmed."
Strategy – Reach out to study group	Resource management strategies	Identifying reach out to study group out of class as a strategy during the learning process when cognitive load occurs in hard modules. S1 " I would go to my study group and we would bounce ideas back and forth off each other to help us to get moving. And then once I have like this little pieces that I was missing. I'm able to more fully understand that subject. So I feel like having other people to kind of bounce those ideas off helps a lot."
Strategy – Time management	Resource management strategies	Identifying time management strategies as a strategy when cognitive load occurs during learning. S2 "I felt most overwhelmed with the in class assignments. That's what I felt when I remember felt getting overwhelmed at least once. The other stuff it wasn't as overwhelming as it was just there were times that I didn't manage my time very well."
Strategy – Reach out to recitation leader	Resource management strategies	Identifying reach out to zoom recitation leader in class as a strategy when cognitive load occurs. S2 "I think I asked zoom meeting recitation leaders for some help and we were able to get me caught up I believe."
Strategy – Highlight the content	Cognitive strategies	Identifying highlight the learning content as the strategies to reduce cognitive load in the performance phase. S3 "And sometimes if I was struggling on concepts, I would go back through the chapter and just highlight things that I outlines is important or things that I found difficult, I would highlight those."
Strategy – Read the content multiple times	Cognitive strategies	Identifying read the content multiple times as a strategy when cognitive load occurs. S3 "Or, just read through it again. I read through maybe one, two, or three times depending on how hard it was."
Strategy – Write down the difficult content	Cognitive strategies	Identifying write down the difficult knowledge as the strategy to memory when felt overwhelmed. S3 "I would write down all the things that were hard for me

		to remember, equations that I couldn't memorize. Anything that I couldn't memorize, I could write down on that paper. And that paper I didn't actually use it during the exam, but that way of studying helps me to remember it."
Strategy – Reach out to teacher	Resource management strategies	Identifying reach out to teacher as a strategy when felt overwhelmed in hard modules. S3 "in harder modules, sometimes I would reach out to her. Sometimes, if I didn't do like in the first module that was hard for me, I didn't do very well on the assignment, I thought I did but I didn't. So I asked her to come back and look through with me and explained what I was doing wrong so that I can do well on the exam. So that was something I did in the harder ones." S3 "I started a week before the deadline. And then I would work on it for a couple of hours each day. And when I got stumped, I called my teacher or I would email her or emailed my student teacher again. Because I feel like they have time to answer my questions cause it wasn't the day of the deadline. If I had a problem, they were able to answer it."
Strategy – Show motivation of learning	Cognitive strategies	Identifying show more willing to learn interesting thing as a strategy when cognitive load occurs in hard modules. S3 "I like it so I still put a lot of more timing into it. While it is not necessarily easier, I just like doing it more. Because I enjoy it, I put four times as much time into it as I did in the others. So I did a lot better in that one."

Question 1c – Manage cognitive load for the hard modules on reflection	Interview Question "When you felt overwhelmed in the hard modules, what did you do on reflection after learning?"

Strategy - Reflection based on survey questions send by research team	Cognitive strategies	Identifying reflection based on the self-regulation surveys that sent by research team as a strategy when cognitive load occurs. S1 "And then at the end of it, she'll have these little exit tickets. So it was like did you set goals, did you do your reading, all this kind of stuff just kind of helps you reflect

		back to see did I actually put in the work. And when I did those reflections, I always try to improve from those." "Just do the exit ticket and find the information and they would just be like little tiny quizzes at the end of the class."
Strategy – Check previous learning	Cognitive strategies	Identifying look back as a strategy when cognitive load occurs in hard modules after learning. S1"It's just look back at your modules. If you had a hard time understanding it, make sure to go back and do the reading if you didn't do that before." "If I didn't do the reading one section, I would make sure to do it in the next and take really good notes and stuff. And it helps me a lot because looking back at it." S3 "look back on the assignments that I did."
Strategy – No reflection	Cognitive strategies	Don't do reflection. S2 "I never really took specific time outside of class to reflect."

Question 2a – Manage cognitive load in the forethought phase for easy modules		Interview question "What did you do to manage it when you felt overwhelmed before learning the easy modules?"
Strategy – Skim the tasks	Cognitive strategies	Identifying skim learning tasks they would engaged with as a strategy when they worried about load they engaged with to prepare. S1 "Before learning each module, I would just make sure to be prepared for it and kind of read the information beforehand so that way it's easier to process." S1 "For each module just make sure you study it before she was introduced it. It makes it a lot easier to manage and bring it down to me at least." S3 "I would just read all of the materials that the instructor put down… I would read "to start here", I would read the assignments, modules"
Strategy – Arrange time	Resource management strategies	Identifying arrange study time appropriately as a strategy when cognitive load occurs before learning in easy modules. S1 "It's usually just like

		make sure to complete this at this time. So I'm not like stacking up all my assignments at one place because I'm like, oh, it's easy, I can just wait. But I think making sure you have good time management with it. I think it makes the class a lot easier." S3 "In easier modules, I think what helped me the most was putting in more time before I actually got to the assignment before the deadline basically. So I put in more time a few days before somethings was due to understand it."
Strategy – Nothing	Cognitive strategies	Do nothing when cognitive load occurs before learning. S2 "I wasn't very structured outside of the class in preparing myself."

Question 2b – Manage cognitive load in the performance phase for easy modules		Interview Question " When doing the readings, quizzes, assignments, what did you do when you felt overwhelmed in easy modules"
Strategy – Procrastination problem	Cognitive strategies	Identifying procrastination problem when doing reflection. S1 "I think when it's easier, I have a tendency to wait on it. I'll wait until like the day is due or the day before that. Not like stressing out because I realized oh, it's easy. I have time and I don't need to do it right away. Like I said before, as long as I set to complete certain things on certain days. It doesn't become overwhelming and make me crunched my time and then…I guess."
Strategy – Willing to spend more time into learning	Cognitive strategies	Identifying put more time into learning as a strategy when cognitive load occurs. S3"I wish that I would spend more time in studying. I think I did a lot of time into practice in the easy modules. And in reflection, I could put more time in maintain study."
Strategy – No reflection	Cognitive strategies	No reflection. S2 "I don't have any sort of reflection after learning easy modules. After the

		easy module, I would just focus on other class that I won't be worry about it."

Question 2c – Manage the overwhelmed on reflection for the easy modules	Interview Question "When you felt overwhelmed in the hard modules, what did you do on reflection after learning?"	
Strategy – Take notes	Cognitive strategies	Identifying take notes of learning materials as a strategy to reduce cognitive load in easy modules during learning. S1 "Just taking little notes and making sure that your take it slowly."
Strategy – Others help	Resource management strategies	Identifying solicit help from others as a strategy when cognitive load occurs in easy modules. S1 "If I don't understand something, I usually go to my teacher or go to another student. I'll be like, can you clarify this? And that usually helps clear it up." "If I need help, I'll go to people that like to understand it better." S3 "I did ask the student-teacher." "I guess because of the hard modules I didn't really understand. I understand a lot less than in hard modules. When I asked for help, I didn't really understand the answers. There was just a lot that I was missing a lot of false. If I asked questions in the easy modules, I knew exactly what questions to ask and knew when they give me the answer."
Strategy – Take a break	Cognitive strategies	Identifying take a break from learning to reduce the load for a while as a strategy when cognitive load occurs during learning. S2 "If that did happen, I would like organize my room or something. Just

		get my mind off of it for a little and kind of reset.”
Strategy – Not reach out to others	Resource management strategies	Not reach out to others. S2 “And generally, if it was easy, I just wouldn't have to ask any questions”
Strategy – Search the internet	Resource management strategies	Identifying search the internet to seek answer of the problem as a strategy when cognitive load occurs during learning in easy modules. S3"I would like search the internet and take care what was wrong."