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Exploring sequences of challenges and regulation in collaborative learning with
process mining methodology

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The present study investigated the sequential interplay between cognitive and emotional/motivational challenges and regulation in collaborative learning groups of two profiles, high and low performing groups. The 77 participants were students of higher education institution, who collaboratively worked on a computer-based simulation in groups of three. The video data of approximately 34 hours was coded on a fine-grained level. Sequential analysis was applied by means of process mining methodology. The results show that in both groups cognitive regulation (i.e., planning, monitoring, and controlling) has a strong sequential relationship with emotional/motivational regulation than cognitive challenges. Unlike low performing groups (LPGs), high performing groups (HPGs) triggered a strong sequential relationship between cognitive regulation and emotional/motivational regulation to tackle cognitive challenges. Moreover, the results reveal that both groups initiated a regulatory process of monitoring. However, for LPGs monitoring manifested more sequences of emotional/motivational challenges which deterred them to run a regulatory process of controlling. Whereas HPGs were active enough to not only monitor but also control their learning by applying different strategies to progress in the task. Regarding statistical analysis, no difference was observed between HPGs and LPGs in terms of duration and frequency of each coding category. In addition, the process models of both groups also demonstrate that one regulatory process (i.e., cognitive) could have more and stronger sequential relationship with other regulatory processes (i.e., emotion/motivation) than cognitive and emotional/motivational challenges. The current study establishes theoretical grounding to advance understanding about the sequential relationship between challenges and regulation in low and high performing collaborative groups. On the practical implication's front, it also provides empirical insights to develop pedagogical methodologies and designed tailored support to help collaborative groups deal with challenges by initiating regulatory processes to proceed in learning task.

Keywords: Challenges; Regulation, Sequential Relationship, Regulatory Process, Collaborative Learning; Process Mining

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1. Introduction

The growing globalization has urged us to look towards collaboration to tackle complex challenges, we confront (Järvelä et al., 2020). Collaborative learning is considered one of the vital skills to thrive in the 21st-century. Considering this, many education systems across the globe are adopting various pedagogical strategies such as constructive teaching methodologies involving inquiry-based learning, and problem and practiced-based learning to cope pupils with collaborative learning skills (Cukurova et al., 2018).

Empirical studies have shown that to succeed in collaborative learning, group members have to plan, monitor, control and evaluate their cognitive, emotional, motivational and behavioral aspects. This is coined as regulation of learning in the literature (Hadwin, Oshige, Gress, and Winne, 2010; Järvelä, Järvenoja, and Veermans, 2008; Volet and Mansfield, 2006). Understanding regulation of learning, especially in collaborative learning settings have been increased since it not only ensures joint knowledge construction but also copes learners to deal with different challenges (Malmberg et al., 2017).

In collaborative learning settings, learning happens in sequential nature. Sequential nature could be defined as an order of actions/events during collaborative learning, i.e., when and how learning processes take place, what comes after, which actions/events lead to another (Bannert, Reimann, and Sonnenberg, 2014). Unfolding the sequences of learning processes could reveal the sequentiality of regulatory processes in relation to different types of challenges in collaborative learning. It can help advance research on regulation of learning by revealing which regulatory process (i.e., planning, monitoring, and controlling) is more strongly related to a certain type of challenges in terms of sequences, which regulatory process help learners resolve the challenges, which sequential patterns between regulatory processes and challenges are consistent and lasting and which regulatory processes affect the subsequent learning process when the learners confront different types of challenges while proceeding towards learning goals (Malmberg et al., 2017).

Most of the studies in collaborative learning regarding sequences have mainly focused on regulatory processes. Malmberg et al. (2017) explored the sequential association between regulation and executive processes. Their study revealed a strong sequential relationship between planning and monitoring. In Schoor and Bannert's (2012) study, regulatory processes were investigated by the analysis means of process mining. The process models of low and high achieving dyads of Schoor and Bannert's (2012) study had no differences in terms of sequential relationships. Molenaar and Chiu (2014) studied the sequential relationship of regulatory processes. They found that planning was sequentially

related to low cognition, which was sequentially connected by high cognition. Chang et al. (2017) also studied regulatory processes. They found the sequential relationship of monitoring and reflecting with planning and executing in unsuccessful groups. Whereas successful groups of their study had the sequential association of monitoring and reflecting with exploring and understanding and representation and formulating.

Although the contribution of the above studies has advanced the theoretical understanding and methodological grounding regarding the sequential relationship of regulatory processes, there is a dearth of research investigating the sequential relationship of regulatory processes in association with different types of challenges in collaborative learning. There is empirical evidence that in collaborative learning settings, different types of challenges, such as cognitive, motivational, and emotional can emerge (Hadwin, Järvelä, and Miller, 2018). Besides, research has shown that groups in collaboration react differently to different types of challenges and situations (Barron, 2003; Schoor and Bannert 2012; Khosa and Volet, 2014, Chang et al., 2017; Paans et al., 2019a; Zheng, Xing, and Zhu, 2019). Their cognitive and regulative activities in collaborative learning also differ (Molenaar and Chiu, 2014).

Therefore, regulatory processes are needed to be initiated to not only tackle such challenges but also to attain learning goals (Järvelä et al., 2016; Järvelä, Malmberg et al., 2016; Järvelä, Kirschner et al., 2016). Hence, it is argued that investigating the sequential relationship between challenges and regulation is essential. Some studies though explored sequences of regulatory processes with challenges, have remained limited, first in terms of no categorization of collaborative groups in high and low performing groups, and second sequences of challenges were studied mainly in relationship with emotion regulation (Järvenoja et al., 2019). Cognitive regulation (i.e., planning, monitoring, and controlling) along with emotional/motivational regulation is yet to be explored in sequential relationship with cognitive and emotional motivational challenges in high and low performing collaborative groups.

Considering this, therefore, the current study advances Järvenoja et al.'s, (2019) study on two fronts; first it explores sequentiality of cognitive regulation in association with cognitive as well as emotional/motivation challenges. Second, it explores the phenomena by categorizing collaborative groups into two profiles (i.e., high and low performing). Considering the ongoing research in collaborative learning, it is argued that the current study would advance theoretical and methodological understanding and practically contribute to the field. Theoretically, understanding sequential patterns of regulatory processes in relation

to different types of challenges in collaborative learning can provide researchers with empirical insights to study and advance theory and establish solid theoretical grounding for advancing understanding of learner's regulatory behaviour while confronting challenges in collaboration. Methodologically, unlike other methodologies (i.e., lag sequential analysis, statistical discourse analysis) applied for investigating sequences, the state-of-art methodology, process mining in the current study would comprehensively unpack the sequential patterns not only between different variables but also recurrent pattern (sequential loop within) of variables. Exploring recurrent pattern could be helpful to broaden the theoretical understanding as the same regulatory behavior can be repeated over and over before switching to a different regulatory behavior. Moreover, this would provide in-depth insights into the sequences for further methodological advancement in the field. At a practical level, for educational technology developers, the sequential patterns between challenges and regulation in collaborative learning could provide grounding to develop supportive tools for scaffolding to foster regulation of learning in face of different types of challenges in collaborative learning. For teachers, the patterns can help them design pedagogical strategies, learning content and understand which types of challenges were resolved by learners, and in which types of challenges teachers should support learners to cope with the challenges and help collaborative groups to remain on joint task to succeed.

In sum, much is known about sequential relationships of regulatory processes in collaborative learning. However, detailed empirical evidence of the sequential relationship of regulatory processes with different types of challenges in categorized collaborative groups (i.e., high and low performing) is still scarce. To fill this significant research gap and support the argument above, the study aims to explore the sequential relationship between challenges and regulation in high and low performing collaborative learning groups.

The paper is structured as follows; first, it presents a theoretical approach towards collaborative learning and discusses the challenges and regulation that emerge during collaborative learning. Then, it highlights the sequential characteristics of regulation and present state-of-art research on understanding the sequentiality of group regulation in collaborative learning. Following, the study explains the approach towards process mining and its importance to advance an understanding of regulatory processes in relation to challenges in collaborative learning. Maintaining advantages of process mining, the study presents its importance and contribution to further empirical understanding about learning processes vis-à-vis different types of challenges and regulation. Then, it presents the methodology and the results. Thereafter, the study discusses the findings with the lens of the

theoretical framework of regulated learning and previous research in the field. The practical, theoretical and methodological implications of the study come after the conclusion. After that limitations and future studies are explained. The last section of the study highlights evolution, validity and reliability and ethical issues.

2. Literature Review

2.1 Collaborative learning

Collaborative learning settings have been proven fruitful for the enrichment of individuals' learning, for they provide opportunities for sharing and extending group members' understanding (Roscoe and Chi 2008; Sinha et al., 2015). However, a mere forming collaborative group of learners does not ensure successful learning (Kirschner and Erkens, 2013). Empirical studies suggest that the objectives of collaboration, construct new knowledge and enhance understanding, are challenging to attain (Kuhn, 2015). Successful collaboration depends on how individual members adjust themselves to determine mutual learning goals and put deliberate efforts to plan strategies to achieve their shared goals, monitor their progress and take initiative to control their learning (Ku, Tseng, and Akarasirworn, 2013).

Despite a willingness to regulate various aspects of learning and develop a mutual understanding of the shared tasks, there emerge various challenges during collaborative learning that learners have to cope with (Hadwin, Järvelä, and Miller, 2018). Different challenges in collaborative learning affect learning outcomes (Paans et al., 2019a). From the group cohesion's perspective, a challenging situation arises when individual learners confront with lack of interest in achieving shared learning goals and task, disdain collaboration (Blumenfeld, Rogat, and Krajcik, 2006; Järvelä, Järvenoja, and Veermans, 2008; Järvelä, Volet, and Järvenoja, 2010), face conflicting reactions from group members (Barron, 2003; Chiu and Khoo 2003; Zschocke, Wosnitza, and Bürger, 2016) or face lack of mutual harmony and understanding in a group (Khosa and Volet, 2014). Moving towards cognitive perspective, group members face a challenge of understanding the task or content, selecting strategies to focus and complete the task (Järvenoja, Näykki, and Törmänen, 2019; Näykki, et. al., 2014; Hadwin, Bakhtiar, and Miller, 2018). Moreover, negative affective reactions such as frustration, anxiety and different personal priorities, lack of self-efficacy are also other challenging situations (Järvenoja et al., 2019; Järvenoja, Volet, and Järvelä, 2013) that hinder learners succeed in collaborative learning.

2.2 Socially shared regulation of learning (SSRL)

Challenges urge learners to commence regulation (Hadwin et al., 2011). The emerging theoretical grounding of socially shared regulation of learning (SSRL) adequately explains regulation and core regulatory processes in connection with different types of challenges in collaborative learning (Järvelä et al., 2016). In regulation's perspective, SSRL involves

learners jointly share their understanding of the task, belief, and knowledge to initiate negotiation and plan strategies for regulation of individual as well as collective cognitive, emotional, motivational and behavioral aspects (Hadwin and Oshige, 2011; Järvelä and Hadwin, 2013; Järvelä et al., 2016). To succeed in collaborative tasks, learners have to focus their SSRL and accordingly regulate different aspects of learning such as cognition (i.e., using strategies, building task perfection), emotion and motivation (i.e., building a sense of willingness and interest to work collaboratively to meet the task requirement and maintaining social inclusiveness, coherence and socio-emotional balance) (Malmberg et al., 2015).

Regarding regulatory processes, SSRL explains how learners plan, monitor and control not only their joint learning but also establishing mutual understanding of the task and group cohesion to attain their collective learning objectives (Järvelä and Hadwin, 2013; Panadero and Järvelä, 2015). For instance, the regulatory process of monitoring could be involved by learners not only to meet task standards but also for collaborative progress and ensuring joint understanding of the task and its content (Kempler-Rogat, and Linnenbrink-Garcia, 2011).

With the lens of SSRL, different types of challenges trigger different forms of regulatory processes by influencing different individual and/or collective aspects (i.e., cognitive, emotional, motivational, and behavioral). Regulatory process of cognitive aspect could be observed when learners initiate planning by negotiating and explaining task understanding to each other, constructing shared perceptions about the task, articulate learning goals, set standards for the shared tasks and set the plan of actions needed to accomplish the task goals, which consequently affect their overall regulation and task performance (Hadwin, Järvelä, and Miller, 2011; Panadero et al. 2013). Besides, learners initiate monitoring process to ensure their collaborative learning progress, as well as each other's task understanding of the content (Kempler-Rogat, and Linnenbrink-Garcia, 2011) to make sure they are on track to attain learning goals. If the situation demands, the regulatory process of controlling takes place when learners apply different strategies, i.e., making outlines, doing a calculation, and structuring their environment. To ensure controlling of learning is cultivating beneficial outcomes, learners evaluate their learning outcome with the standards they set at the beginning of the task. Learners might make changes in their regulatory strategies to bridge the eventual gap between initial learning outcome standards and the final outcomes they secure (Panadero et al. 2013).

Deliberate influence on emotions under experience and emotion to express could be considered as emotion regulation (Järvenoja et. al., 2019). Moreover, challenges in

collaborative learning such as underestimating other's opinion, overruling, status centric interaction or when the expertise of one group member is overemphasized at the cost of other group member/s views also trigger emotional regulation (Ben-Eliyahu and Linnenbrink-Garcia 2013; Bakhtiar, Webster, and Hadwin 2018; Järvenoja, Järvelä, and Malmberg 2017; Näykki et al. 2014).

Learners apply different emotional regulatory strategies such as social reinforcement, attentional shift or deployment, and increasing awareness, (Järvenoja, et al., 2019; Näykki, et. al., 2014) to maintain a healthy environment of collaborative learning and achieve their mutual shared learning goals. Social reinforcement refers to purposefully draw attention from the emotionally challenging situation by creating a positive socio-emotional environment (Järvenoja, et al., 2019). Attentional shift or deployment posits to deliberately selecting a strategic way of attention in order to divert the attention from the situation (i.e., distraction) or to focus on positive aspects (features) of the situation (i.e., concentration) (Näykki, et. al., 2014). Lastly, increasing awareness indicates the awareness of expressing negative emotions and which provides group members with opportunities to regulate the negative emotions (Järvenoja, et al., 2019). For instance, asking each other whether they are feeling negative emotions could provide grounding for joint efforts to tackle factors behind negative emotions.

2.3 The sequential characteristics of regulation in collaborative learning

Collaborative learning is an interactive learning setting (Isohätälä et al., 2017). The group interaction formulates events of different types (i.e., cognitive, emotional/motivational) of challenges and regulations. These events are linked and influence each other in sequences that form paths of regulatory processes in relations to challenges in collaborative learning. These paths need to be unfolded to understand sequential patterns of different events in collaborative learning (Järvelä et al., 2016).

Unfolding the paths of challenges and regulatory processes in collaborative learning helps researchers to address certain challenging questions in educational research (Kapur, 2011) such as which type of challenges triggers regulatory processes, how do collaborative groups initiate planning and monitor their learning, how do they take initiatives and strategies to control their learning to meet the learning goals and how do they react or even not react to any specific challenge, which challenges or regulatory actions are more prominent and frequent in sequences (Bannert, Reimann, and Sonnenberg, 2014; Knight et al., 2017) and guide their learning by regulating cognitive, emotional, and motivational aspects at different

stages of learning.

As regulatory processes evolve in sequences, unpacking them has been challenging in the field of learning sciences and is considered helpful to improve the learning outcomes (Kapur, 2011). Considering this, some studies have investigated processes of regulation in collaborative learning from a sequential perspective (Schoor and Bannert 2012; Molenaar and Chiu, 2014; Chang et al., 2017; Malmberg et al., 2017; Järvenoja et al. 2019, Paans et al., 2019a). Järvenoja et al. (2019) captured the variables of cognitive, emotional and motivational challenges from video data of collaborative groups to explore their sequential relationship with emotion regulation strategies (i.e., encouragement, task structuring, social reinforcing and increasing awareness). Among different types of challenges, emotional and motivational challenges triggered more frequencies of emotional regulation. Regarding sequences, the authors found that cognitive challenges were more prominently followed by their repetitions and they were followed less frequently by emotional and motivational challenges. Their study revealed that emotional regulatory strategies such as social reinforcement and increasing awareness had a strong sequential relationship with social context and interaction and emotional and motivational challenges as compared to cognitive challenges. Process analysis of their study helped them found that regulation of emotional and motivational challenges could trigger cognitive challenges.

Malmberg et al. (2017) studied the sequential relationship between regulation and executive processes in collaborative learning. The authors captured planning and monitoring along with task execution from video data of collaborative learning. By applying lag sequential analysis, the authors found a strong relationship between planning and monitoring. Besides, they also found that socially shared monitoring fostered collaborative knowledge construction.

Chang et al., (2017) investigated sequential patterns of collaborative problem solving through the variables of exploring and understanding, representing and formulating, planning and executing, and monitoring and reflecting in successful and unsuccessful groups. Descriptive analysis of their study revealed that successful groups had higher frequencies of monitoring and reflecting than unsuccessful. Whereas unsuccessful superseded successful groups in terms of higher frequencies of planning and executing. By applying lag sequential analysis, they found that unsuccessful groups had “monitoring & reflecting/ planning & executing” in sequential patterns. Whereas successful groups had the sequential relationship between “monitoring & reflecting” with “representation & formulating” and “exploring & understanding”. Frequency-wise, successful groups

demonstrated more frequencies of “monitoring & reflecting” than unsuccessful groups. Unsuccessful groups, on the other hand, had higher frequencies of “planning & executing” as compared to successful groups.

Molenaar and Chiu (2014) utilized statistical discourse analysis (SDA) to track sequential patterns from collaborative learning activities of three categories (low, middle and high achievers) of groups. They examined groups’ activities in relation to sequences of cognitive, metacognitive and relational activities to understand their impact on lower cognitive activities (i.e., reading and information processing to acquire knowledge) and higher cognitive activities (construction of meaning). The authors found that low and high cognition affected each other and were in sequence to planning. Their study also revealed that monitoring helped collaborative groups to proceed and take “controlling actions”, i.e., planning and orientation to attain their goals. In their study, planning was in a sequential relationship with low cognition (reading and processing) which was followed by high cognition (meaning constructions).

Paans et al., (2019a) investigated regulatory processes of cognitive, metacognitive, relational and off-task activities from utterances of dyads in a high and low level of social challenge during hypermedia learning. In terms of frequency analysis, the authors found that cognitive processing and high cognition were more prominent for low challenge dyads than the high challenge dyads. Contrary, off-task activities were higher in frequency for high challenge dyads as compared to low challenge dyads. Through sequential analysis, the study found that low challenge dyads demonstrated high cognition, developing a unidirectional sequence from reading to processing and then to support. Besides, it discovered that high challenge dyads went off-task in a sequence related to challenge. Whereas, for low challenging dyads, the challenges led them towards processing and analyzing/evaluation. Moreover, low challenge dyads showed the position of social challenges between analysis and evaluation and cognitive processing. Their initiatives for monitoring were bi-directional and sequentially related to metacognitive activities. Whereas high challenge dyads’ process model demonstrated social challenges bi-directionally linked to off-task activities and monitoring was not in a sequential relationship with metacognitive activities.

Schoor and Bannert (2012), using process mining, explored regulatory processes in low and high achieving dyads. Among others, they investigated regulatory processes in exploring variables of planning, monitoring, evaluation and motivation. The authors could not compare the groups in terms of the frequency of the research variables. Their study could not find differences between the two categories of the groups in terms of frequencies of the

regulatory activities. Further, the process models of low and high achieving dyads had no differences.

One of the most recent studies, (Zhang et al., 2021) used epistemic network analysis (ENA) to examine types of regulation and regulatory patterns between high and low performing groups in three phases of online collaborative learning. They found higher frequencies of planning and monitoring in HPGs. By comparison two groups (i.e., high and low performing) of their study, proportionally both groups were similar in planning, monitoring and evaluating. Besides, their study also revealed that monitoring is quite critical in both groups. Further, they also found that positive and negative emotions were helpful for HPGs than LPGs. Last, ENA analysis helped them find that HPGs had a higher connection of monitoring with socio-emotional regulatory behavior.

Although the above studies unpacked the regulatory processes in a collaborative learning setting and contributed to the literature theoretically and methodologically, the studies mostly focused on regulation processes. They could not deal with the sequential relationship between challenges and regulatory processes. For instance, the recent study of (Zhang et al., 2021) though explored patterns of planning, monitoring socio-emotional in online collaborative learning, the sequential relationship of regulatory processes with challenges remains underexplored. Cognitive regulation in sequential relationship to challenges was not the scope of most of the studies (Schoor and Bannert, 2012; Molenaar and Chiu, 2014; Malmberg et al., 2017; Chang et al., 2017; Su et al. 2018; Paans et al., 2019a; Zhang et al., 2021). Moreover, some previous studies also could not provide empirical grounding for the pathways of regulatory processes of emotion/motivation in an association of cognition with emotional/motivational and cognitive challenges by categorizing collaborative groups into two profiles (i.e., high and low performing groups).

The groups were categorized in two profiles as the literature suggests that learners act and respond differently towards learning tasks and learning contexts as well as pedagogical consideration influence learners' regulatory behavior differently (Järvelä and Hadwin, 2013; Hadwin, Järvelä, and Miller, 2018; Zhang et al., 2021). Another reason for group categorization was to be consistent with recent research studies in regulated learning, which has been central to sequential analysis, have categorized groups in two profiles (i.e., high vs less successful and high vs low performing groups) (Chang et al., 2017; Su et al. 2018; Paans et al., 2019a, Zhang et al., 2021). Findings of regulatory actions of extreme groups in the wake of challenges during collaborative learning could have implications for designing tailored learning content, environment, and pedagogical methodologies to

maximize student learning outcomes. Therefore, further exploration of extreme groups (i.e., high, and low performing groups) was considered and seems necessary to broaden understanding of the key features in regulated learning processes (Zhang et al., 2021).

It is argued that there is a clear-cut research gap of sequentiality of cognitive regulation (i.e., planning, monitoring, and controlling) with challenges in collaborative learning. Besides, the literature on collaborative learning lacks empirical evidence of how high and low performing groups react and develop pathways of regulation in the wake of encountering different challenges. The regulatory process of emotional/motivational regulation with an association of cognitive regulation in sequential relationship to challenges is still underexplored in empirical research in the field of collaborative learning. Hence, it is argued that the current study bridges the research gap, mentioned above. First, it takes account of critical phenomena of cognitive and emotional/motivational challenges and regulations in face-to-face computer-supported collaborative learning. Second, the groups are categorized into two profiles, high and low performing groups. Although some studies have investigated the sequential relationship between challenges and regulation (Järvenoja et al., 2019), they do not provide an understanding of how challenges and regulations unfold in high and low performing groups.

Last, mostly regulation of learning has been captured through video coding of group interaction (Näykki, et. al., 2014; Järvenoja et al. 2019; Isohätälä, Näykki, and Järvelä, 2020; Mänty, Järvenoja, and Törmänen, 2020). Very often empirical studies apply time segmentation of 20 or 30 seconds (Isohätälä, Näykki, and Järvelä, 2020) or even 5 minutes (Sinha et al., 2015; Sullivan, and Wilson, 2015) to capture coding categories (i.e., research variables) from the interaction. This study, however, applies a fine-grained approach, a systematic procedure that helped to capture events/episodes of coding categories at a micro level, as short as one-second event/episode in which a combination of words such as “Oh my God!” was coded. In other words, the fine-grained approach enabled to code meaningful events/episodes from the starting and ending of words that were meaningful and related to the coding categories of this study. Hence, it is not unreasonable to argue that the current study empirically investigated sequential relationships between least-explored phenomena of cognitive and emotional/motivational challenges and regulation by bridging the research gap of previous studies and minimizing the limitation.

3. Aim and Objectives

The study aims to examine how cognitive and emotional/motivational challenges and regulations unfold in high performing groups (HPGs) and low performing groups (LPGs) in collaborative learning. Specifically, the study investigates pathways of the challenges and regulations in high and low performing groups during collaborative learning. The specific research questions are:

RQ1: Is there a difference between high and low performing groups in terms of the frequency and duration of challenges and regulation observed during collaborative learning?

RQ2: Is there a difference between high and low performing groups in terms of sequential pathways of their cognitive and emotional/motivational challenges and cognitive and emotional/motivational regulation?

4. Research Methods

4.1. Participants and the task

The participants (Mean age = 27.8; SD age = 5.43, female = 41; male = 33) were the students of the University of Oulu, Finland. They were enrolled in different international degree programmes, representing 35 different countries. The initial dataset included 77 participants. However, some groups had to complete the task in groups of two due to a participant not attending data collection or leaving the group before the task was over ($n=11$). Thus, the final dataset of 66 participants, consisting 22 groups (three participants in each group) were considered for conducting analysis.

A group of three participants was given a simulation of the Tailorshop task to work in collaboration. The Tailorshop task simulates complex a problem-solving scenario in which participants run a garment company (Danner, Hagemann, Schankin, Hager, and Funke, 2011). The participants are given a goal to raise the company's value as much as possible. There are 24 variables (e.g., store locations, shirt price, raw material cost, retail shop rent, employee wages) that directly and indirectly affect the company's value in the simulation. The group members are free to change the variables.

The simulation is designed into two phases: exploration and performance. In the first phase of exploration, the participants run the company for six simulated months to better acquaint themselves with the simulation and relationship between the variables and the company's value. In the second phase of performance, simulation restarts from the beginning for twelve simulated months. It keeps a record of all changes in the variables including the company's value. After each month, the company's value is displayed in relation to changes made in the variables during the month.

4.2. Data Collection

Social media posts and flyers distribution at the university campus were the channels to recruit the participants. Each participant was compensated with a free lunch ticket in exchange for participation. Since the participation was completely voluntary, all the participants were free to withdraw from the study at any time.

The video data collection took place at Leaf research infrastructure (<https://www.oulu.fi/leaf-eng/>) at the University of Oulu, Finland. Leaf is a state-of-the-art infrastructure, equipped with adaptable equipment and particularly designed for research in collaborative learning. Leaf was portioned into three soundproof rooms to collect video data from three groups simultaneously. Participants provided information about their availability

for specific time and day. Their limited availability could not enable the researchers to assign all of them randomly to groups. Hence, participants were assigned to groups according to their specific time and day of availability. Before their arrival to recording rooms, the participants were requested to fill consent forms and then introduced to their team members. In each room, group members seated in front of a table with a desktop computer, equipped with a touchscreen. Before the simulation started, the participants were given instructions about how to accomplish the group task in the simulation.

4.3. Data Analysis

4.3.1. Categorization of high and low performing groups

In the tailorshop, collaborative groups' performance was calculated by analyzing trend scores of the company's values in each month (Danner et al., 2011). An increase in the company value was considered a collaborative groups' success. Hence, the trend score was calculated by summing the number of each month, in which the groups added the company's value. As the simulation consisted of twelve months, the trend scores could range between zero to twelve. Cluster analysis was applied to classify high and LPGs considering their trend scores. Specifically, by using the trend scores in order to categorize the groups, K-mean clustering was used. Trends score below five was considered as low performance and above as high performance. Table 1 shows the trend scores for each group in each categorization.

4.3.2. Analysis procedure

The actual duration of video data of twenty-two groups was approximately 36 hours and 45 minutes. However, the total duration of coded data (i.e., the start of the instructions of the task till the simulation was finished) was around 34 hours. The coding scheme (see Table 2) was developed based on prior research studies (Toni Kempler Rogat and Lisa Linnenbrink-Garcia 2011; Ucan and Webb, 2015; Järvenoja, et al., 2019) considering SSRL theoretical framework.

The data was analyzed by capturing research variables of the study; cognitive challenges and regulation and emotional/motivational challenges and regulation, and evaluation from the utterances of the participants (Heirweg et al., 2020). Each captured event was applied to group level (Mänty, Järvenoja, and Törmänen, 2020; Järvenoja et al., 2019). Some studies used segmentation of 20-s, 30-s (Isohätälä, Näykki, and Järvelä, 2020) and even 5-min (Sinha et al., 2015; Sullivan, and Wilson, 2015). Instead of applying a time-segmented window, I applied a fine-grained approach to focused on meaningful sentences

first. Then I captured the starting and end of the combination of words (utterances) that were related to the research variables of this study (Heirweg et al., 2020). This approach enabled me to capture as short as one second of challenge or regulation events.

Table 1

Trends scores of groups in high and low performing groups.

Categorization of groups	Groups	Trend scores
HPGs	Two	8
	Four	10
	Six	5
	Nine	9
	Ten	8
	Eleven	7
	Twelve	7
	Eighteen	9
	Twenty	6
	Twenty-one	10
	Twenty-four	10
	Twenty-six	6
LPGs	Three	0
	Seven	2
	Eight	3
	Thirteen	0
	Fourteen	1
	Fifteen	0
	Sixteen	4
	Nineteen	1
	Twenty-two	0
	Twenty-five	0

Table 2

Scheme of coding categories applied for the video data

Category name	Definition	Examples
Cognitive challenge	A cognitive challenge was coded when group members' utterances were related to facing a problem in understanding the task or content, choosing effective strategies to complete the task and focusing on task (Järvenoja, et al., 2019; Näykki, et. al., 2014; Hadwin, Bakhtiar, and Miller, 2018).	<i>"maintenance! I don't know"</i> <i>"I have the question as well, I don't know"</i> <i>"This is something we don't know"</i> <i>"But we don't know what is the relationship"</i>
Emotional/motivational challenge	An emotional/motivational challenge was coded when group members' utterances were related to negative emotions such as annoyance, anxiety, or frustration or faced problems in overcoming them. Lack of self-efficacy, interest, and difference in personal priorities and respective goals were also considered emotional/motivational challenges (Järvenoja et al., 2019, Järvenoja, Volet, and Järvelä, 2013).	<i>"Oh shit, this is gonna be so complicated"</i> <i>"Shirt stock is zero, I don't like that"</i> <i>"What the hack is this?"</i> <i>What's wrong, oh my God!"</i>
Cognitive regulation planning	A cognitive regulation planning was coded when group members' utterances were associated with understanding the task or content, coordinating and clarifying conditions about the task, selecting/suggesting effective strategies/actions and setting goals to complete the task, or reading and interpreting the task directions and engaging with the task or content (Toni Kempler Rogat and Lisa Linnenbrink-Garcia 2011).	<i>"Just get some workers first"</i> <i>"Decrease the number of machines we need"</i> <i>"What if we do it, I mean slowly"</i> <i>"How many workers do you want?"</i>
Cognitive regulation monitoring	A cognitive regulation monitoring was coded when group members' utterances were related to recording/tracking of their performance, noting/checking their progress or results, and	<i>"In the first month, I lowered the wage and we ordered 300 hundred more, right?"</i>

	<p>monitoring own or group members' mutual understanding of the task content or learning were coded as monitoring (Ucan and Webb, 2015).</p>	<p><i>"Raw material price eight, its doubled"</i></p>
		<p><i>"Customers interested, it has slowed down"</i></p>
		<p><i>"We sold a lot more shirts this month"</i></p>
		<p><i>"I start writing down because I will follow [makes calculations]"</i></p>
Cognitive regulation controlling	<p>A cognitive regulation controlling was coded when group members' utterances were associated with controlling of their performance of the task. By controlling performance, group members' forecast/prediction or designing or figuring out a strategy such as doing calculation, making outlines, taking picture of screen, making mind-map etc were coded as controlling.</p>	<p><i>"Can we take a picture of this?"</i></p>
		<p><i>"If we buy if we get store we will lose and, yah we don't have[money]"</i></p>
		<p><i>"I am gonna take a [screenshot]"</i></p>
		<p><i>"Don't worry about it"</i></p>
		<p><i>"I am happy because we figured out this one relationship there"</i></p>
Emotional/motivational regulation	<p>An emotional/motivational regulation was coded when group members' utterances were related to regulation of negative feelings such as encouraging each other that they can do the task (Järvenoja, et al., 2019), conveying awareness of their negative emotional experiences, praising and complementing to each other and conveying awareness of their motivational experiences (Ucan and Webb, 2015).</p>	<p><i>"Good job, we stocked up"</i></p>
		<p><i>"I think that's fine you know I am interested in too many products and"</i></p>
		<p><i>"I need a number man then I can see how successful we are"</i></p>
		<p><i>I think it would if we kept retail to we didn't change anything else then perhaps yah but yah its okey, we learn a lot"</i></p>
Evaluating	<p>An evaluating was coded when group members' utterances were related to evaluation of overall learning processes and outcomes, i.e., evaluating/reviewing the group's overall learning in the task (Ucan and Webb, 2015).</p>	

4.3.3. Inter-rater reliability

To enhance the reliability of the data analysis, coding categories/scheme and criteria were elaborated, discussed with examples, and agreed on with a panel of researchers who have extensive experience in SSRL research. To ensure consistency of the coding, a researcher was invited to code three random groups from the dataset. The researcher has a vast understanding of the theoretical grounding of challenges and regulation in collaborative learning. Under the light of the coding scheme, video data was coded by the researcher. The inter-rater reliability between the two researchers was checked by calculating the kappa value of three random groups' video data. The total duration of the three groups in minutes was approximately 294 minutes. The percentage of the three groups' video data was 13.6 compared to the whole dataset.

The inter-rate reliability coding achieved acceptable Cohen's kappa(K) values for all coding variables which are presented in Table 3 (Fleiss, 1981). I omitted the inter-rater reliability for the evaluation coding category since only one event was captured in each category of the groups.

Table 3

Cohen's Kaapa (K) values of all coding categories

Variables	Group 1	Group 2	Group 3
Cognitive challenge	0.89	0.72	0.75
Cognitive regulation planning	0.65	0.59	0.58
Cognitive regulation monitoring	0.64	0.63	0.57
Cognitive regulation controlling	0.59	0.65	0.69
Emotional/motivational challenge	0.66	0.87	0.93
Emotional/motivational regulation	0.65	0.90	0.91

4.3.4 Comparison of HPGs and LPGs in terms of frequency and duration of challenges and regulation

To compare both categories of the groups, I calculated minimum, maximum, mean, standard deviation, and time-weighted scores from the absolute frequencies of each coding category. Moreover, I also calculated time duration (seconds) spent by HPGs and LPGs on each coding category. I calculated two types of time-weighted scores: time-weighted frequency and time-weighted duration. For time-weighted frequency, the absolute frequency of each coding category was divided by whole group task time duration (seconds), separately for each group in HPGs and LPGs. Whereas time-weighted duration was calculated by dividing the total duration of each coding category to the whole group task time, separately for each group in HPGs and LPGs. The coding category of the evaluation was excluded because it occurred

once in both groups.

I conducted Mann-Whitney U tests to analyze the overall frequencies, duration (seconds), time-weighted frequencies and time-weighted duration of each of the coding category. Mann-Whitney U tests were conducted to thoroughly investigate whether there were significant differences between HPGs and LPGs in terms of frequencies and duration of each coding categories. I applied Mann-Whitney U test instead of independent samples t-tests due to the small sample size of the groups in the current study. Second, Mann-Whitney U test is a nonparametric test and allows researchers to compare two independent samples with less likely to have a Type II error (Huck, 2008). T-tests are conducted when there are at least fifteen groups/participants in each category of the groups/participants (Ziegel, 1989).

4.3.5. Process mining analysis

Event log data was formed from video coding data which was run through the R package “BupaR” for visualizing sequences of coding categories (Janssenswillen et al., 2019). BupaR package plots process map to help understand insightful sequences between events. Figure 3 and 4 present the process models of absolute frequency of coding categories in high and low performing groups. The process maps demonstrate two elements. First, the boxes represent the absolute frequencies of events that occurred during the group learning. Second, Connections or paths (arrows) are bidirectional which displays sequences among events. The *play* sign indicates the starting of the process and the *stop* sign indicates the ending. Unidirectional arrows, which originates and follows the same coding category is known as a recurrent pattern (sequential loop within). It indicates that the category has occurred in consecution (i.e., in succession).

Like Disco and ProM, process mining with BupaR package enables researchers to unpack learning processes by visualizing the interpretability of events and paths, ranging from 1 to 100 per cent of the events that occurred. Events are visualized based on two parameters: significance and correlation. It depends on the researchers to determine the percentage of events and paths to obtain in the process models (Van der Aalst 2011). Significance posits the relative importance of events and paths. Whereas correlation refers to including those major paths which are closely connected to events (Günther and van der Aalst, 2007).

Hence, similar to other studies (Heirweg et al., 2020; Sonnenberg, and Bannert, 2015; Paans et al., 2019a) I retain only those events and paths in process models of high and low performing groups (see figure 3 and 4) which were more significant; more frequently occurred and correlated and closely connected events. In educational research, there are not

any fixed criteria for retaining the percentage of events and paths in the process model (Heirweg et al., 2020). To avoid complexity and present significantly important correlation, absolute frequencies of events and paths are displayed in the process models by following the general guidelines (Fluxicon, 2019).

5. Results

5.1 RQ1: Is there a difference between high and low performing groups in terms of the frequency and duration of challenges and regulation observed during collaborative learning?

Table 4 presents the results of descriptive statistics of frequencies of each coding category in HPGs and LPGs. Altogether 5720 and 4409 events were observed in HPGs and LPGs, respectively. The absolute frequency of cognitive regulation (i.e., planning, monitoring, and controlling) was the most prominent figures in both categories of the groups. Among all variables, planning occurred the most in both groups. The absolute frequency of planning was 2416 and 1875 in HPGS and LPGs, respectively. Regarding duration, it was the most time spending regulatory strategy in both groups. Table 5 shows a descriptive analysis of duration (seconds) high and low performing groups spent on each coding category.

Monitoring occurred second to planning with an absolute frequency of 2219 in HPGS and 1688 in LPGs. In terms of duration, it was the second most time-consuming coding in both groups. The frequency of controlling was similar to the proportion of events that occurred in both groups. Due to fewer events of controlling as compared to planning and monitoring in both groups, it occupied less duration on the part of HPGs and LPGs.

Moreover, Cognitive challenges had the least values of absolute frequency. Table 4 shows 230 events of cognitive challenges in HPGs and 192 in LPGs. Besides, the duration of cognitive challenges was in proportion to their absolute frequency for both groups.

Regarding the frequencies of emotional/motivational challenges, LPGs faced 111 and HPGs 75. Since there were fewer frequencies of emotional/motivational challenges, table 5 shows that HPGs spent 86 seconds confronting them. LPGs faced emotional/motivational challenges for 127 seconds.

As compared to cognitive regulation (i.e., planning, monitoring, and controlling), emotional/motivational regulation was less observable in terms of frequency and duration. The frequency of emotional/motivational regulation in HPGs was 105 and 38 for LPGs. Duration in seconds for emotional/motivational regulation was spent in proportion to its frequencies by both groups, as can be seen in table 4.

Table 4

Frequency statistics of coding categories in high and low performing groups

	HPGs						LPGs					
	Absolute frequency	Relative frequency	Min	Max	SD	Mean	Absolute frequency	Relative frequency	Min	Max	SD	Mean
Cognitive challenge	230	0.0402	5	58	15.68	19.16	192	0.0435	3	36	11.45	19.2
Cognitive regulation planning	2416	0.4223	128	323	49.58	201.33	1875	0.4252	55	298	73.22	187.5
Cognitive regulation monitoring	2219	0.3879	117	280	48.37	184.91	1688	0.3828	54	303	73.29	168.8
Cognitive regulation controlling	674	0.1178	10	135	36.17	56.16	504	0.1143	1	132	37.64	50.4
Emotional/motivational challenge	75	0.0131	0	24	6.92	6.25	111	0.0251	0	31	11.62	11.1
Emotional/motivational regulation	105	0.0183	0	10	7.11	8.75	38	0.0086	0	11	3.82	3.8
Evaluating	1	0.0001	0	1	0.28	0.08	1	0.0002	0	1	0.31	0.1

Table 5

Duration (seconds) statistics of coding categories in high and low performing groups

	HPGs						LPGs					
	Absolute duration (seconds)	Relative duration (seconds)	Min	Max	SD	Mean	Absolute duration (seconds)	Relative duration (seconds)	Min	Max	SD	Mean
Cognitive challenge	254	0.0091	7	60	17.42	21.16	200	0.0107	3	40	12.49	20
Cognitive regulation planning	11312	0.4093	323	1401	296.84	942.66	7600	0.4066	149	1248	353.29	760
Cognitive regulation monitoring	10015	0.3623	359	1366	331.99	834.58	6573	0.3516	145	1096	326.13	657.3
Cognitive regulation controlling	5831	0.2109	44	1172	368.62	485.91	4131	0.2210	2	1096	350.26	413.1
Emotional/motivational challenge	86	0.0031	0	28	8.39	7.16	127	0.0067	0	36	12.91	12.7
Emotional/motivational regulation	136	0.0049	0	25	9.00	11.33	43	0.0023	0	15	4.73	4.3
Evaluating	3	0.0001	3	3	0.86	3	17	0.0009	17	17	5.37	17

Table 6

Mann-Whitney U values of absolute frequency and duration (seconds) of coding categories in high and low performing groups

	Absolute frequency		Time duration (seconds)	
	Mann-Whitney U	P	Mann-Whitney U	P
Cognitive challenges	54	.692	57.5	.869
Cognitive regulation planning	53.5	.668	43	.262
Cognitive regulation monitoring	51.5	.575	39	.166
Cognitive regulation controlling	52	.598	54	.692
Emotional/motivational challenges	45	.320	45	.320
Emotional/motivational regulation	34.5	.091	32	.063

Table 7

Mann-Whitney U values of time-weighted frequency and time-weighted duration of coding categories in high and low performing groups

	Time-weighted frequency		Time-weighted duration (seconds)	
	Mann-Whitney U	P	Mann-Whitney U	P
	U		U	
Cognitive challenges	46.5	.373	47	.391
Cognitive regulation planning	36	.114	57	.843
Cognitive regulation monitoring	33	.075	60	1
Cognitive regulation controlling	47	.391	60	1
Emotional/motivational challenges	41.5	.222	41.5	.222
Emotional/motivational regulation	36.5	.212	39.5	.175

The Mann-Whitney U test was applied to analyze frequencies and duration (seconds) as well as time-weighted frequency and time-weighted duration of six coding categories to check whether there is difference between high and low performing groups in terms of frequencies and duration of coding categories. Table 6 and 7 do not show a statistically significant difference in any of the frequencies and duration time-weighted frequency and time-weighted duration of six coding categories between the groups. The coding category of evaluating was excluded since it occurred once in both groups.

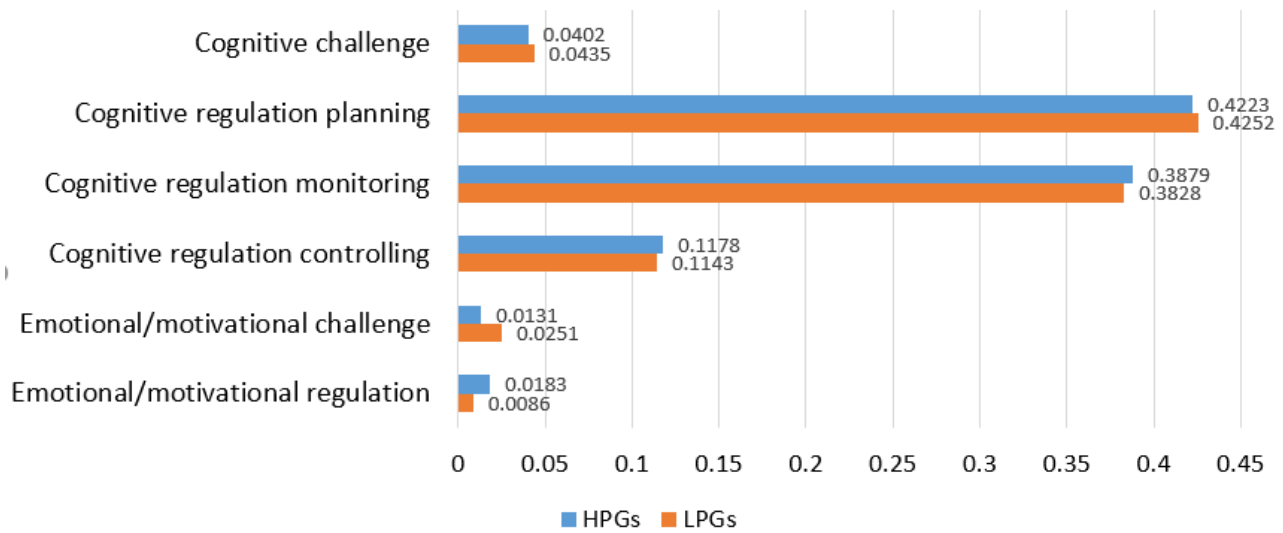


Figure 1. Relative frequencies of absolute frequencies of coding categories occurred in HPGs & LPGs.

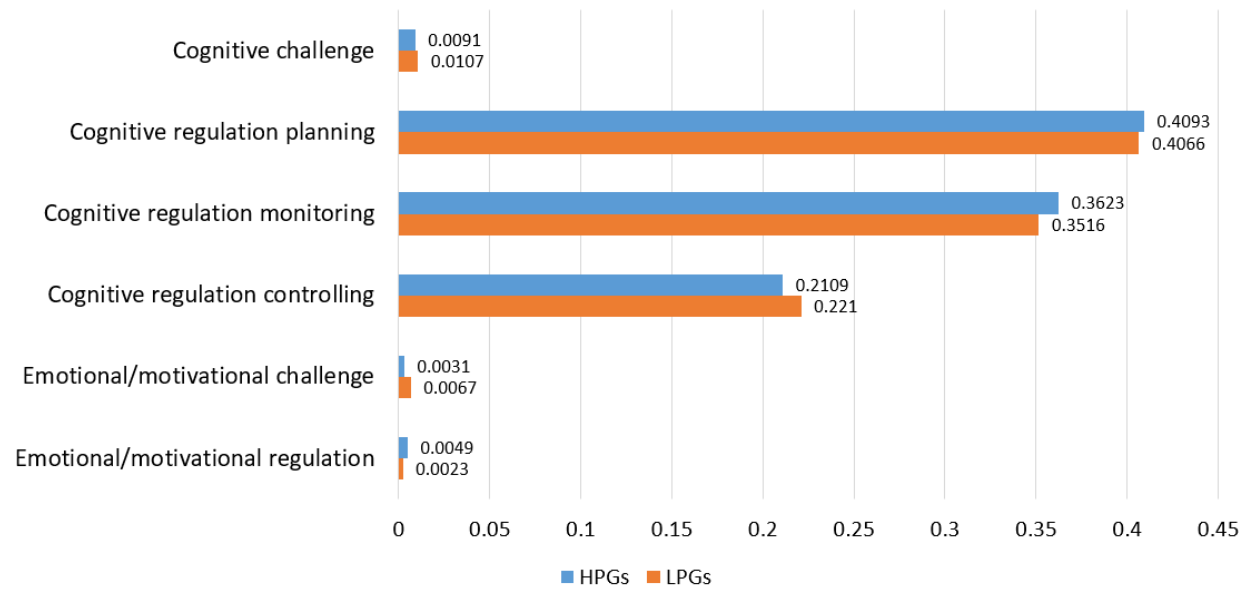


Figure 2. Relative frequencies of duration (seconds) HPGs and LPGs spent in each coding category.

5.2 RQ2: Is there a difference between high and low performing groups in terms of sequential pathways of their cognitive and emotional/motivational challenges and cognitive and emotional/motivational regulation?

Although the processes models (see figure 3 and 4) of high and low performing groups show almost similar pathways of starting from cognitive regulation (i.e., planning) they differ in subsequential pathways between challenges and regulations.

The major differences were found between the sequential relationship between cognitive regulation (i.e, planning, monitoring, and controlling) and emotional/motivational regulation in both categories of the groups. HPGs switched more between cognitive regulation (i.e., planning, monitoring, and controlling) and emotional/motivational regulation as compared to LPGs.

The sequential relationship of planning with emotional/motivational regulation was stronger in HPGs, as their process map shows 30 and 26 frequencies of pathways. In LPGs, on the other hand, sequential pathways between planning and emotional/motivational regulation were weak, 9 and 6 were the frequencies of pathways, which can be observed from their process maps.

Similarly, HPGs frequently switched more between monitoring and emotional/motivational regulation, 51 and 43 was the frequency values of the sequences, whereas in the same pathways LPGs could not switch more, as it is observed from their process model that they switched half of the number (22 and 24) as compared to HPGs.

LPGs did not establish a stronger sequential relationship of emotional/motivational regulation with controlling. They witnessed frequencies of 2 and 4. HPGs, however, showed more patterns of a sequential relationship between controlling and emotional/motivational regulation. They established the pathways at the frequencies of 10 and 15.

Regarding recurrent pattern (sequential loop within), HPGs showed proportionally greater sequences, 13 in emotional/motivational regulation as well as planning, 1319, monitoring, 1115 and controlling, 144. LPGs, on the other hand, had less frequencies of recurrent patterns in emotional/motivational regulation, 1 as well as planning, 1020 monitoring, 850 and controlling, 103.

The sequences between emotional/motivational challenges and cognitive regulation (i.e., planning, monitoring, and controlling) were occurred differently in terms of patterns in HPGs and LPGs. LPGs, compared to HPGs, established stronger sequential pathways between planning and emotional/motivational challenges with the pathways' frequency of 35 and 32. HPGs, contrary, transit less in terms of frequency (22 and 18) between

emotional/motivational challenges and planning.

Similarly, in the face of emotional/motivational challenges, the process model of LPGs shows more pathways (43 and 48) between monitoring and emotional/motivational challenges. HPGs, in the same situation, had comparatively fewer pathways. As far as controlling in the wake of emotional/motivational challenges is concerned, LPGs show more sequences than HPGs.

As mentioned above, the recurrent patterns (sequential loop within) of planning, monitoring, and controlling are proportionally higher in HPGs than LPGs. However, recurrent patterns (sequential loop within) of emotional/motivational challenges are more than double in terms of frequency in LPGs, 11) than HPGs, 5. The stronger pathways of planning, monitoring and controlling with emotional/motivational challenges in LPGs could be justified in front of the fact that LPGs faced higher frequency, 111 of emotional/motivational challenges than in HPGs who confronted less frequency, 75.

Regarding the sequential pathways between cognitive challenges and cognitive regulation (i.e., planning, monitoring, and controlling) the process models of both groups show similar patterns proportionally. Even recurrent patterns (sequential loop within) of cognitive challenges are almost similar in both groups. The sequential relationship between emotional/motivational challenges and emotional/motivational regulation are also quite similar in both groups.

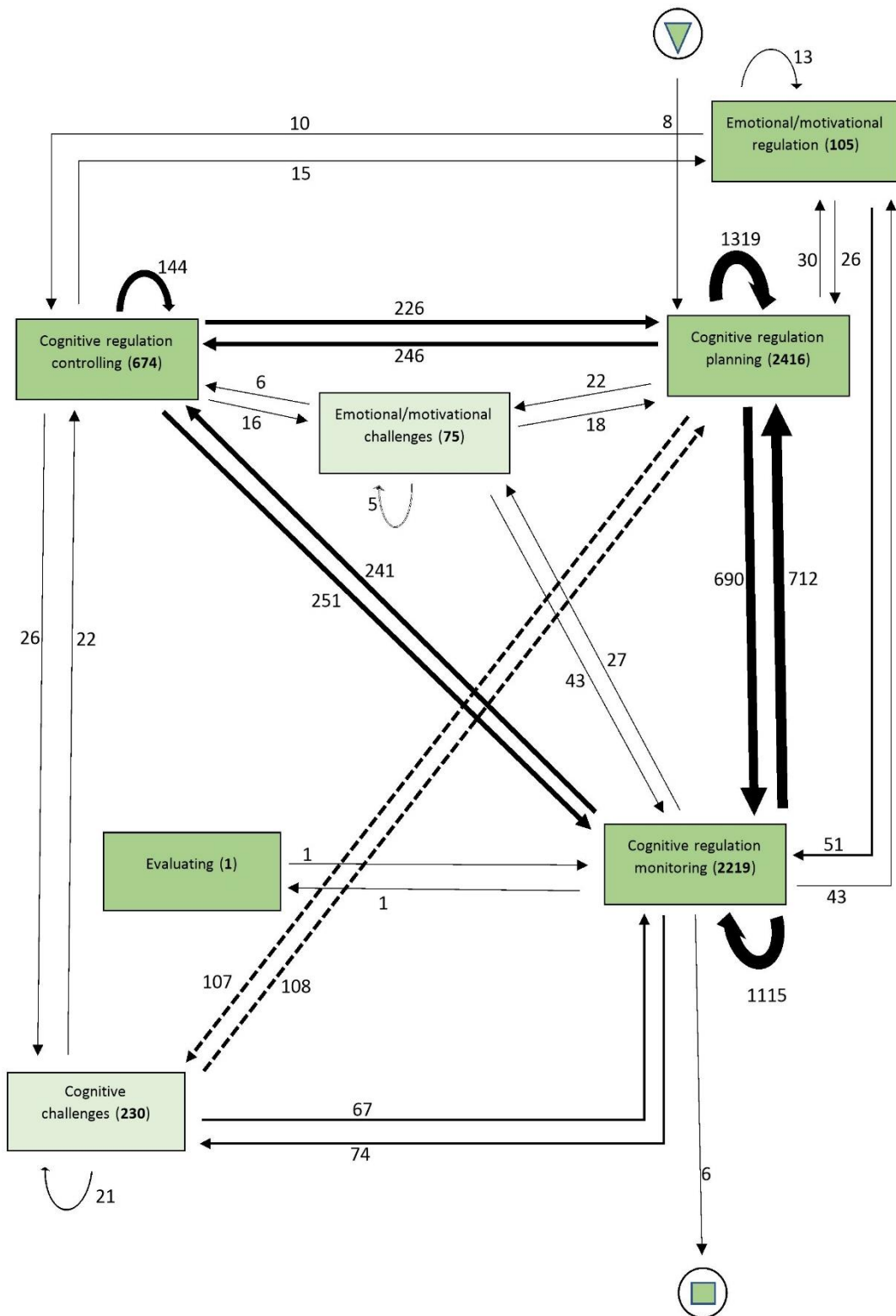


Figure 3. Process Model of HPGs showing pathways/sequential relationship of coding categories (boxes) and bidirectional paths (arrows). The paths (arrows) refer to the sequence in which events were occurred and their thickness indicates the stronger relationship between the events (boxes). The dashed paths are made unique just to show they interact with other paths. The number on the paths refers to the absolute frequency of the research variable.

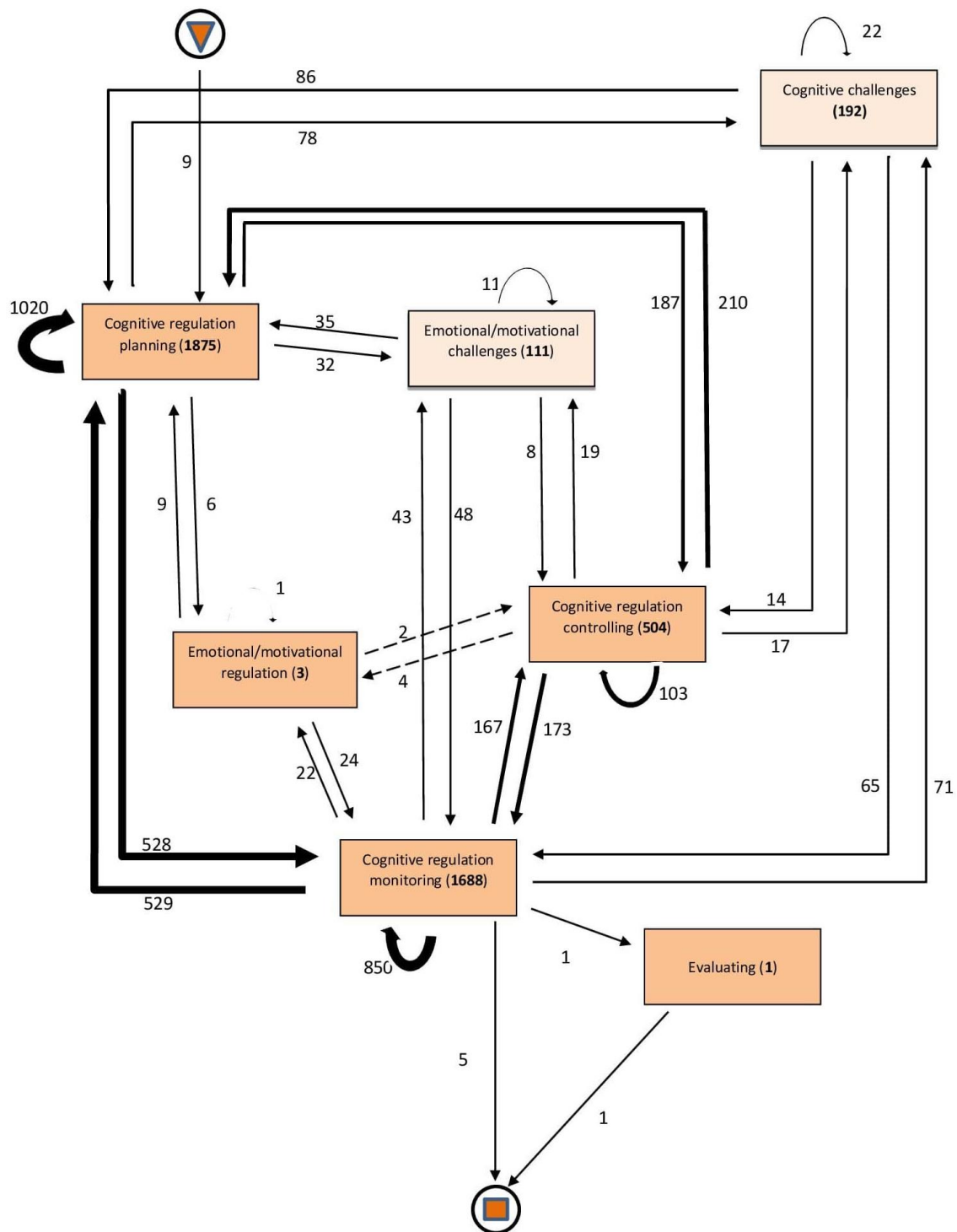


Figure 4. Process Model of LPGs showing pathways/sequential relationship of coding categories (boxes) and bidirectional paths (arrows). The paths (arrows) refer to the sequence in which events were occurred and their thickness indicates the stronger relationship between the events (boxes). The dashed paths are made unique just to show they interact with other paths. The number on the paths refers to the absolute frequency of the research variable.

6 Discussion

Research has put forward evidence of the benefits of regulatory learning processes in collaborative learning (Malmberg et al., 2017). Nevertheless, studies have not fully explored how these processes in sequential connection with challenges unfold in high and low performing collaborative groups. Therefore, the study examined the interplay between cognitive and emotional/motivational challenges and regulation in high performing and low performing collaborative groups in terms of frequency, duration and sequential relationship.

I was interested in whether there is a difference between high and low performing groups in terms of the frequency and duration of challenges and regulation observed during collaborative learning. Several Mann-Whitney *U* tests were conducted. Table 6 and 7 show that none of them revealed statistically significant differences between high and low performing groups in terms of frequency and duration of each coding category. Research often does not yield statistically significant difference between coding categories captured in two profiles of learning groups. For instance, by applying Fisher's exact test, Schoor and Bannert, (2012) found no statistically significant difference of frequencies of coding categories (social regulation - planning, monitoring, and coordination, and motivation - positive, negative and regulation of motivation) between successful and less successful groups. Moreover, some of the research variables (monitoring, evaluation, reading, and supporting) in Paans et al., (2019a) could not differ statistically in terms of their frequencies. The research study of Bannert, Reimann, and Sonnenberg, (2014) also faced almost the same fate and could not reveal statistical differences of some of the coding categories (orientation, searching, planning, monitoring, and evaluating) in terms of frequencies. As far duration is concerned, Malmberg et al., (2017) applied Mann-Whitney *U* tests to find a difference between duration spent on planning, monitoring, and task execution by three profiles of groups. To large extent, their study could not reveal a statistical difference in coding categories between the groups. The above studies could not find statistical differences between two profiles of groups (i.e., high vs low performing) in terms of frequencies. However, the following research studies did find differences.

Su et al., (2018) found statistically significant differences between HPGs and LPGs in terms of frequency analysis of regulatory behavior of planning, monitoring, evaluating, and positive emotions. The researchers found that HPGs had higher frequencies of planning, monitoring, and positive emotion than LPGs. However, both groups had almost similar frequencies of evaluating. Chang et al., (2017) also found significant results in differences between successful and unsuccessful groups in terms of frequencies of planning and

executing, monitoring, reflecting. Chang et al., (2017) found that unsuccessful groups had more frequencies of planning and executing than successful ones. However, successful groups manifested more frequencies of monitoring and reflecting. Zhang et al., (2021) found significant results of frequency analysis in terms of the difference between two groups (HPGs and LPGs). The authors found that while HPGs exhibited a higher frequency of content monitoring than LPGs, LPGs showed a noticeably higher frequency of task understanding. In addition, HPGs also superseded LPGs in terms of higher frequency of positive emotion and organizing.

In some perspectives, the current study is parallel with those studies which did not find any difference between two profiles of groups (i.e., high vs low performing groups or successful vs unsuccessful groups) in terms of frequencies. First, Bannert, Reimann, and Sonnenberg, (2014) found that successful groups manifested more frequencies planning, monitoring and motivation. The findings of the current study are quite similar as HPGs showed a higher frequency of planning, monitoring and emotional/motivational regulation. Second, the study of Paans et al., (2019a) shows that low challenge dyads (similar to HPGs) manifested higher frequencies of cognitive aspects and lower frequencies of challenges with a higher quality of assignments than high challenge dyads (similar to LPGs). To large extent, these findings of Paans et al., (2019a) sustain HPGs' higher frequencies of cognitive regulation, less frequency of challenges and better performance during the tailor shop task as compared to LPGs. Last, Bannert, Reimann, and Sonnenberg, (2014) revealed that fewer successful groups demonstrated less frequencies of metacognitive activities (i.e., planning, monitoring, orientation, and evaluation) than successful groups. The current study's findings that HPGs show a higher number of frequencies planning and monitoring are consistent with the frequency results of Bannert, Reimann, and Sonnenberg, (2014).

In short, it is argued that success in collaborative learning is not solely determined by how much, how long or how frequently regulation is manifested. It is about sequential associations between challenges and regulation. As we can observe, the above studies could not find statistical significance between the group of learners in term of frequencies of coding categories, nevertheless, they have unpacked the black box of learning processes and advanced theoretical and methodological understanding by examining regulatory processes in different types of collaborative groups (i.e., successful vs less successful). Therefore, this study could also be considered similar to them as it furthers understanding in collaborative as well as SSRL theoretical and methodological framework by unfolding sequential relationship between challenges and regulation, discussed below.

Calculation of duration spent on different types of challenges and regulatory processes has not been a scope of many studies even though the studies captured their research variables from utterances (Sinha et al., 2015; Sullivan, and Wilson, 2015; Järvenoja et al., 2019; Isohätälä, Näykki, and Järvelä, 2020; Mänty, Järvenoja, and Törmänen, 2020). The coding granularity was different in those studies to this study. Thus, the current findings might not be compared with the previous study.

Bannert, Reimann, and Sonnenberg, (2014) applied process mining methodology. They discussed that they could not consider quantitative temporal aspects. In other words, it was not the scope of their study to count the duration of events, they captured for the analysis. Taking this into account and as I the applied fine-grained approach to capture the research variables from utterances of the groups, I found it appropriate to further analysis by calculating duration in seconds.

I found no significant result of duration analysis. Considering this into account, the current study further found that even duration of regulation does not affect the performance of collaborative groups. In other words, success or failure in collaborative learning is not determined by how much time learners spend regulating their learning by initiating different regulatory processes. Regarding the duration of challenges and regulation, the higher the number of each coding category in terms of absolute frequency, the more duration was spent on it by HPGs and LPGs.

I was also interested to explore whether is there a difference between high and low performing groups in terms of sequential pathways of their cognitive and emotional/motivational challenges and cognitive and emotional/motivational regulation. The process models of both categories of the group show different pathways of the sequential relationship of regulatory processes with cognitive and emotional/motivational challenges. The result is contrary to Schoor and Bannert (2012). The process models of low and high achieving dyads in their study had no differences in terms of sequential relationships of planning, monitoring, evaluation and motivation.

However, the results of sequential analysis of this study corroborate the sequential analysis results of Su et al., (2018). The authors found a statistically significant difference between high and low performing groups in terms of sequential patterns of planning, monitoring, evaluating, positive and negative emotions. Su et al., (2018) revealed that low performing groups confronted more challenges in achieving an understanding of the task. From the light of this study's coding, it implies that low performing groups in Su et al., (2018) faced cognitive challenges. The process model of low performing groups of this study

also supports this finding by showing stronger sequentiality of cognitive challenge. Su et al., (2018) found that HPGs had more sequential links between different regulatory processes (i.e., social-emotional regulation and monitoring). To large extent, this finding is parallel to the sequential analysis finding of this study that, unlike low performing groups, HPGs along with cognitive regulation (i.e., planning, monitoring, and controlling) activity run the regulatory process of emotion/motivation to counter challenges.

Research suggests that students' use of regulation processes such as planning has been an important factor to not only deepen an understanding in collaborative learning (Kempler-Rogat, and Linnenbrink-Garcia, 2011), but also could be a predictive factor of performance during collaborative (Janssen, Erkens, Kirschner, & Kanselaar, 2012). Moreover, theories of regulation of learning posit that learners initiate planning not only for task understanding and clarifying the learning conditions including learners' perceptions about the task and its content to begin with learning task but also design roadmap to attain learning goals (Kempler-Rogat, and Linnenbrink-Garcia, 2011; Malmberg et al., 2017). Under this theoretical context, it can be deduced that HPGs might have realized to purposefully run regulatory processes of planning since the process models show HPGs had switched more between cognitive challenges and planning as compared to LPGs. LPGs, however, could not initiate planning to encounter cognitive challenges. The reason behind it could be that LPGs might have a lack of awareness of when to take initiatives of planning to proceed and deal with the challenges.

Both groups had almost similar patterns between monitoring and cognitive challenges. It indicates that LPGs had quite a similar understanding as that of HPGs to initiate the regulatory process of monitoring to check their performance during the task. Although research indicates that information gathered from monitoring help learners decide and choose actions for controlling (Molenaar and Chiu, 2014), when faced with cognitive challenges, LPGs fell short in coming up with new plans to improve their task performance. Research shows in collaborative learning learners need to respond while facing challenges (Isohätälä, Näykki, and Järvelä, 2020). Besides, challenges can also create room for regulation of cognitive aspects. However, LPGs were unable to cope with cognitive challenges and that might have deterred their performance during the task.

Regarding taking the initiative to control their learning in face of cognitive challenges, HPGs showed more strong relationship of controlling with cognitive challenges. LPGs, on the other hand, figured out fewer strategies to tackle cognitive challenges and improve their performance during the task. Research has revealed that in collaborative

learning, students are unable to recognize a demand or an opportunity to regulate learning (Järvenoja, Järvelä, and Malmberg, 2017). However, the case of LPGs can only substantiate it, as they were pretty less aware of controlling their learning in the face of cognitive challenges. But HPGs adopted regulatory processes of controlling effectively. They recognized the need for regulation and applied strategies to overcome cognitive challenges. Besides, it is witnessed that monitoring usually leads to control activities (Molenaar and Chiu, 2014). Both groups had almost similar patterns of monitoring with cognitive challenges. Nonetheless, it is the process model of HPGs, not LPGs that shows a stronger sequential relationship of controlling with cognitive challenge. Poor monitoring on the part of LPGs could be the reason behind lack of sequentiality between cognitive challenges and controlling in their process model, as literature shows poor monitoring deters learners to approach controlling activities (Molenaar and Chiu, 2014).

Observing the recurrent patterns (sequential loop within), proportionally both groups exhibit similar patterns in planning, monitoring, and controlling. However, LPGs faced more recurrent patterns (sequential loop within) of cognitive challenges than HPGs. The reason could be that LPGs, as discussed earlier, though monitored their performance yet could not initiate regulatory processes of controlling to tackle cognitive challenges. In other words, they could not come up with effective regulatory strategies to tackle the challenges. They look somehow trapped in the challenges and keep repeating the challenges than getting over them. Hence, lack of controlling might lead LPGs to face constant more recurrent patterns of cognitive challenges than HPGs.

The theoretical framework of regulated learning maintains that shared planning helps learners develop a shared understanding of the task and its content (Ucan and Webb, 2015). Since compared to HPGs, LPGs established a less sequential relationship of planning with cognitive challenges, it could have caused a lack of shared understanding of the task, leading to constant trigger in cognitive challenges. Further, as discussed earlier, LPGs.

The results of recurrent patterns of cognitive challenges in both groups contrast with Järvenoja et al., (2019). The researchers found the most prominent recurrent patterns of cognitive challenges and different types of challenges (i.e., emotional, motivational, social context and interaction) following each other rather than regulatory processes of emotion regulation. In this study, sequential paths between cognitive and emotional/ motivational challenges are not only significantly rare but also similar with no interesting insight. Hence, I omitted them from the process models of both categories of the groups. Challenges consequently following each other and developing recurrent patterns in research the study of

Järvenoja et al., (2019) could be because the collaborative groups might have failed to identify which specific challenges they were facing. For research has established that collaborative groups have to accurately recognize a challenging situation that might deter them in collaboration to design strategies in order to tackle the challenges (Malmberg et al., 2015). Hence, it led them not to come up an exact constructive regulatory strategy to tackle the challenges. For instance, cognitive challenges such as difficulty in understanding the task or each other thinking and perception of the task and its content or difficulty in negotiating diverse perspectives of group members about the tasks (Kirschner, Beers, Boshuizen, & Gijselaers, 2008), might have led them to motivational challenges such as clash in having different goals, expectations and priorities within the group regarding joint group activities to proceed the task (Blumenfeld, Marx, Soloway, & Krajcik, 1996; Järvelä, Järvenoja, & Veermans, 2008; Rogat, Linnenbrink-Garcia, & DiDonato, 2013). Moreover, these challenges might have triggered socio-emotional challenges such as conflicting interpersonal dynamics (i.e., lack of communication, overruling, clash in interacting styles cycle (Barron, 2003; Näykki, et. al., 2014). Hence, these constant challenging situations might have caused a cycle of challenges as could be seen in the process model.

The process analysis of Järvenoja et al., 2019 also revealed that regulation of any type of challenge could lead to cognitive challenges. It indicates the more they initiated regulation in the face of challenges the more it led them to face cognitive challenges. However, the current study did not find regulation of any type of challenges lead to cognitive challenges. There could be several reasons behind this difference. One of them could be that overall cognitive regulation had much more events in terms of frequency in both groups than cognitive challenges. Another, in Järvenoja et al., 2019 focused was one regulatory aspect (i.e., emotion), though their study cognitive challenges were also captured and analyzed. Whereas the current study focused on cognitive and emotional/motivational regulations. The process models of both groups witness that in the wake of challenges, not only cognitive but also emotional/motivational regulatory processes were triggered. Therefore, the potential to face recurrent patterns of challenges or sequentiality within them diminished in this study.

In concluding sequential relationship between cognitive challenges and regulation (i.e., planning, monitoring, and controlling), although in confronting cognitive challenge, both groups proportionally switched to cognitive regulation in a quite similar way, HPGs along with cognitive regulation developed a slightly more sequential relationship with the regulatory process of emotion/motivation than LPGs. Research has emphasized the importance of emotional regulation in successful collaboration (Näykki, et. al., 2014;

Järvenoja et al., 2019). Where there is emotion regulation, collaborative groups apply regulation strategies, formulate joint perceptions through observation and interpretation of emotional response, which fosters inclusion, diminish socio-emotional conflict and generate a healthy environment to progress in the task (Bakhtiar, Webster, and Hadwin, 2018; Järvenoja, Järvelä, and Malmberg 2015; Kwon, Liu, and Johnson 2014). Moreover, group-level emotion regulation help learners collaborate in synchrony, which leads to socially shared regulation of learning Järvenoja et al., 2019. Through the lens of this theoretical perspective, it is argued that HPGs were quite aware of the challenging situation (cognitive in this case) and hence they triggered socially shared regulation of learning by initiating regulatory processes of emotion/motivation while facing the cognitive challenge.

Moreover, it also demonstrates that's HPGs were not applying only one form of regulatory process (cognitive regulation) rather they were active to tackle cognitive challenges with different regulatory strategy (emotional/motivational). This result parallels with Zheng and Yu (2016). The authors explored the behavioral patterns in computer-supported collaborative learning (CSCL) and found that high achievers are more consistent in implementing regulatory strategies such as monitoring the performance, forming strategies to control group progress, goal setting etc. to attain their learning goals.

It was striking to observe that emotional/motivational challenges generated stronger and more sequential pathways in relationship with cognitive regulation (planning, monitoring, and controlling) than emotional/motivational regulation in both groups. Both groups might have found the context and situation to initiate regulatory processes of cognition rather than emotion/motivation to tackle emotional/motivational challenges. Research has shown that initiating regulatory processes depends on the context and the tasks (Winne, 2014) and the need for that specific situation (Järvenoja et al., 2015, 2018). Further, research has also shown that in collaborative learning regulation of cognitive aspects are more prominent than emotion regulation (Kwon et al., 2014; Ucan and Webb, 2015). Besides, from this finding, it can be deduced that in the context of this study, emotional/motivational challenges might be related to cognitive processes during the collaboration. Emotional/motivational challenges can be observed as outcomes of failing in the task rather than socio-emotional conflicts among the group members. Thus, emotional challenges led group members to focus on cognitive regulation rather than emotional/motivational regulation.

Surprisingly, the connection between emotional/motivational challenges and regulatory processes of planning, monitoring and controlling was pretty much stronger in

LPGs than HPGs. LPGs initiated more, almost double of sequential pathways between planning and emotional/motivational challenges as compared to HPGs. Literature suggests that less successful groups often do not figure out the effective strategy to deal with the challenges and progress in the task rather they stick to the approach of trial-and-error (Hong and Liu, 2003; Beheshitha et al., 2015; Chang et al., 2017). The case of LPGs corroborates in the light theoretical grounding, as they go back and forth frequently between planning and emotional/motivational challenges because they failed to design an effective strategy to improve their progress during the task. In other words, it seems that LPGs failed to tackle the task, then faced emotional/motivational challenge after that they plan a strategy, which could not work then they again faced emotional/motivation challenge. Similar results were found in (Beheshitha et al., 2015). The authors found that surface learners (similar to LPGs) could not come up with an effective strategy rather stick to trial-and-error approach to proceed in the task. Heirweg et al., (2020) also found that high achievers (HPGs in this study) more frequently adopt strategies than low achievers (LPGs). Hence, the finding that a stronger sequential relationship between planning and emotional/challenges in the process model of LPGs confirms earlier research.

Both groups have an almost similar sequential path from emotional/motivational challenge towards monitoring. It means both groups while monitoring their learning processes encountered emotional/motivational challenges with almost similar sequentiality. Contrary, the process model of LPGs shows almost double paths from monitoring to emotional/motivational challenges. It could be because LPGs become aware of their lack of progress during the task which paved the way for emotional/motivational challenges within the group. Consequently, they developed stronger pathways from monitoring to emotional/motivational challenges. These results are parallel with the findings of (Zhang et al., 2021). The authors found that HPGs were more active to generate a pattern of monitoring and simultaneously maintained a positive emotional environment to progress in the task.

To some extent, this finding is contrary to what Paans et al., (2019b) had found and assumed that less successful learners in their research, struggled to realize when they had to monitor their learning. In the current study, it is argued that LPGs knew when to monitor their learning, for they consistently developed more sequential patterns of monitoring with emotional/motivational challenges. Moreover, they might be competent in monitoring their progress but without proper strategies of controlling they might still fail and encountered emotional/motivational challenges.

LPGs established more pathways between emotional/motivational challenges and

controlling. Research has shown that less successful learners frequently and ineffectively use different strategies to come over challenges without rationally analyzing the problems (Beheshitha et al., 2015). It could be explained that LPGs were applying a trial-and-error strategy. They could not come up with an exact strategy to deal with the emotional/motivational challenges. They tried a random strategy of controlling and taking over to emotional/motivational challenges. These findings are consistent with the results of Chang et al., (2017) who found unsuccessful groups applying an approach of trial-and-error. Similarly, Hong and Liu (2003) also found that novice groups (LPGs in this study) adopted trail-and-error strategy to proceed with their learning task. Moreover, to tackle emotional/motivational challenges, both groups had a few sequential paths with the regulatory process of emotion/motivation. Nevertheless, LPGs generated more regulatory process of emotion/motivation to deal with emotional/motivational challenges.

SSRL theory posits that to tackle a specific challenge, group members initiate regulation of cognition, emotion, motivation and/or behavioral aspects (Hadwin et al., 2018). However, observing the process models of both groups, it is found that instead of demonstrating a strong sequential relationship with challenges, both groups, especially HPGs, show interesting patterns between cognitive and emotional/motivational regulations. Literature in the regulation of learning maintains that regulatory processes are typically driven from a cognitive perspective (Järvelä et al., 2016). The finding confirms the literature as it is discussed above, both groups could not face challenges of socio-emotional perspective. Challenges were triggered by cognitive perspective of the task. Thus, they established stronger sequential pathways between cognitive and emotional/motivational regulation.

Moreover, along with planning and monitoring, HPGs were taking the initiative to control their learning more than what LPGs did. To some extent, this finding is consistent with Kempler-Rogat, and Linnenbrink-Garcia, (2011) who concluded that synergy among planning and monitoring improves collaboration to attain mutual learning goals. However, the process model of HPGs shreds of evidence that it is synergic inclusion of controlling with planning and monitoring that enable groups to sustain their collaboration and achieve their group tasks.

The recurrent pattern (sequential loop within) of emotional/motivational regulation was significantly higher in HPGs than LPGs. LPGs were not consistent to regulate emotional/motivational aspects. Research has highlighted the importance of emotional/motivational regulation in sustaining positive group climate and successful

learning (Järvenoja and Järvelä, 2009; Järvelä et al., 2013; Näykki et al., 2014). HPGs' consistency to regulate emotional/motivational aspects of their learning is well-grounded theoretically.

Both groups had quite parallel paths between cognitive and emotional/motivational challenges. Similarly, the sequential interplay between emotional/motivational challenge and emotional/motivational regulation is not that striking. This finding is contrary to the analysis of Ucan and Webb, (2015). They found that groups activate emotional and motivational regulatory processes in response to socially challenging conditions. However, it is argued that emotional/motivational challenges could not only be generated by socio-emotional challenges. They could be emerged by facing difficulties in cognitive processes during the task progress and generate a sequential stronger relationship between different aspects of regulation then challenges, as theories have established that regulatory processes have a typical origin in cognitive perspective (Järvelä et al., 2016). Thus, in this study's process models of both groups show that emotional/motivational regulation is more prominent in the situations of planning, monitoring, and controlling rather than cognitive and emotional/motivational challenges. It seems that when faced with cognitive or emotional/motivational challenges, group members first take regulatory actions (i.e., planning, monitoring, or control) to deal with the challenges. Emotional/motivational regulation emerges as a result of those regulatory actions not directly due to the challenges themselves.

7 Conclusion

The sequential relationship between challenges and regulatory processes of cognition and emotion/motivation in high and low performing collaborative groups are rarely investigated. Hence, to fill this research gap, by applying the state-of-the-art methodology, process mining, this study contributes to research on learning processes by providing fine-grained insights into sequential patterns between challenges and regulation in high and low performing collaborative groups. The process mining method cultivated insightful findings that, unlike LPGs, HPGs along with cognitive regulation (planning, monitoring, and controlling) initiate the regulatory process of emotion/motivation to deal with cognitive challenges. Moreover, strong recurrent patterns of emotional/motivational challenges in LPGs reveal that when LPGs are unable to understand the task and consequently stick to the approach of trial-and-error rather than applying effective strategies to control their learning. The rise and constant emergence of emotional/motivational challenges are more predominantly caused by the cognitive perspective of the task rather than socio-emotional conflicts within group members. Theories of regulated learning posit that in collaborative learning, learning happens in series of unfolding events. Thus, it becomes inevitable to unfold the interplay of sequential order between challenges and regulation in collaborative learning. The empirical findings of this research not only confirm established theoretical grounding but also contribute further to enrich our understanding of regulatory actions of high and low performing groups while encountering challenges. The findings also have meaningful implications for designing tailored pedagogical methodologies and prompts in learning content to support students to initiate regulatory processes in the wake of confronting challenges. Despite innovative sequential analysis methodology, fine-grained approach to video data and broader implication of the findings on practical, theoretical, and methodological fronts, limitations are unavoidable. Hence, future research should take multimodality of data for the triangulation and confirming events of occurrence of research variables (challenges or regulation) from a different data set. Along with sequentiality, future studies should also examine temporal aspects of challenges and the regulation.

7.1 Implications

To evaluate the practical implications of this study, the results of this study might be considered in advancing pedagogical methodologies and developing learning content by paying weight to the sequential relationship between regulation and challenges in collaborative learning. Studies have suggested that collaborative learning environments

could be more helpful for knowledge constructions if they are integrated with components to support socially shared regulation of learning Järvelä and Hadwin (2013) and Järvelä et al. (2015). In light of this, the current study provides insights into low and high performing collaborative groups learning processes and their responses to challenges. Hence, it provides directions to design supportive elements which may encourage learners to regulate their learning.

Research in the field of learning analytics (LA) aims to provide individualized and tailored feedback to learners (Gašević, Dawson, Rogers, & Gasevic, 2016). Unfolding the sequential relationship between the emerging challenges and regulation can help develop tailored support to learners. This study could have constructive implication in LA, as it advances theoretical understanding of regulatory processes vis-à-vis different types of challenges through empirical evidence in collaborative learning. For instructional designers, the findings of the study suggest that in collaborative learning, learning content and pedagogical strategies should contain prompts for not only fostering students for monitoring the group progress but also controlling of learning processes (i.e., initiating some strategies while encountering different challenges. For, the process models of HPGs reveals that monitoring the progress could not be sufficient to tackle challenges. To proceed towards learning, along with monitoring, controlling is key to resolve challenges and attain learning goals.

Theoretically, the study also establishes the evidence of different behaviors of learners towards challenges and regulation. The findings of the study advance theoretical grounding on multiple fronts. First, the duration of regulation does not matter in success or failure during collaborative learning. Second, the findings reveal that it is not necessary that emotional/motivational challenges always lead to emotional/motivational regulation. Cognitive regulation (planning, monitoring, and controlling) could be a cause of emotional/motivational challenges. Third, previous research mentioned that less successful groups (i.e., LPGs) might not know when to monitor the progress (Paans et al., 2019b). However, the process model of LPGs demonstrates that they knew when to monitor. Fourth, LPGs bank on a trial-and-error approach to tackle the challenges, consequently, face constant emergences of challenges, as it can be observed from recurrent patterns of cognitive challenges in the process model of LPGs. Last, HPGs do not rely on one form of regulatory process (cognitive regulation) to deal with the challenges but also switch to other regulatory processes (emotion/motivation) simultaneously.

Methodologically, the current study applied a state-of-the-art methodology of process

mining which is still untapped in collaborative learning (Schoor and Bannert, 2012). The process mining methodology can provide useful insights into the learning processes (Schoor and Bannert, 2012). Mostly, this process mining methodology of sequential analysis has been narrowly used in self-regulated learning (Bannert, Reimann, and Sonnenberg, 2014; Sonnenberg, and Bannert, 2015; Sobocinski, Malmberg, and Järvelä, 2017; Heirweg et al., 2020) and CSCL (Schoor and Bannert, 2012; Paans et al., 2019a).

It consists of many other algorithms to comprehensively explore sequential and temporal aspects of learning processes (Bannert, Reimann, and Sonnenberg, 2014). Temporal aspect was not the scope of current research. However, with a potential of this methodology and fine-grained approach to capture the research variables (coding categories), I analyzed the duration of events, a quantitative temporal aspect which is crucial and recommended in process-oriented research (Bannert, Reimann, and Sonnenberg, 2014). Therefore, this study took a wide approach to utilize the methodology of process mining to open the black box of regulatory processes with not only sequential association with different types of challenges in collaborative learning but also unfold recurrent patterns of each coding category and time spent on it by high and low performing groups.

7.2 Limitations and future research

The current study's findings could be generalized but they are limited in some perspectives. First, although video data, self-reports, and physiological data were collected, the study depends on the sole data source of video. Relying on video data sets some limitations, such as analysis of research variable/phenomenon (i.e., specific regulatory behaviour) to find an explanation for its occurrence in a particular pattern and its relation in learning processes and collaboration (Jarvenoja et al., 2019). In future, studies should utilize multiple sources of data to maximize the generalizability of the findings and capture group members' subjective accounts regarding challenges and regulation and their impact on overall group progress and collaboration. Besides, another advantage of multiple sources of data would be to unleash the possibilities of data triangulation (Azevedo et al. 2016).

Second, the participants were grouped according to their convenience rather than clustering them into possible similar educational background, demographic aspects etc. It caused the formation of some groups who knew each other and were studying in the same degree programs and courses and some groups who were not familiar with themselves. It might have impacted collaboration and regulatory processes during the task. In future, research studies investigating the sequential relationship of challenges and regulation may consider homogeneity in terms of education, demographic etc.

Third, the video data of this study could not enable us to measure the sequential interplay of off-task activities of the learners in association with challenges and regulation. It would have been insightful to explore whether collaborative groups in confronting challenges turn to off-task activities or if there is an association between regulatory processes and off-task activities in collaborative learning. Aiming to explore sequential associations, future studies should also take account of learners' off-task activities.

Fourth, from a methodological perspective, process mining falls short to unfold temporality of the occurrence of challenges and regulation and their interplay. Hence, future research can combine process mining with temporal methods such as temporal network analysis or statistical discourse analysis.

Last, some groups members in different collaborative groups left the collaboration/task incomplete. It caused two profiles of group category, low and HPGs unequal in terms of the number of groups in each category. Future research may consider forming homogeneity of groups profiles to sustain the generalizability of the findings.

8 Evaluation

In this research study, I have empirically explored the sequential association between challenges and regulation in collaborative learning with process mining methodology. The video data was collected in the CLEVER research project at the University of Oulu. With the lens of theoretical grounding and adopting previous studies, a coding scheme was developed to capture coding cognitive and emotional/motivational challenges and regulation from the utterances of collaborative groups.

During academic research studies, data and findings need to be evaluated properly to sustain credibility in which “researcher needs to demonstrate the trustworthiness of their data by measuring reliability” (Krippendorff, 2019, p.278). Besides, maintaining validity in research is also crucially important for the authenticity of results and research quality (Krippendorff, 2019). Therefore, valid research tantamount to good quality research. The following section deals with the validity and reliability of this study and the means of processes applied to synthesize previous research studies. The final part of this section highlights ethical considerations taken into account while conducting this research study.

8.1 Validity and Reliability

Considering Morse et al., (2002) studies, a researcher has to apply different strategies of verification. That is, research needs to demonstrate a sense of analytical approach, responsiveness and methodologically coherent and organized in conducting a research study. Since the nature of the current study falls in the fold of qualitative research, my capabilities and endeavors play an important role to ensure the credibility of this study.

The fundamental principles of conducting research such as analytical approach, methodologically structuredness and responsiveness Morse et al., (2002) were keenly adopted for the direction of this study in order to ensure validity and reliability. Throughout the iterative process of conducting this study, video data analysis, literature review of the theoretical framework of challenges and regulatory processes in collaborative learning and methodological procedure were meticulously considered and were made aligned to accomplish the aims of the study. Moreover, the coding scheme was designed in consideration of theoretical background and previous research (Toni Kempler Rogat and Lisa Linnenbrink-Garcia 2011; Ucan and Webb, 2015; Järvenoja, Näykki, and Törmänen, 2019) so that there should not be validity and reliability issue in the process of capturing the research variables of the study from the utterances of collaborative groups.

Moreover, inter-rater reliability was considerably given weight to avoid the issues of validity and reliability. A panel of researchers, having extensive experience in the field of SSRL research, discussed the coding scheme under the light of the theoretical framework of SSRL. To ensure reliability, another researcher from the panel was invited to code three random videos. More than thirteen percentage of video data was taken into account for inter-rater reliability. Acceptable Cohen's kappa(K) for each coding category was achieved which maximizes the reliability of the study.

8.2 Ethical Issues

Research studies need to collect information from different sources. Similarly, to the present study, different sources were utilized for the collection of information. To avoid any ethical issues such as plagiarism and misappropriation, referencing techniques were applied rigorously. Hence, the study ensures authorship acknowledgement, authenticity, and originality.

As mentioned earlier, the video data was collected under the CLEVER project in the most authenticated learning environment, sticking to ethical guidelines, implemented by Finnish National Board on Research Integrity, 2009. Following the ethical guidelines, the involvement of the participants was voluntary, all the participants were respected for their autonomy and dignity. None of the participants was harmed or put at risk during the collection of the data. Participants were free to withdraw from the study any time they wished.

It is understood that video data cannot be anonymous itself (Derry et al., 2010), participant's confidentiality could possibly be protected. As I was not present during the data collection, I just reviewed the video material with no access to their personal information. Following the agreement of using the data for thesis purpose, I did not share the material with any individual nor it was shared in any cloud services or public space. Methodological and ethical accounts were considered during the process of data analysis. Last, reporting the results are in accordance with the findings of the study.

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