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EXPLORING SELF-REGULATION THROUGH LEARNING NAVIGATION PATHWAYS IN ONLINE LEARNING DURING THE PANDEMIC

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Online learning has shown significant growth as a powerful alternative method to deliver learning through the pandemic situation. In the meantime, many studies have been attempting to investigate how to provide education within online platforms effectively; however, a few have examined how students regulate their learning during online courses.

Through the lens of self-regulated learning theory and Zimmerman's cyclical model (2000), the present study examines how successful students and less successful students regulate their learning in hypermedia contexts. Moreover, the research aims to explore self-regulatory behaviors via the learning pathways between successful students and less successful students in a learning management system.

The process-oriented method was applied to investigate the student's learning paths from the log data collected. The coding was done based on a new coding scheme created through the lens of self-regulated learning theories, in which half of the events were assigned with self-regulatory activities due to the lack of theoretical explanation. The frequency analysis and process mining analysis of coded learning events were generated to examine the differences in self-regulated learning between successful and less successful students.

The results indicate how successful and less successful students regulate differently in their learning navigation. For educators, the study provides insights to better design online learning courses and suggests self-regulatory strategies to support students in hypermedia contexts.

Keywords: Self-regulated Learning, Online learning, Learning management system, process mining.

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1. Introduction

Covid-19 has dramatically impacted and disrupted the education systems across the globe, which forces teaching and learning in most schools to switch into distance education (Mukhtar, Javed, Arooj, & Sethi, 2020). In this context, digital education has gained increasing interest among educational communities, and several related studies have been conducted to facilitate the learning process. Research has sought to understand the online learning needs and find ways to fulfill such needs to help online learners be proactive and thriving based on the provided instruction (Mishra, Gupta, & Shree, 2020; Mukhtar et al., 2020).

With regards to online education, the ability to self-regulate learning is critical to learners' academic success (Azevedo & Hadwin, 2005a; North, 2019). Many studies have emphasized the independence, self-direction, and responsibility in successful online education (Broadbent & Poon, 2015; Hung, M., Chou, Chen, & Own, 2010; Kauffman, 2015). According to Cheng and Jang (2010), online learning, including synchronous and asynchronous learning activities, requires students to possess several self-regulatory strategies to achieve their goals. Meanwhile, teachers and educators should consider these challenges in selecting online platforms reasonably.

In order to support learners in their own knowledge construction independently and collaboratively, learning management systems (LMS) have been evolved with advanced features that can visualize learning progress through learning tracking, content delivery, course management, and content sequencing (Lee, 2009). The LMS has been proven to be an effective learning delivery service widely used by educational institutions worldwide. Previous research has established that the data obtained from LMS can help understand the causality of the unsuccessful students (Bogarín Vega, Cerezo Menéndez, & Romero, 2018). With the growth of LMS, a large number of studies have shown several approaches and tools to support learners in online learning environments. For instance, Hsiao (2012) integrated navigation support (meter skill) and social visualization for personalized e-learning to increase student's awareness and motivation for promoting their self-regulated learning. Likewise, Lee (2009)

proposed a theoretical model to access learners' satisfaction in LMS while adopting self-regulated learning strategies. By providing the holistic learning analytics framework, Dirk and Widanapathirana (2014) show how data related to the learning profile can support the learner in the digital learning environment. Moreover, a study by North (2019) identifies practical strategies and implications for educators in supporting student self-regulation and online education success. While students get more advantages from the flexibility in the online learning platforms, they also encounter various challenges regarding self-directed learning or self-regulated learning (North, 2019). Furthermore, Tempelaar, Rienties, & Nguyen (2017) combined the data capture from LMS with Student information systems (SIS) to create powerful predictive models allowing to detect students-at-risk and provide the provision of personalized and timely feedback regarding their learning progress. Even though previous studies have recognized LMS as a helpful learning environment, little is known about how the pedagogical design on an online learning platform influences students' ability to regulate their learning pathways.

It is crucial to understand how learners self-regulate through the online learning platform to provide an effective pedagogical design as well as implement reasonable learning strategies. Accordingly, the present study set out to explores the learning navigation pathways between successful and less successful students on a learning management system to deliver navigation support design implications promoting learning regulation. In the meantime, providing suggestions for teachers and educators while designing online learning courses. Moreover, the process mining method was employed to analyze log data from Cohota LMS, visualizing snapshots of student in their programs. Through the lens of self-regulated learning theory, the differences between successful and less successful students' navigation from the results prove the crucial role of self-regulated learning in the online context and provide better understanding and solid ground in future research on how students self-regulate in the hypermedia learning environment.

2. Literature Review

According to Zimmerman (1989), self-regulated learning is assumed to be an indispensable part of constructivism theory, highlighting the essential factors for effective learning. However, to understand how learning is facilitated by different strategies, the study will initially review the literature involving constructivism, self-regulated learning, and self-regulated learning in the online learning environment. The chapter begins with a discussion of constructivism, its elements, and principles that shape how the theory works and applies in hypermedia. The discussion then moves to self-regulated learning theory and its characteristics application in the online learning context.

2.1 Constructivism theory

The term constructivism is often used as different meanings interchangeably and without precise definition. Constructivism can be referred to as a paradigm, approach, or philosophical grounding, i.e., epistemology (Ültanir, 2012). There are different aspects of constructivism, such as personal constructivism, psychological constructivism, pedagogical constructivism, or social constructivism (Ernest, 1994). Although the term has been used differently, there appears to be some agreement that constructivism is an important learning theory, which equates learning with acquiring knowledge or skills through one's experiences as a learner (Bednar, Cunningham, Duffy, & Perry, 1992). Compared with the common thought that the human mind replicates what happens in the real world, constructivists believe that humans self-generate meaning and construct their own knowledge by filtering information from their experiences (Jonassen, 1991). In other words, individuals build their own interpretation by interacting and experiencing with the external world; moreover, content knowledge can be changed if new information complexes or expands on previous information.

Two of the most famous views on constructivism are social and individual constructivism. While the former emphasizes knowledge construction through social communities' interaction, the latter believes that knowledge construction is more on a

personal level, which is created from an individual's interactions. Lev Vygotsky and Jean Piaget are two significant constructivism. Lev Vygotsky (1980) worked on the subject of social constructivism that describes cognitive development as a social process in which knowledge is developed by interacting with a more knowledgeable person across their community. On the other hand, individual constructivism proposed by Jean Piaget (1937) concluded that knowledge is invented and reinvented through interacting between one person with their own world. In that sense, the individual constructivist theorists promote learner-centered and discovery-oriented learning styles, while social constructivism's view gives a higher position to the interactions within the community as stimulates for cognitive development.

In general, constructivism describes several elements and principles in learning. The first one is knowledge construction, in which knowledge is created and built upon other previous understanding. One common core from constructivism is that people construct knowledge instead of finding them (Boghossian, 2006). From this point of view, rather than dispensing knowledge, educators provide students with opportunities and incentives to build them up (Fosnot & Perry, 2005). In his major study, Piaget questioned the nature of knowledge, how it is grown and developed. He postulated that humans cannot immediately understand the information they have just been given; instead, based on their existing knowledge, they gradually build their own understanding (Piaget, 1952). For example, learning multiplication is one of the most daunting tasks young students encounter at school. Instead of memorizing multiplication facts, teachers can relate to the addition concept, which is the math concept students already knew, to help them understand how multiplication works**.**

From the constructivism perspective, the term "learning" refers to an active process that requires learners to engage in their meaning-making process, and they have to take responsibility for their own learning. According to Glassersfeld (1995), "knowledge is not passively received but built up by the cognizing subject". This view is also supported by Gagnon & Collay, who saw knowledge requirement as an active process to construct understanding rather than passively receiving information. Thus, learners need to take actions to learn, not to record reality, but to enrich their

experience through constructing the right and wrong about the world. From this perspective, a teacher represents á a facilitator of learning rather than an instructor. The teacher must ensure that their students understand the preexisting concepts and receive explicit guidance for the following activities before moving into the next level. (Oliver, 2000).

According to social constructivism, Lev Vygotsky (1980) claims that learning is a collaborative process, or social activity, where knowledge is constantly developing through an individual's interactions with culture and society. Active learning and collaborative learning are instructional methods derived from constructivist principles, in which peer involvement is a highly recommended way to learning (Applefield, Huber, & Moallem, 2000).

As learning is contextual, knowledge is inseparable from the context in which it appears. Dewey's opinions center on "live experience" in the classroom's natural world environment on this subject, he argues: "We always live at the time we live and not some other time, and only by extracting at each present time the whole meaning of each current experience are we prepared for doing the same thing in the future. This is the only preparation that, in the long run, amounts to anything" (Dewey, 1986). Daloglu et al. (2009) also agree that learning should be done through context and should be both meaningful and applicable to the real world. Also, knowledge is not transferred until it is applied. To help this, constructivism believes that making the lessons personal to students' interests will help them reach a more profound understanding because they are motivated and see the learning as purposeful.

Knowledge is personal; in terms of individual constructivism, an individual is seen as the center of their learning. Previous studies have established that learners enter the learning environment with different backgrounds, prior knowledge, and beliefs that influences how they construct their new knowledge (Taylor, Fraser, & Fisher, 1997; Wigfield, Eccles, & Pintrich, 1996). It is essential to link what they already know and experience to the new learning.

One typical constructivism goal is solving problems that require content knowledge through a complex domain, critical thinking, collaboration, reasoning,

reflection, and developing personal inquiry skills. Also, collaborative learning can help students understand both basic views and multiple representations. When solving a problem to help promote independence and personal accountability, collaborative learning, critical thinking, and higher-order thinking skills are all meant to help students become masters of their own knowledge.

Motivation is also the key to learning. According to the Self-Determination Theory (Elias, Bryden, & Bulman-Fleming, 1998; Ryan, R. M. & Deci, 2000), autonomy, competence, and relatedness are defined as the basic psychological needs, which encourage students to actively choose learning content and work in a way that is most effective for their learning process (Ryan, R. M. & Deci, 2000). When students are being controlled or are not having the autonomy due to being instructed, the quality of their work and their affective experience are likely to be negatively influenced, and the intrinsic motivation may be diminished as a result (Deci, Vallerand, Pelletier, & Ryan, 1991; Deci & Ryan, 2012). Many studies have shown that intrinsically motivated learners tend to perform better in a constructivist learning environment (Hughes & Daykin, 2002; Martens, Gulikers, & Bastiaens, 2004; Ryan, R. M. & Deci, 2000).

Constructivism is also one of the predominant theories used in online education (Gulati, 2004). At the center of their learning experience, learners activate their prior knowledge and build their background knowledge while interacting or collaborating with their peers through text-based or multimedia computer-mediated communication. Although the online learning environment allows students to make their own choices and have their personal learning path, they are required to take more responsibility for their learning (Williamson, 2010). The technological advancements in the field of online education also provide learners with up-to-date features tracing their learning behaviors and helping them reflect on their progress. However, a lack of explanation between learning theories with collected data in this field is still present (Goldie, 2016).

While researching how students perceive constructivism elements when contributing to their learning, Kilgore (2004) found that the control of knowledge

construction can change from individual process to shared knowledge creation process with other members in a group. Discussion forums, collaborative group research, and blogs are common constructivism tools regarding knowledge construction embedded in hypermedia. The result from her research also highlights the impact of learning tools within knowledge construction among learners in online learning. However, there is still no valid and reliable method to measure individual knowledge construction (Williamson, 2010).

In higher education, online learning has increasingly integrated with delivering learning and applying various constructivism learning approaches (Kaye & Volkers, 2007). Some examples are collaborative learning through a project, where group members have to collaborate with others and activate learning through these online learning interactions. Although these interactions do not create learning, they stimulate and activate the mechanisms of acquiring knowledge in individual learners, such as asking questions, clarifying points, explaining, debating, comparing points, presenting new ideas, etc (Dillenbourg & Schneider, 1995). Another point from constructivism learning theory is that the constructing learning process in the e-learning field allows online learners to build their own knowledge based on their prior experience and even developing further within the support from the online learning platform (Hung, D., 2001; Hung, D. & Nichani, 2001; Koohang & Harman, 2005).

Although students get clear benefits while constructing their knowledge in the online environment, they also encounter challenges regarding self-regulated learning. The following chapters first discuss self-regulated learning, then link it to online education, and finally suggest instructions and strategies enhancing self-regulated learning in hypermedia contexts.

2.2 Self-regulated learning

Self-regulated learning is a process in which each learner is active metacognitively, motivationally, and behaviorally in their learning (Zimmerman & Schunk, 2001). According to Zimmerman (2000) self-regulation is “self-generated thoughts, feelings, and actions that are planned and cyclically adapted to the attainment

of personal goals". Zimmerman (2000) self-regulation model is adopted as the theoretical framework guiding this study. From Zimmerman's model, the self-regulation process can be thought of in three phases: the forethought phase, the performance phase, and the self-reflection phase.

The forethought phase involves the self-regulatory processes, which happens before an individual act, such as analyzing the task, setting goals, or planning. The main difference between Self-regulated learners and Non-self-regulated learners lies in the forethought phase since non-self-regulated learners begin learning without this phase. Setting goals is one of the first actions that students act in their learning to decide which specific outcomes they desire for their knowledge or performance (Zimmerman & Cleary, 2009). Some examples for learning goals are learning how to understand the concept of inertia in a physics course, completing a task before midnight, or learning how to create a poster using Adobe illustration software. Effective self-regulated learners also engage in strategic planning, which involves selecting strategies and then sequence them logically to best enhance learning. For example, to learn the concept of inertia, students may watch a couple of related YouTube videos before reading the textbook section on this topic, then complete required tasks related to inertia. Learners can also sequence these actions differently, reading the textbook before watching YouTube and finally doing the homework. The main point is that this conscious process arises in the forethought phase before implementing the strategies. Another self-regulatory process in the forethought phase is self-motivational beliefs. According to Zimmerman, self-motivational beliefs include self-efficacy beliefs, outcome expectation, intrinsic interest, and goal orientation, which prefer to expectation about one's ability to reach the learning goals, how well they perform, the value of the task, and one's interest in the task, and the types of goals learners construct at the beginning of their learning process (Pajares & Schunk, 2001; Zimmerman, 1989b). However, there is a lack of clue to trace these points in the learning process due to the difficulty in measuring the motivational effects (Panadero & Alonso Tapia, 2014a).

The performance phase includes self-regulatory processes occurring during the behavior of self-control and self-observation (Zimmerman & Moylan, 2009a). When learners participate in task activities, they are required to keep their concentration, implement what they thought in the forethought phase, and maintain their interest. It is not effortless to sustain focus and attention; on the contrary, it requires effective and efficient metacognitive strategies and motivational strategies (Panadero & Alonso Tapia, 2014b). One strategy to overcome distraction and reclaim focus is structuring the learning environment (Corno, 2001). Arranging all learning materials beforehand also helps maintain concentration while doing a task (Zimmerman & Moylan, 2009a).

One typical type of self-observation is self-monitoring, also known as metacognitive monitoring (Panadero & Alonso Tapia, 2014b). After understanding the task requirement and setting their own goals, learners have to continuously make the comparison between what they are doing and what is supposed to be done to keep on track of their paths and monitor their learning when necessary (Hacker, 1998). In order to have an awareness of undetected learning aspects, learners can self-record their performance for monitoring and reflect after completing a task. Especially in learning language, when learners need to improve their pronunciation, they can compare their recorded voice, which was recorded in the performance phase, with a native speaker to self-monitor, in the self-reflection phase, if needed.

The self-reflection phase involves self-regulatory processes that occur after the behavior and influence a person's response to the experience. The processes include self-judgment and adaptive self-reaction. Regarding self-evaluating judgment, learners can use the standard they set for themselves to judge their learning or performance, or they can also base on received feedback from teachers or their peers to judge themselves (Zimmerman & Schunk, 2011). Another type in this segment is causal attribution judgment. By attributing their result to specific aspects, such as strategy use, their effort, or their ability, learners explain their success and failure. When students complete their tasks, they may have positive or negative feelings. Researchers showed that those who experience positive feelings tend to be motivated

to continue their effort to learn, while students having unhappy or disappointed feelings have less motivation to improve performance next time. There are also circumstances where being upset over a result can motivate learners to work harder to improve performance next time. This is undoubtedly true in the case of sport. After a significant loss, athletes often put more effort into winning over their competitors next year. Therefore, their next behaviors depend on how learners judge their failure (Weiner, 1985). As a part of the self-reflection phase, adaptive self-reaction refers to learners' inclusion for their future attempts. To determine the effect of self-satisfaction of learners, Zimmerman and Bandura (1994) concluded that when students have a high level of satisfaction, they are more likely to make adaptive inferences for their errors by choosing more effective strategies next time. Students who are unhappy with their performances tend to make defensive inferences, such as helplessness, procrastination, or avoiding a task, so they can prevent negative feelings in the future.

These self-judgment and self-reaction in the self-reflection phase then affect the forethought processes so that they might make decisions about whether different needed actions or adjustments need to be made, such as establishing a new goal or employing more effective strategies. In this way, self-regulation is viewed as a cyclical form that involves taking feedback and adapting the learning process.

According to Zimmerman and Schunk (2011), there are four regulation levels: observation, emulation, self-control, and self-regulation. Observation is the first level of regulation. At this level, learners observe model performing activities from their peers, teachers, or experts. Giving examples plays a vital role in visualizing the task requirement in teaching and learning, helping learners imagine how to carry out the task. The next level is emulation, where students emulate the model and get help from another person, who can be teachers or classmates. However, the students will replicate the general styles or patterns instead of copying the exact models. The third level involves self-control of skills where students practice the activities without having models. One example is students' complement homework by themselves. Self-regulation, as the final level, refers to the ability to self-regulate for a task or project. Students need to practice skills in an unstructured setting, where there are more

dynamic and contextual conditions. Based on the outcome, students must learn to make adjustments and identify the needs to perform and adapt. In an analysis of self-regulated skills, Zimmerman and Schunk (1997) found that these skills are not inborn, but they are teachable.

2.3 Self-regulated learning in an online context

In the context of online learning, self-regulated learning skills are especially important due to the lack of teacher's present. Bandura (1991) highlighted the essence of self-regulation in the social context. In 2001, he identified the dual influences between self-regulated learners and the learning environment in his social cognitive theory analysis.

Previous researches on academic achievement in the classroom suggest that one of the best predictors of academic success is self-regulation and the use of self-regulatory strategies in educational environments (Pintrich & De Groot, 1990; Zimmerman & Pons, 1986; Zimmerman, 2002). Similarly, Dabbagh & Kitsantas (2004) also confirmed that one of the essential requirements for successful learners in the open learning environment is their self-regulated learning. Extensive research has shown that the learning environment's design can scaffold poor self-regulated learners and enhance good self-regulated learners simultaneously (Azevedo & Hadwin, 2005b).

SRL strategies bring many benefits to online learners, especially in the knowledge constructing progress in hypermedia, where learners may experience a sense of isolation (Azevedo, Cromley, & Seibert, 2004). Online learning opportunities provide learners with more freedom in choosing their own learning strategies. Following the learning path suggested by the instructor and promoted by SRL theories can help a student to self-regulate effectively (Ley & Young, 2001). In the same vein, Mayville (2007) conducted research on how nursing students apply self-regulated learning strategies in online learning. She showed that students are more likely to succeed if they receive practical self-regulating learning strategies from their instructor's sharing. Other researchers, however, have found that instructors can also

integrate various strategies while running online courses to foster student's self-regulated learning instead of providing them with these strategies in advance (Barnard-Brak, Paton, & Lan, 2010; Ferla, Valcke, & Schuyten, 2010). Therefore, during the online learning process, students can be guided and informed to enhance their self-regulated learning and get better learning outcomes eventually.

Many studies have invested in tools designed to support learners in the aspect of self-regulation. Regarding online learning, LMSs provide a variety of meaningful features supporting self-regulation (Cerezo et al., 2010). In which, one key factor that drives success is the ability to record every learning behavior in the learning platform, which not only helps learners easily reflect on their progress, but also provides more clues for instructors to support their students.

2.4 Fostering self-regulated learning in an online context

Based on previous studies, self-regulated learning is a necessary skill contributing to success factors in online learning, where the level of teacher presence is low (Lehmann, Hähnlein, & Ifenthaler, 2014). Research on SRL also points out that these skills can be learned and nurtured in many ways. The instructions and strategies are available in many pieces of research.

Dabbagh and Kisantas (2005) created a list of self-regulated learning strategies in the online course, including time management, note-taking, goal setting, help-seeking. Specifically, effective time management involves setting specific goals, estimating the time interval to achieve them, and monitoring one's progress while implementing them. Previous research suggested that time management skills can be acquired by recording study time usage while implementing selected performance strategies (Zimmerman, 2000). Processing as a way to assist in elaborating and organizing information, note-taking helps learners outline learning text and rewrite main points, while help-seeking also contributes to the self-regulatory process where a learner may ask for help from a more knowledgeable person or look for external

material to deal with complex concepts or unexpected situations(Butler & Winne, 1995; Ryan, A. M. & Pintrich, 1997).

Hu and Driscoll (2013) also suggested giving online materials, such as videos, articles, and notes, to discuss the importance of self-regulation in the learning content. This method can work effective on learning platform, such as LMS. The LMS allows users to upload a broad range of file types, which might help the instructor explain how to apply self-regulated learning theory in a specific situation. Also, this self-regulatory support can be in a pop-up note, frequent announcement, or additional video clips from the instructor.

To support self-regulated learning development, Wandler and Imbriale (2017) emphasized the need to prompt students, such as using reminders as a critical success factor. For example, teachers can require their students to return their study plan before starting the course or at the beginning of every study module, which intends to remind students of self-regulatory processes in the forethought phase. Another example of prompting is sending message reminders of what needs to be accomplished in each learning module. Besides, providing opportunities for frequent feedback combined with allowing students to correct their mistakes can help students engage more in their self-regulatory learning processes.

The result from the research on facilitating SRL during online learning also suggests the scaffolding of self-regulated learning behaviors (Choi, Land, & Turgeon, 2005), which should be applied in the performance phase. It helps to provide guiding activities to enrich the learning experience. When students encounter difficulty, this scaffolding can encourage them to attempt different learning approaches or apply seeking help when needed. Online courses can employ many forms of scaffolding. The scaffolding technique's effectiveness has been exemplified in a report by Dabbagh & Kitsantis (2005). They utilized a grading rubric to specify learning goals relating to the desired grade for students in advance. Based on the provided grading rubric, the student can design their action plan to align with their performance expectation. Another example of what is meant by scaffolding is to provide additional learning materials in some parts of online courses that students are often struggling with.

Many studies have shown that when students are involved in self-regulatory learning processes, they become more engaged in their learning and ultimately reach higher achievement levels. However, each SRL strategy is best suited to a specific situation, which requires the instructor to implement strategies carefully and reasonably (Zimmerman, 1990).

In summary, self-regulated learning skills and strategies bring clear benefits to online learners, including improving current learning performance and supporting lifelong learning. It is common that students may execute different activities within an online course, even though they have the same provided instruction. Besides competency in SRL skills, therefore, one key factor that drives a successful online self-regulated learner is understanding how students navigate in an online platform.

3. Aim and research question

The research aims to explore self-regulatory behaviors via the learning pathways between successful students and less successful students in online courses. This research seeks to answer the following research questions:

RQ 1: How successful students and less successful students regulate their learning pathways differently?

RQ 2: How can students learning events in learning management system reflect self-regulated learning?

To answer these questions, the process mining approach was used to analyze two groups of students during their successful and less successful English online courses through a learning management system. The implications for teachers and educators in this study include suggestions for designing online courses or teaching strategies to enhance student self-regulated learning.

4. Research methods

4.1 Data collection and participants

The participants of this study include 65 students (42 were female and 23 males) enrolled in six English online courses at Edspace English Center in Ho Chi Minh City, Vietnam, in which each course lasted three months. All participants were Vietnamese and were collected according to the course they chose. I considered only courses with containing action plans and reflection requirements and lively discussion among teachers and students in the current study. The data for this study were collected from an online learning environment in the pandemic situation. Log data from a learning platform was chosen as the main source for this study due to its ability to capture the sequences and relationships among learning behaviors (Bannert & Reimann, 2012). The material was collected in 2020, from March 1st, 2020 to September 30th, including log data, online learning activities, learning content, and performance in a learning management system.

For analysis, participants are divided into successful students and less successful students, based on their final total grade in each course. Those whose grades are higher than the course average will be in the group of successful students, and the remaining will be less successful students. The number of successful and less successful students is approximately 32 successful students and 33 less successful students. Specific figures are provided in the table below:

Table 1 Number of successful and less successful students each course

Course	Successful students	Less successful students
CC78_0820	4	5
CT24-0520	5	6
K1T35-0720	6	3
K2T35-0320	5	8
OCT24-0420	7	5

OFT24-0420	5	6

As the coronavirus pandemic impacted, almost all the educational institution in Vietnam was closed, and suddenly, students were forces to become online learners. Meanwhile, they haven't been prepared for this alternative to traditional face-to-face instruction. Like any students in this period, participants from the current study did not have time to get familiar with the online platform, where learning is delivering through distance. Moreover, they were not trained in applying SRL strategies in online learning in advance, which caused them to create many irrelevant online activities through the lens of SRL theory.

4.2 Instruments and materials

4.2.1 Learning management system:

Data for this study was collected through Cohota LMS in Vietnam, an open-source web-based learning management system (LMS) used to develop and deliver online courses in diverse learning types, such as instructor-led, self-paced, blended learning, mobile learning, gamification, etc.

Figure 1 Cohota Learning Management System

In Cohota LMS, learners are provided with shared course content through modules, assignment, discussions, quizzes and pages. Depending on online course design, learners may have different course navigation, and different types of learning activities, such as collaborative learning or individual learning. Regarding assessment, the LMS allows the instructional designers or instructors to create their own evaluation methods for grading or assessing their learners. It is also able to integrate other meaningful software within the system to enhance learning, such as H5P, Note taking, etc. One special feature from Cohota LMS is that it allows students to comment on announcements. This can support operating some activities such as asking questions to generate discussion or trigger deeper thinking.

4.2.2 Course structure

The English courses from Edspace Center aim to enable students to use English effectively in learning and working. The data collection was carried out after completing the English courses in Edspace English center (Vietnam). During Covid-19, all courses have been completed remotely or as blended learning methods. Each course lasts 3 months, in which students may have face-to-face lectures, virtual meetings, and using a learning management system, but the majority of learning happened online. In particular, students are required to spend 48 hours (50%) of guided learning and 48 hours (50%) of independent learning through the online platform.

The online learning platform is illustrated in fig 1.

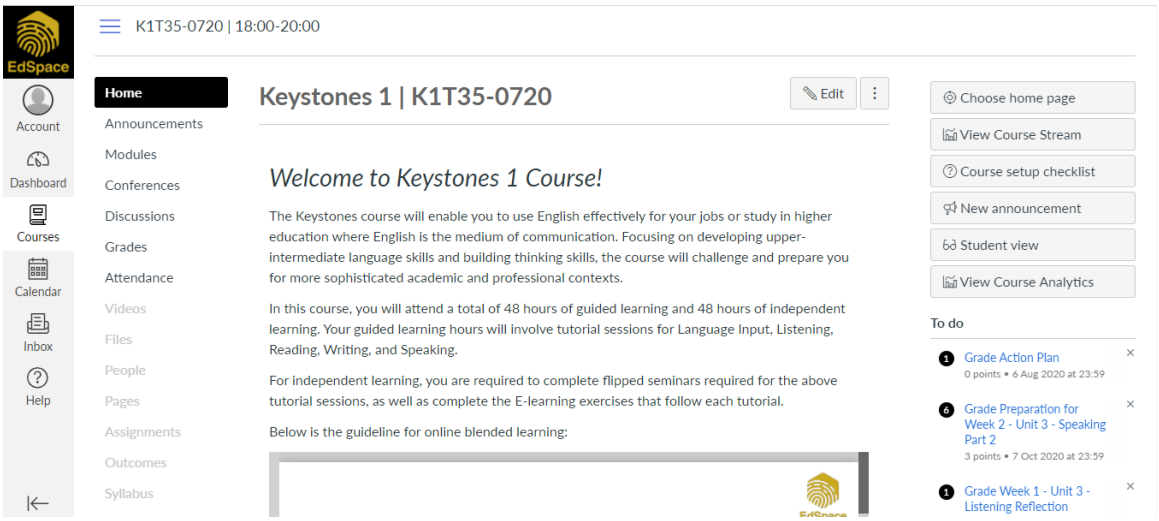


Figure 2 Edspace English course

In the course, each module represents a learning unit, including content, task, assignment, quiz, etc. Significantly, the announcement plays an essential part in these English online courses. When enrolling in the English courses, students received learning tasks through the announcement feature, allowing the instructors to manage the course's flow and create the progress that a student might take through her course work. After being given announcements from the system, students were reminded to complete quizzes, assignments or return their performance differently.

In order to follow students learning progress in the current study, these announcements were categorized by learning announcement, study plan announcements, mentoring announcement, reflective announcement, and irrelevant announcements. Students also worked on discussion features from LMS for discussing or asking for help. On the other hand, instructors can utilize this feature to deliver different assignments, such as reflecting tasks or action plan tasks each week.

During the course, students used the learning management system for some learning activities, such as open announcement, complete a quiz, attempt a quiz again, open a conference, open discussion topic, reply discussion topic, submit an assignment, etc. The course only included individual online works, so there are no collaborative activities. The final grading course was based on a weighted grade

system designed by the instructor. Specifically, the final score would be 100 percent equals each grading items multiply their own percentage. Within the learning management system, the instructors can adjust the weighted grade to calculate the corresponding final grading course reasonably.

4.3 Data analysis

Research has revealed SRL from an event perspective to explain learning activities through observable traces data (Winne, 2010). Considering this potential, this study adopted a process-oriented approach for data analysis. The log data file was provided by Cohota and Edspace English center containing all users' events recorded during English courses stored in Learning Locker. In particular, it is an open-source Learning Record Store (LRS), designed to store learning activities generated from learning experience platforms. The frequency analysis and process mining analysis were developed to examine the differences in self-regulated learning between successful and less successful students.

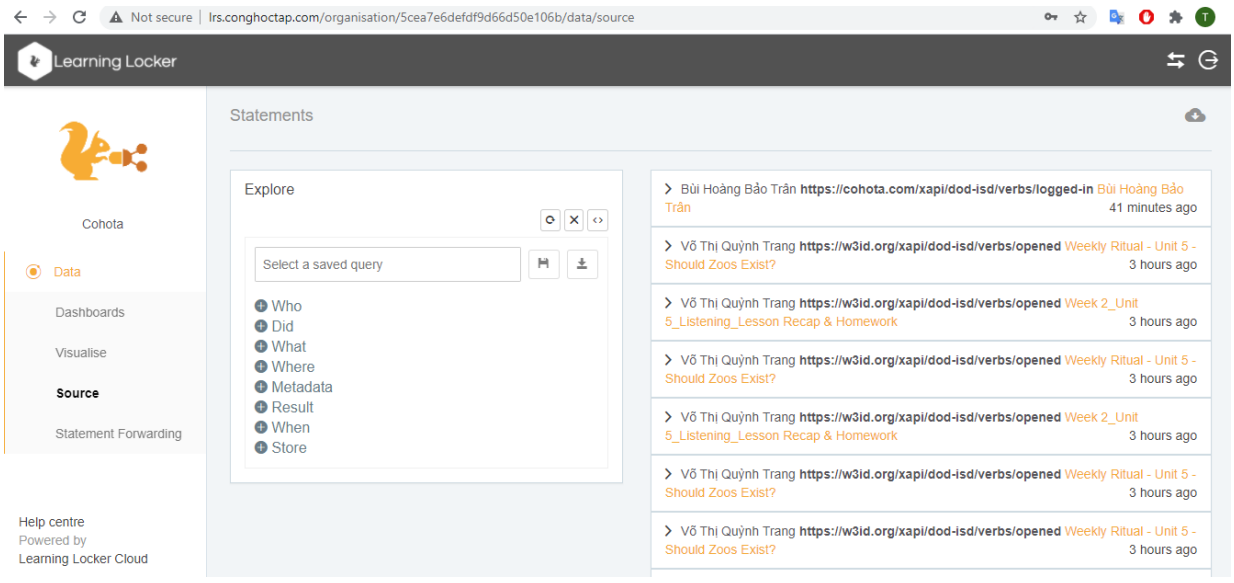
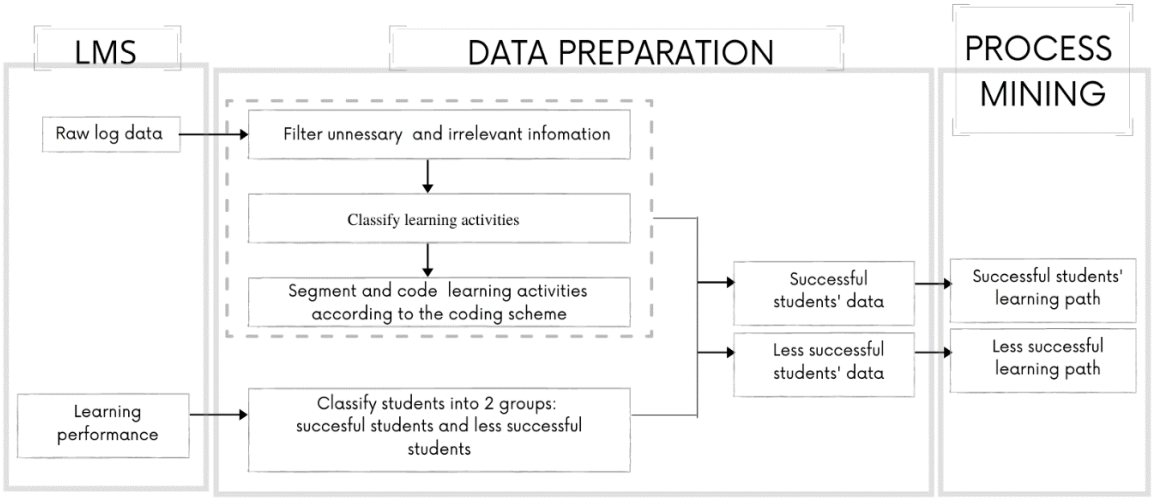


Figure 1 Learning Locker

From the original log data downloaded in Learning Locker, I filtered some relevant actions in log data. Several events had the same name but with different meanings, so I had to classify them carefully before allocating them into specific groups according to self-regulated learning theories. Based on the learning performance, I also divided students into two groups. Those whose final grade is higher than the average will be successful students, and the remaining will be in the group of less successful students.

Combining all these data, I created two data set for each group of students, including timestamps, actors, and learning activities. Following that, I input these two data sets into the Disco program to visualize the student's learning paths. The process of analyzing data was presented below:

Figure 2 The process of analyzing data



4.4 The coding scheme

The coding scheme was created using theory-based intervention within the conceptual framework of self-regulated learning. Following Zimmerman cyclical model of SRL, the data was segmented and coded based on the scheme below:

Table 2: Coding scheme

SRL phase	Coding Category	Definition	Activities	Sample In online learning LMS
Forethought	Task analysis	Task analysis refers to identify strategies, steps setting or series of goals that learner want to attain. During this phase, learners often use modeling, which is the process of witnessing another person performing a task with the intention of learning to perform the task being modeled (Pajares & Schunk, 2001). Schunk defines modeling as "behavioral, cognitive, and affective changes deriving from observing others". He also refers to modeling as social modeling (2001) and peer modeling (1987), but the meaning is the same. Seeing others, either peers or experts, succeed at the same tasks that the learner is trying to accomplish gives the learner	User opened a study plan announcement User opened a study plan discussion topic User opened a quiz	User opened an announcement welcome!-love-to-see-your-study-plans!_2587 User opened a discussion topic your-study-plan_2586 *Discussion topic was designed under the form of task being modeled.* User opened a quiz unit-6---listening-e-practice_29602

		confidence in reaching her own task intentions. Additionally, it provides learners with examples of goal setting and planning that they furthermore can follow.		
	Self-motivational beliefs	According to Zimmerman, self-motivational beliefs include self-efficacy beliefs, outcome expectation, intrinsic interest, and goal orientation, which prefer to expectation about one's ability to reach the learning goals, how well they perform, the value of the task, and one's interest in the study, and the types of plans learners construct at the beginning of their learning process (Pajares & Schunk, 2001; Zimmerman, 1989b). It is a lack of clue to trace these point in the learning process due to the difficulty in measuring the motivational	User replied a study plan discussion topic (User replied a discussion topic related to self-efficacy beliefs, outcome expectation, intrinsic interest and goal orientation before processing their learning). User submitted a study plan assignment User submitted an action plan assignment	User replied a discussion topic: your-study-plan_2586 *Note: study plan works as strategic planning which sets steps to succeed in the course.* User submitted a assignment homework-wed-03/06---study-plan-_21219 User submitted a assignment listening-and-speaking-post-mentoring-action-plans_16587

		effects. (Panadero & Alonso Tapia, 2014c) Social cognitive theorists assume that learners enter learning environments with some type of goal in mind; simultaneously, they have a level of self-efficacy for reaching these goals. Within an informal environment, these activities still occur, though they are not explicitly stated (Pajares & Schunk, 2001)		
Performance	Self-control	Self-control refers to maintain the concentration on the task and use the most efficient strategies to achieve their learning goals (Zimmerman, 1989b)	User submitted a quiz User submitted an assignment User answer a question in a quiz User replied a help-seeking discussion topic	User submitted a quiz: e-practice: -table-completion-_29603 User submitted an assignment: speaking-part-2-recordings---a-place-to-see-interesting-animals_35861 User answer a question in a quiz question-1_18303 User replied a discussion topic q&a_1366,

	Self-observation	Self-observation involves monitoring specific aspects of performance, optimizing, and tracking their learning during a task. To maintain focus and execute the goal task, the learner must monitor her own performance critically, Zimmerman (2005, 2011) refers to this as self-observation. As the learner observes her own version, she adjusts her performance as needed (Zimmerman & Kitsantas, 2005; Zimmerman & Schunk, 2011).	User submitted an assignment (requiring to record their performances) User replied a learning discussion topic (requiring to comment on their answers)	User submitted a assignment speaking-e-practice-(contrast)_35976 User replied a discussion topic book-adaptation_2439
Self-reflection	Self-judgement	Self-judgement related to the way students judge their work and formulate the reasons for their results (Panadero & Alonso Tapia, 2014c).	User submitted a reflective assignment User replied a reflective discussion topic	User replied a discussion topic: exhibition---reflection-video-_2785
	Self-reaction	The willingness to perform the task again is also an adaptive/defensive decision in self-	User attempt quiz again	User attempt quiz again: e-practice: -the-honey-badger_28218

		reaction (Weiner, 1972; Zimmerman & Moylan, 2009b).		
User opened a learning announcement		User opened an announcement which is served as guiding through an assignment or a requirement task.	User opened a learning announcement	User opened an announcement unit-5---reading-and-vocabulary---recap-and-homework_2654
User opened a learning discussion topic		User opened a discussion topic which contains an additional requirements, such as watching video clip, reading book …	User opened a learning discussion topic	User opened a discussion topic vocabulary-&-sentences---should-zoos-exist?-_2640
User opened a reflective discussion topic		User opened a discussion topic which require them to return a reflection task in comment.	User opened a reflective discussion topic	User opened a discussion topic 3-2-1-for-unit-5:-the-animal-world_1619,
User opened a reflective announcement		User opened an announcement which require them to return a reflection task in comment.	User opened a reflective announcement	User opened an announcement reflection-form-&-l-s-mentoring-&-[unit-3]-week-1-recap-&-week-2-preparation_2907
User opened a mentoring announcement		User opened an announcement about mentoring program	User opened a mentoring announcement	User opened a announcement mentoring-session---tuesday-29.09_2914
User opened a help-seeking discussion topic		User opened a discussion topic which allows them to post their questions	User opened a help-seeking discussion topic	User opened a discussion topic q&a_1366,

User joined a conference	User joined a conference	User joined a conference	User joined a conference cornerstones-|-oct24-0420-conference_4857,
User started a conference	User started a conference	User started a conference	User started a conference keystones-1-|-k1t35-0720-conference_5469
User created a conference	User created a conference	User created a conference	User created a conference keystones-1-|-k1t35-0720-conference_5469
Not relevant	User replied an announcement that not related to learning activities	Not relevant	User replied a announcement week-2---unit-1---writing-task-1_2602 User replied a announcement mentoring-session---tuesday-29.09_2914

The log data from Cohota learning management system was summarized in seven attributions (see table 3).

Table 3: Attributions of log data

TYPE	DESCRIPTION
1. ID	String showing the name of the event.
2. TIMESTAMP	The time at which the event was logged in the current time-zone of the endpoint
3. ACTOR	The user's identification
4. VERB	The action of user
5. OBJECT	The object of the user's action
6. RESULT	The result of student's performance
7. CONTEXT	The context of learning

For analysis, the study only extracted Timestamp, Actor, and Object log data from the Learning Locker, an open-source Learning Record Store. Moreover, the learning results were taken from the Grades session in the learning platform to identify successful students and less successful students.

4.5 The coded learning events

Each learning activity was assigned with a coded learning event following the coding scheme above. However, several learning activities that are not related to regulation and cannot be defined using theory-based intervention within the conceptual framework of self-regulated learning. Thus, these learning activities remained as their original learning events.

During the online courses, since all the participants in the study were free to navigate in their learning process, they created many irrelevant events that required the researcher to filter these data carefully before defining them as learning activities, then assigning them with learning coded events. Double checking content within the

learning management system was also implemented to ensure the meaning of learning events. An example of event coding was presented below:

Verb	Object	Learning activities	Learning events
User opened a announcement	final-test-_3571	User opened a learning announcement	User opened a learning announcement
User opened a discussion topic	final-reflection-_3363	User opened a reflective discussion topic	User opened a reflective discussion topic
User opened a announcement	book-review_3607	User opened a learning announcement	User opened a learning announcement
User opened a announcement	week-12_unit-8_speaking_recap-&-home	User opened a learning announcement	User opened a learning announcement
User opened a discussion topic	unit-8---dos-and-don'ts-in-vietnam-_3277	User opened a learning discussion topic	User opened a learning discussion topic
User opened a announcement	week-11_unit-8_speaking_recap-&-home	User opened a learning announcement	User opened a learning announcement
User joined a conference	cornerstones-|-cc78-0820-conference_73	User joined a conference	User joined a conference
User joined a conference	cornerstones-|-cc78-0820-conference_73	User joined a conference	User joined a conference
User opened a discussion topic	unit-8---stereotype-challenge---myth-or-tr	User opened a learning discussion topic	User opened a learning discussion topic
User opened a announcement	week-910_unit-78_presentation-vocabular	User opened a learning announcement	User opened a learning announcement
User submitted a assignment	speaking-e-practice-(part-2)---holiday-_4	User submitted a assignment	Self-observation
User replied a discussion topic	unit-8---stereotype-challenge---myth-or-tr	User replied a learning discussion topic	Self-observation
User replied a discussion topic	unit-8---dos-and-don'ts-in-vietnam-_3277	User replied a learning discussion topic	Self-observation
User opened a discussion topic	unit-8---museum-wish-list_3204	User opened a learning discussion topic	User opened a learning discussion topic
User opened a discussion topic	unit-7_-4cs-presentation-_3095	User opened a learning discussion topic	User opened a learning discussion topic
User opened a announcement	week-8_unit-7_speaking_recap-&-homew	User opened a learning announcement	User opened a learning announcement
User replied a discussion topic	final-reflection-_3363	User replied a reflective discussion topic	Self-judgement
User submitted a quiz	final---writing_33754	User submitted a quiz	Self-control
User submitted a quiz	final---listening_33762	User submitted a quiz	Self-control
User opened a quiz	final---listening_33762	User opened a quiz	Task analysis
User opened a quiz	final---writing_33754	User opened a quiz	Task analysis
User submitted a quiz	final---reading_33759	User submitted a quiz	Self-control
User opened a quiz	final---reading_33759	User opened a quiz	Task analysis
User opened a announcement	welcome!-love-to-see-your-study-plans!_2	User opened a study plan announcement	Task analysis
User joined a conference	cornerstones-|-cc78-0820-conference_72	User joined a conference	User joined a conference
User opened a announcement	unit-5---reading-and-vocabulary---recap-a	User opened a learning announcement	User opened a learning announcement
User opened a announcement	unit-7_vocabulary-&-listening_recap-&-ho	User opened a learning announcement	User opened a learning announcement
User replied a discussion topic	unit-8---museum-wish-list_3204	User replied a learning discussion topic	Self-observation
User opened a discussion topic	unit-8---voicetube---wanderlust_3192	User opened a learning discussion topic	User opened a learning discussion topic

Figure 3 Example of event coding

5. Results

The findings are reported below. In which, I will present the frequency analysis of coded learning events. Then I will provide the process analysis of coded events applying process mining technique. Both analyses aim to examine how successful and less successful students regulate in the hypermedia learning context.

5.1 The frequency analysis of coded learning events

After the coding was completed, the Disco program was employed to generate the frequency analysis of coded learning events. For more apparent differentiation between two groups, each learning event was counted how many time it appeared, as well as how many percent of that event occurred. In total, there were 10,160 recorded events, in which the majority belong to User opened a learning announcement (n = 3,590; f = 35.33%), task analysis (n = 1,905; f = 18.75%), and self-control (n = 2,491; f = 24.52%).

Table 3: Absolute and Relative frequencies of coded learning events for successful and less successful students.

Activities	**Successful students**		**Less successful students**	
	Absolute frequency	Relative frequency	Absolute frequency	Relative frequency
User opened a learning announcement	1950	0.3652	1640	0.3415
Task analysis	1093	0.2047	812	0.1691
Self-control	1027	0.1923	1464	0.3049
User opened a learning discussion topic	558	0.1045	504	0.0105

Self-observation	259	0.0485	198	0.0412
Not relevant	103	0.0193	34	0.0071
Self-reaction	91	0.0170	37	0.0077
User opened a reflective announcement	83	0.0155	13	0.0027
Self-judgement	65	0.0122	55	0.0115
User opened a help-seeking discussion topic	45	0.0084	5	0.0001
Self-motivational beliefs	22	0.0041	15	0.0031
User opened a mentoring announcement	18	0.0034	11	0.0023
User opened a reflective discussion topic	15	0.0028	13	0.0027
User started a conference	11	0.0021	1	0.0002

The table 1 presents the summary statistics for the frequency analysis of coded learning events between 32 successful students and 33 less successful students. As can be seen from the table, the successful group reported almost all the learning activities with higher frequencies, especially in task analysis (n = 1,093; f = 20.47%), self-

reaction (n = 91; f = 1,70%), User opened a reflective announcement (n = 1950; f = 36.52%), and User opened a help-seeking discussion topic (n = 45; f = 0.84%). Whereas, in the case of self-control, less successful students (n = 1,464; f = 30.49%) have higher frequencies then the other group (n = 1,027; f = 19.23%). Self-motivational belief was rarely executed by students, especially in less successful group (n = 15; f = 0.31%). This finding corresponds to what Ernesto and Jesus (2014) highlighted in their systematic review of Zimmerman's cyclical model of Self-regulated learning.

Accordingly, the table presents association events with reflective phase seldom occurred in both groups, such as self-judgment (n = 65; f = 1.22%, and n = 55; f = 1.15%). It indicated that students rarely reflected their learning without requirements from their courses. Moreover, this can also be explained as inadequate self-regulatory skills among students. This requires instructors in raising students' awareness regarding self-regulatory skills, which can be done through giving online materials, such as videos, articles, and notes, to discuss the importance of self-regulation in the learning content (Hu & Driscoll, 2013).

Concerning "User opened a learning announcement", which is the most frequent event in both groups (n = 1,950; f = 36.52%, and n = 1640; f = 34.15%), explaining the essential role of announcement's feature in the online learning management system. This finding was also reported by Bradford et al. (2007). For teachers and learning instructional designers, the announcement feature should be implemented carefully and reasonably to avoid annoying their students.

The results from absolute and relative frequencies of coded learning events reflected what learning activities generated and their frequencies during the online learning session. Nerveless, it is unlikely to help explore underlying relations between any two different events, as well as the sequence of these learning events, which asking for the further process analysis of coded events in the next step.

5.2 Process analysis of coded events

To explore the learning paths of successful students and less successful students, I employed the Fuzzy miner algorithms (Günther & Van Der Aalst, Wil MP, 2007; Reimann, Frerejean, & Thompson, 2009) in Disco software. The Fuzzy miner uses significance/correlation metrics to concentrate on the main characteristics and simplify the process model at the desired level of abstraction. Furthermore, major events in frequent sequences and the relationships among these events were visualized. The data input was 65 cases (32 cases of successful students and 33 cases of less successful students), including timestamps, actors, and learning activities. The resulted models are illustrated in Figure 6 and Figure 7:

Activities	9
Events	5340
Cases	32

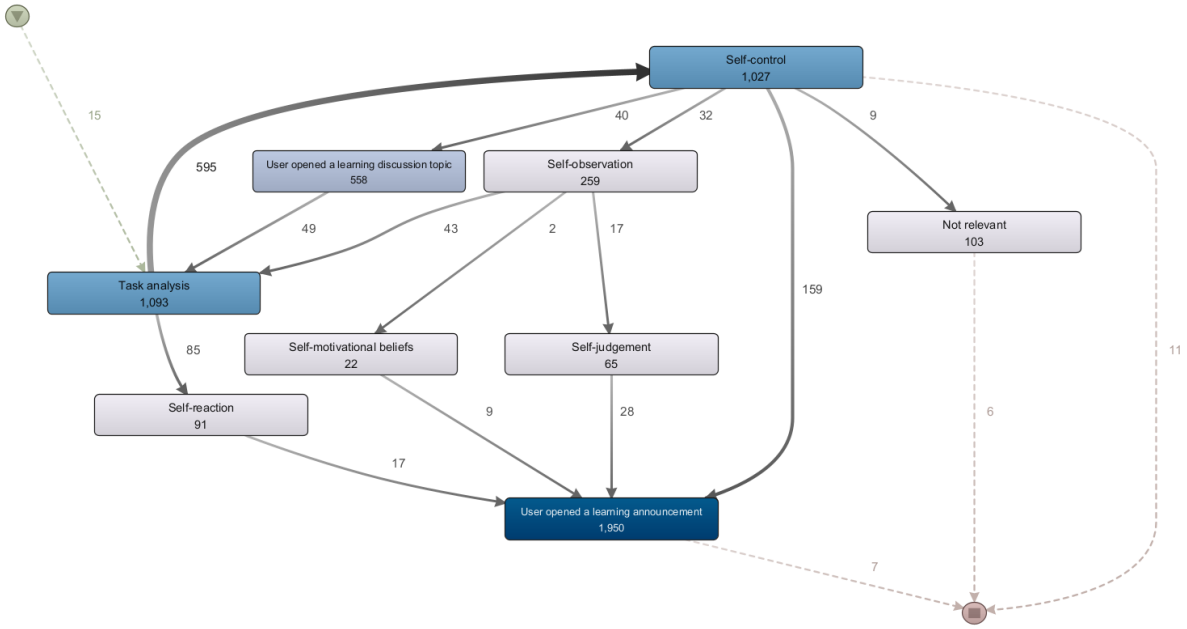


Figure 4 Successful students' learning paths

Activities	9
Events	4820
Cases	33

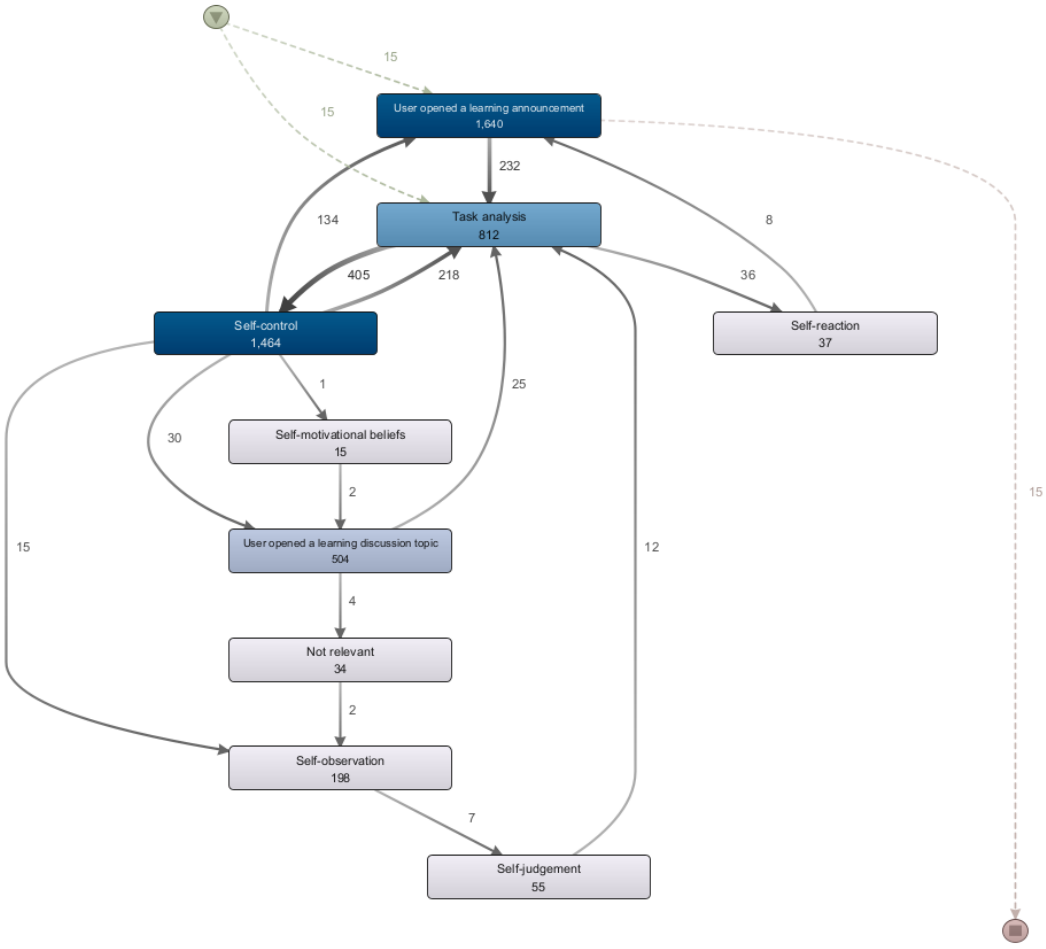


Figure 5 Less successful students' learning paths

The model for successful students includes 14 activities, 32 cases, and 5701 events, whereas the model for less successful students 14 activities, 33 cases, and 5041 events. The models of successful students and less successful students both contain 11 main events categories (self-control, self-motivational beliefs, open learning discussion, self-observation, task analysis, self-reaction, open learning announcement, self-judgment, and not relevant). I set the parameter with activities at 60% and paths at 0% to accommodate the minimum number of activities and the minimum number of paths for my analysis. Then I removed "started conference" and "joined conference" to simplify the models.

Figures 6 and 7 show the two learning paths with main event categories and their process connections. Events are outlined by the rectangular nodes, which include the events' name and their Absolute frequency (the number of times each event appears). Arcs between categories show progressive events and their repetition (the number displays the number of times this process happens). The color-coding and weighted paths also represent their frequency. In addition, all the less significant events were removed from the models (this feature depends on the parameter setting and filter mode).

As SRL theory promotes, one can see in figures 6 and 7 that successful students and less successful students show a variety of SRL activities (self-control, self-motivational beliefs, task analysis, self-observation, self-reaction, self-judgment). Users opened learning announcements with the highest frequency in both models, 36.52% in successful group and 34.15% in less successful group.

Successful students show high frequencies of task analysis (which are *User opened a study plan announcement, User opened a study plan discussion topic, User opened a quiz*), self-motivational beliefs (which are *User replied a study plan discussion, User submitted a study plan assignment, User submitted an action plan assignment*), self-observation (which are *User submitted an assignment, User replied a learning discussion topic, User replied to a learning announcement*), self-reaction (which is *User attempt quiz again*), and self-judgment (which are *User replied a reflective discussion topic, User submitted a reflective assignment*). Interestingly,

successful students displayed more self-observation events (n = 259; f = 4.85%), which also refers to a high degree of interaction with instructors. This result is consistent with Garrison (2005), which noted that online learners who perceive a high degree of interaction with instructors and their peers tend to get higher learning outcomes than those who showed a low degree of interaction. In this case, self-observation is also mainly connected with self-control, task analysis, and self-judgment. “User opened learning announcement” and “user opened learning discussion topic” are primarily connected to self-control. Moreover, there is a double loop with Task analysis, Self-control, Self-observation, and User opened a learning discussion topic. This loop shows a cyclical process between the forethought phase and performance phase in Zimmerman’s model of ideal SRL (2000). The self-reflection activities also come after self-observation and task analysis in successful students’ paths.

Less successful students, although they show the same types of event categories but in less number of events, and different sequences. From the fig 6, there are more self-control activities (n = 1,464; f = 30.49%) which are mainly connected to task analysis (n = 812; f = 16.91%). The loop between self-control and task analysis is significant in less successful student’s learning paths. Whereas successful students tend to open learning announcements after self-reflective activities, less successful students jump among task analysis, open learning announcements, and self-control. This might show how they are uncertain in their learning navigation.

In general, the resulting models for successful and less successful students show the same type of activities but in different flow and frequent. There was a very high degree of connection between task analysis and self-control events, which indicates that the online platform's role, in this case, focuses on doing task activities. Besides, no evidence was found on how self-reflective activities affect the forethought phase in the next round of SRL cyclical.

6. Discussion

This study aimed to analyze students' self-regulated learning process in a learning management system employing the process mining method. Previous research showed that there are different types of data collected in SRL research applying various analytical techniques. Many studies relied on self-report instruments to operationalize regards of SRL, such as the Motivated Strategies for Learning Questionnaire (Pintrich, Smith, Garcia, & McKeachie, 1993); however, this method may fail to capture the small details of the learner's SRL throughout their adaptation process (Zimmerman 2008). Computer tracing learning, thus, appears as an alternative way to investigate the cyclical nature of self-regulated learning (Hadwin, Nesbit, Jamieson-Noel, Code, & Winne, 2007). Moreover, the researchers' perspective has turned from SRL, implying an aptitude to study events during learning (Bannert, Reimann, & Sonnenberg, 2014a; Winne et al., 2006), to prove the advantage of learning events in reflecting self-regulated learning process.

Besides exploring differences in frequencies of self-regulated learning events, I also want to dive deeper into the learning paths through the lens of self-regulated learning theory and the application of data-driven analytics. The study investigates the temporal sequence of events generated during the learning process to understand how students navigate their learning in the online management system. In general, process mining on the learning behavior between two groups reviews a remarkable difference in the frequencies but slightly in flow. For the teachers and educators, while raising learners' awareness of self-regulated learning strategies, they should consider leading the course in a way that allows learners to optimize SRL skills.

The present results are also significant in at least four respects. The most prominent finding to emerge from the analysis is that successful students showed more learning and self-regulatory events than less successful students, which is in line with Bannert (2013). This also confirms the corresponds between successful learning with the frequency of regulatory learning activities (Moos & Azevedo, 2009), especially in

hypermedia, where students are more required to be proactive in their constructive knowledge process (Pintrich, 2000).

Related to self-observation events, in particular, successful students employed more self-observation learning activities in online courses. They connected these activities with self-judgment, task analysis, and self-control events, highlighting the interconnection among forethought, performance, and reflection phases in Zimmerman's cyclical model (2000). In contrast, the less successful students' model executed limited self-observations events and showed a weak relationship with self-judgment events as well as having no connection with any forethought activities. This finding confirms the observation from Zimmerman and Schunk (2001), regarding the necessary of self-observation in reflection.

Another important finding was that less successful students, who performed less self-motivational belief activities, tend to wander among task analysis, open learning announcements, and self-control. A possible explanation for this was mentioned in a study on the relationship between the forethought phase and self-regulation failure, in which the quality of the forethought phase impact the way students guide their learning (Cosnefroy, Fenouillet, Mazé, & Bonnefoy, 2018). Moreover, less successful students often start their learning progress without creating their action plan, which causes them to struggle in learning navigation.

The high frequencies in task analysis and self-control events with their strong connection reviewed the role of the online platform in the first outbreak of the pandemic in Vietnam. It shows that online learning is still in the early stage, which focuses mainly on delivering and doing tasks rather than communicating and interacting to construct knowledge. Even though online learning has been proposed since a decade before the pandemic, it did not capture the attention from educational institutions until the Covid-19 (Maheshwari, 2021). Consequently, Vietnamese teachers and educators had no choice but to facilitate learning via the online platform without preparation. This issue also calls for the training requirement within the online mode integrated with previous teacher training program for educators in the near future.

7. Conclusion:

The present study aimed to explore how students regulate their learning differently in online courses, between successful students and less successful students, through the lens of self-regulated learning theories.

In forethought and performance phases, the successful group presented theoretical similarities with Zimmerman's model of ideal SRL (2000), while the less successful group had little explicit relation to self-regulated learning theory. Likewise, successful groups executed more self-reflection activities than less successful groups, especially in self-reaction, which connected with being willing to try the test again. Moreover, the ways students regulating through the hypermedia setting were enormously influenced by the learning design. Thus, implementing learning strategies reasonable in a suitable learning context may help teachers and educators effectively enhance their students' learning.

7.1 Implications

This study explores how students regulated their learning differently, which influent their learning performance during the online learning mode. The concept of self-regulated learning has shown its essential role in any learning environment. This provides effective strategies in specific learning phases and supports learners in their lifelong learning path. Likewise, the theories suggest how teachers and educators can help learners design learning activities connecting with these theoretical frameworks.

Many studies show that, although the practice of self-regulated learning strategies can help students enhance their learning, they are not naturally conscious about their learning situation. This highlights teachers and educators' essential role in giving their students a greater sense of self-regulated learning when designing the learning environment.

7.2 Limitations

One of the issues that emerge from these findings is the difficulty in reasoning the paths as well as the absence of evidence on how self-reflective activities affect the forethought phase in the next round in the cyclical self-regulated learning model. Although process mining techniques might help explore sequence events and their connections generated from the learning management system, they cannot present the causal explanation. Despite this limitation, the methodology suggests a way to analyze student's navigation following self-regulated learning theory.

Another weakness in this study that could affect the visualization of learning paths was the inclusion of the testing phase in the data set. The log data from the study included the testing phase, where students got familiar with the learning management system. Therefore, more irrelevant events needed to be filtered.

The study also had a small sample with only 65 cases, which affects statistical power analysis. In addition, the small sample does not allow minor SRL events to display on the learning paths. Besides, the data set failed to capture the student's attitude over the courses. The research needs to be validated with a number of suggestions in future investigations.

7.3 Suggestions for further research

In this study, student's behavior in online learning management systems was analyzed with the process mining method, which aimed to explore how successful students and less successful students regulate their learning pathways differently. Despite these promising results, the findings from the research have thrown up one more question related to the coding scheme for self-regulated learning in the online learning environment. Further investigation is necessary to align learning theories with actual behaviors in specific learning situations and learning environments to validate the coding scheme. So that further analysis can be undertaken to investigate the way students regulate in hypermedia context.

Moreover, the study should be repeated using a larger sample to ensure the reliability of the research. Also, multimodal data, integrating log data with other types

of data, such as video or self-reflective data, are expected to capture the student's attitude over the courses in future research.

8. Evaluation

8.1 Reliability and validity

The adopted methodology is valid as it follows learning analysis methodology and applies process mining techniques when analyzing data. This study also has a firm theoretical foundation as it is established based on self-regulated learning as the theoretical framework.

Coding scheme was created using theory-based intervention within the conceptual framework of self-regulated learning. The initial scheme was coded from a systematic review over 14 articles. Following the definition of each learning category, the activities and examples for each event generated from the learning management system were also provided. The final coding scheme comprised 17 items with a clear description of each coded category. In order to test the evaluation of the coding scheme, the Cohen Kappa test was employed. The agreement between two coders is 63.6%, which is moderate, according to Fleiss (2013).

Table 4: Cohen Kappa test

Symmetric Measures

		Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance
Measure of Agreement	Kappa	.636	.040	22.721	.000
N of Valid Cases		172			

8.2 Ethical issues

The log data was collected automatically during the time participants experience their online learning in the LMS. The policies from the Cohota LMS allow

using this collected information from users for research purposes, including submission, browser, operating system, IP address, domain name, and timestamps. In this study, to guarantee privacy and confidentiality, the participants were anonymized and identified by ID code (Jurczyk & Xiong, 2009).

The data was also stored securely in a personal laptop. Similarly, password protection was used during the research conducting process, and access was also restricted to this study.

The results have been reported according to finding from the current study. Also, method and analyzing processes is based on the methodological and ethical perspectives of research implementation.

References

Applefield, J. M., Huber, R., & Moallem, M. (2000). Constructivism in theory and practice: Toward a better understanding. *The High School Journal, 84*(2), 35-53.

Azevedo, R., Cromley, J. G., & Seibert, D. (2004). Does adaptive scaffolding facilitate students' ability to regulate their learning with hypermedia? *Contemporary Educational Psychology, 29*(3), 344-370.

Azevedo, R., & Hadwin, A. F. (2005a). No title. *Scaffolding Self-Regulated Learning and metacognition–Implications for the Design of Computer-Based Scaffolds,*

Azevedo, R., & Hadwin, A. F. (2005b). No title. *Scaffolding Self-Regulated Learning and metacognition–Implications for the Design of Computer-Based Scaffolds,*

Bannert, M., Reimann, P., & Sonnenberg, C. (2014a). Process mining techniques for analysing patterns and strategies in students' self-regulated learning. *Metacognition and Learning, 9*(2), 161-185.

Bannert, M., Reimann, P., & Sonnenberg, C. (2014b). Process mining techniques for analysing patterns and strategies in students' self-regulated learning. *Metacognition and Learning, 9*(2), 161-185.

Barnard-Brak, L., Paton, V. O., & Lan, W. Y. (2010). Self-regulation across time of first-generation online learners. *Alt-J, 18*(1), 61-70.

Bednar, A. K., Cunningham, D., Duffy, T. M., & Perry, J. D. (1992). Theory into practice: How do we link. *Constructivism and the Technology of Instruction: A Conversation, 8*(1), 17-34.

Bogarín Vega, A., Cerezo Menéndez, R., & Romero, C. (2018). Discovering learning processes using inductive miner: A case study with learning management systems (LMSs). *Psicothema,*

Boghossian, P. (2006). Behaviorism, constructivism, and Socratic pedagogy. *Educational Philosophy and Theory, 38*(6), 713-722.

Broadbent, J., & Poon, W. L. (2015). Self-regulated learning strategies & academic achievement in online higher education learning environments: A systematic review. *The Internet and Higher Education, 27*, 1-13.

Butler, D. L., & Winne, P. H. (1995). Feedback and self-regulated learning: A theoretical synthesis. *Review of Educational Research, 65*(3), 245-281.

Cerezo, R., Núñez, J. C., Rosário, P., Valle, A., Rodríguez, S., & Bernardo, A. B. (2010). New media for the promotion of self-regulated learning in higher education. *Psicothema, 22*(2), 306-315.

Chen, K., Jang, S., & Branch, R. M. (2010). Autonomy, affiliation, and ability: Relative salience of factors that influence online learner motivation and learning outcomes. *Knowledge Management & E-Learning: An International Journal, 2*(1), 30-50.

Choi, I., Land, S. M., & Turgeon, A. J. (2005). Scaffolding peer-questioning strategies to facilitate metacognition during online small group discussion. *Instructional Science, 33*(5), 483-511.

Corno, L. (2001). Volitional aspects of self-regulated learning. *Self-Regulated Learning and Academic Achievement: Theoretical Perspectives, 2*, 191-225.

Cosnefroy, L., Fenouillet, F., Mazé, C., & Bonnefoy, B. (2018). On the relationship between the forethought phase of self-regulated learning and self-regulation failure. *Issues in Educational Research, 28*

Dabbagh, N., & Kitsantas, A. (2004). Supporting self-regulation in student-centered web-based learning environments. *International Journal on E-Learning, 3*(1), 40-47.

Dabbagh, N., & Kitsantas, A. (2005). Using web-based pedagogical tools as scaffolds for self-regulated learning. *Instructional Science, 33*(5-6), 513-540.

Daloglu, A., Baturay, M., & Yildirim, S. (2009). Designing a constructivist vocabulary learning material. *Handbook of research on e-learning methodologies for language acquisition* (pp. 186-203) IGI Global.

Deci, E. L., & Ryan, R. M. (2012). Motivation, personality, and development within embedded social contexts: An overview of self-determination theory.

Deci, E. L., Vallerand, R. J., Pelletier, L. G., & Ryan, R. M. (1991). Motivation and education: The self-determination perspective. *Educational Psychologist, 26*(3-4), 325-346.

Dewey, J. (1986). (1986). Experience and education. Paper presented at the *The Educational Forum, , 50*(3) 241-252.

Dillenbourg, P., & Schneider, D. (1995). No title. *Collaborative Learning and the Internet,*

Elias, L. J., Bryden, M. P., & Bulman-Fleming, M. B. (1998). Footedness is a better predictor than is handedness of emotional lateralization. *Neuropsychologia, 36*(1), 37-43.

Ferla, J., Valcke, M., & Schuyten, G. (2010). Judgments of self-perceived academic competence and their differential impact on students' achievement motivation, learning approach, and academic performance. *European Journal of Psychology of Education, 25*(4), 519-536.

Fleiss, J. L., Levin, B., & Paik, M. C. (2013). *Statistical methods for rates and proportions* john wiley & sons.

Fosnot, C. T., & Perry, R. S. (2005). Introduction: Aspects of constructivism. *CT Fosnot (2005).Constructivism: Theory, Perspectives and Practice,* , 8-38.

Gagnon, G. W., & Collay, M. (2005). *Constructivist learning design: Key questions for teaching to standards* Corwin Press.

Garrison, D. R., & Cleveland-Innes, M. (2005). Facilitating cognitive presence in online learning: Interaction is not enough. *The American Journal of Distance Education, 19*(3), 133-148.

Goldie, J. G. S. (2016). Connectivism: A knowledge learning theory for the digital age? *Medical Teacher, 38*(10), 1064-1069.

Gulati, S. (2004). Constructivism and emerging online learning pedagogy: A discussion for formal to acknowledge and promote the informal.

Günther, C. W., & Van Der Aalst, Wil MP. (2007). (2007). Fuzzy mining–adaptive process simplification based on multi-perspective metrics. Paper presented at the *International Conference on Business Process Management,* 328-343.

Hacker, D. J. (1998). Self-regulated comprehension during normal reading. *Metacognition in Educational Theory and Practice,* , 165-191.

Hadwin, A. F., Nesbit, J. C., Jamieson-Noel, D., Code, J., & Winne, P. H. (2007). Examining trace data to explore self-regulated learning. *Metacognition and Learning, 2*(2-3), 107-124.

Hsiao, I. (2012). No title. *Navigation Support and Social Visualization for Personalized E-Learning,*

Hu, H., & Driscoll, M. P. (2013). Self-regulation in e-learning environments: A remedy for community college? *Journal of Educational Technology & Society, 16*(4), 171-184.

Hughes, M., & Daykin, N. (2002). Towards constructivism: Investigating students' perceptions and learning as a result of using an online environment. *Innovations in Education and Teaching International, 39*(3), 217-224.

Hung, D. (2001). Theories of learning and computer-mediated instructional technologies. *Educational Media International, 38*(4), 281-287.

Hung, D., & Nichani, M. (2001). Constructivism and e-learning: Balancing between the individual and social levels of cognition. *Educational Technology, 41*(2), 40-44.

Hung, M., Chou, C., Chen, C., & Own, Z. (2010). Learner readiness for online learning: Scale development and student perceptions. *Computers & Education, 55*(3), 1080-1090.

Ifenthaler, D., & Widanapathirana, C. (2014). Development and validation of a learning analytics framework: Two case studies using support vector machines. *Technology, Knowledge and Learning, 19*(1-2), 221-240.

Jonassen, D. H. (1991). Evaluating constructivistic learning. *Educational Technology, 31*(9), 28-33.

Jurczyk, P., & Xiong, L. (2009). (2009). Distributed anonymization: Achieving privacy for both data subjects and data providers. Paper presented at the *IFIP Annual Conference on Data and Applications Security and Privacy,* 191-207.

Kauffman, H. (2015). A review of predictive factors of student success in and satisfaction with online learning. *Research in Learning Technology, 23*

Kaye, C., & Volkers, E. (2007). Constructivism online: Vygotskian applications for 21st century learning in higher education. *Online education for lifelong learning* (pp. 99-121) IGI Global.

Koohang, A., & Harman, K. (2005). Open source: A metaphor for e-learning. *Informing Science, 8*

Lee, J. (2009). The Effects of Self-Regulated Learning Strategies and System Satisfaction Regarding Learner's Performance in E-Learning Environment. *Journal of Instructional Pedagogies, 1*

Lehmann, T., Hähnlein, I., & Ifenthaler, D. (2014). Cognitive, metacognitive and motivational perspectives on preflection in self-regulated online learning. *Computers in Human Behavior, 32*, 313-323.

Ley, K., & Young, D. B. (2001). Instructional principles for self-regulation. *Educational Technology Research and Development, 49*(2), 93-103.

Maheshwari, G. (2021). Factors affecting students' intentions to undertake online learning: an empirical study in Vietnam. *Education and Information Technologies,* , 1-21.

Martens, R., Gulikers, J., & Bastiaens, T. (2004). The impact of intrinsic motivation on e-learning in authentic computer tasks. *Journal of Computer Assisted Learning, 20*(5), 368-376.

Mishra, L., Gupta, T., & Shree, A. (2020). Online teaching-learning in higher education during lockdown period of COVID-19 pandemic. *International Journal of Educational Research Open, 1*, 100012.

Moos, D. C., & Azevedo, R. (2009). Self-efficacy and prior domain knowledge: to what extent does monitoring mediate their relationship with hypermedia learning? *Metacognition and Learning, 4*(3), 197.

Mukhtar, K., Javed, K., Arooj, M., & Sethi, A. (2020). Advantages, Limitations and Recommendations for online learning during COVID-19 pandemic era. *Pakistan Journal of Medical Sciences, 36*(COVID19-S4), S27.

North, S. (2019). Understanding Students' Self-Regulation in Asynchronous Online Learning.

Oliver, K. M. (2000). Methods for developing constructivist learning on the web. *Educational Technology, 40*(6), 5-18.

Pajares, F., & Schunk, D. H. (2001). Self-beliefs and school success: Self-efficacy, self-concept, and school achievement. *Perception, 11*(2), 239-266.

Panadero, E., & Alonso Tapia, J. (2014a). How do students self-regulate?: review of Zimmerman‟ s cyclical model of self-regulated learning. *Anales De Psicologia,*

Panadero, E., & Alonso Tapia, J. (2014b). How do students self-regulate?: review of Zimmerman‟ s cyclical model of self-regulated learning. *Anales De Psicologia,*

Panadero, E., & Alonso Tapia, J. (2014c). How do students self-regulate?: review of Zimmerman‟ s cyclical model of self-regulated learning. *Anales De Psicologia,*

Piaget, J. (1937). La construction du réel chez l'enfant.

Piaget, J. (1952). Jean Piaget.

Pintrich, P. R. (2000). The role of goal orientation in self-regulated learning. *Handbook of self-regulation* (pp. 451-502) Elsevier.

Pintrich, P. R., & De Groot, E. V. (1990). Motivational and self-regulated learning components of classroom academic performance. *Journal of Educational Psychology, 82*(1), 33.

Pintrich, P. R., Smith, D. A., Garcia, T., & McKeachie, W. J. (1993). Reliability and predictive validity of the Motivated Strategies for Learning Questionnaire (MSLQ). *Educational and Psychological Measurement, 53*(3), 801-813.

Reimann, P., Frerejean, J., & Thompson, K. (2009). Using process mining to identify models of group decision making in chat data.

Ryan, A. M., & Pintrich, P. R. (1997). " Should I ask for help?" The role of motivation and attitudes in adolescents' help seeking in math class. *Journal of Educational Psychology, 89*(2), 329.

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist, 55*(1), 68.

Schunk, D. H., & Zimmerman, B. J. (1997). Social origins of self-regulatory competence. *Educational Psychologist, 32*(4), 195-208.

Taylor, P. C., Fraser, B. J., & Fisher, D. L. (1997). Monitoring constructivist classroom learning environments. *International Journal of Educational Research, 27*(4), 293-302.

Tempelaar, D. T., Rienties, B., & Nguyen, Q. (2017). Towards actionable learning analytics using dispositions. *IEEE Transactions on Learning Technologies, 10*(1), 6-16.

Ültanir, E. (2012). An epistemologic glance at the constructivist approach: Constructivist learning in Dewey, Piaget, and Montessori.

Vygotsky, L. S. (1980). *Mind in society: The development of higher psychological processes* Harvard university press.

Wandler, J. B., & Imbriale, W. J. (2017). Promoting undergraduate student self-regulation in online learning environments. *Online Learning, 21*(2), n2.

Weiner, B. (1972). Attribution theory, achievement motivation, and the educational process. *Review of Educational Research, 42*(2), 203-215.

Weiner, B. (1985). An attributional theory of achievement motivation and emotion. *Psychological Review, 92*(4), 548.

Wigfield, A., Eccles, J. S., & Pintrich, P. R. (1996). Development between the ages of ll and 25. *Handbook of Educational Psychology, 148*

Williamson, W. D. (2010). Assessing constructivist elements in the online learning environment.

Winne, P. H. (2010). Improving measurement of self-regulated learning. *Educational Psychologist, 45*(4), 267-276.

Winne, P. H., Nesbit, J. C., Kumar, V., Hadwin, A. F., Lajoie, S. P., Azevedo, R., & Perry, N. E. (2006). Supporting self-regulated learning with gStudy software: The Learning Kit Project. *Technology Instruction Cognition and Learning, 3*(1/2), 105.

Zimmerman, B. J. (1989a). A social cognitive view of self-regulated academic learning. *Journal of Educational Psychology, 81*(3), 329.

Zimmerman, B. J. (1989b). A social cognitive view of self-regulated academic learning. *Journal of Educational Psychology, 81*(3), 329.

Zimmerman, B. J. (2000). Attaining self-regulation: A social cognitive perspective. *Handbook of self-regulation* (pp. 13-39) Elsevier.

Zimmerman, B. J. (2002). Becoming a self-regulated learner: An overview. *Theory into Practice, 41*(2), 64-70.

Zimmerman, B. J., & Bandura, A. (1994). Impact of self-regulatory influences on writing course attainment. *American Educational Research Journal, 31*(4), 845-862.

Zimmerman, B. J., & Cleary, T. J. (2009). Motives to self-regulate learning. *Handbook of Motivation at School, 247*

Zimmerman, B. J., & Kitsantas, A. (2005). The Hidden Dimension of Personal Competence: Self-Regulated Learning and Practice.

Zimmerman, B. J., & Moylan, A. R. (2009a). Self-regulation: Where metacognition and motivation intersect.

Zimmerman, B. J., & Moylan, A. R. (2009b). Self-regulation: Where metacognition and motivation intersect.

Zimmerman, B. J., & Pons, M. M. (1986). Development of a structured interview for assessing student use of self-regulated learning strategies. *American Educational Research Journal, 23*(4), 614-628.

Zimmerman, B. J., & Schunk, D. H. (2001). *Self-regulated learning and academic achievement: Theoretical perspectives* Routledge.

Zimmerman, B. J., & Schunk, D. H. (2011). *Handbook of self-regulation of learning and performance.* Routledge/Taylor & Francis Group.