Exploring Online Collaborative Learners' Socially Shared Regulation of Learning Behavior Patterns in Different Engagement Groups

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Abstract—Online collaborative learning has become an important way of learning, and focusing on the socially shared regulation of learning behaviors is important for improving learning performance. Based on an online collaborative learning course, this study collected discussion data from 18 collaborative learning groups over 6 sessions. Behavioral patterns of socially shared regulation of learning were explored through frequency statistics and lagged sequence analysis. Learning engagement variables were also introduced to compare the differences in significant behavioral sequence patterns between high- and low-engagement groups. It was found that (a) most of the regulation behaviors in the early stage were focused on the task itself and the work of the members, while the regulation behaviors in the later stage were more concerned with the progress and results of the group. (b) The high-learning engagement groups had a higher frequency of socially shared regulation of learning behaviors and more appropriate temporal characteristics. The study shows that appropriate regulation behaviors guarantee the smooth progress of collaborative learning activities and the stability of the group in learning engagement. Finally, the study suggests recommendations for improving online collaborative learning performance.

Keywords—online collaborative learning, socially shared regulation of learning, learning engagement, lagged series analysis

I. INTRODUCTION

In the era of e-learning and globalized learning, online learning has become an indispensable form. The massive opportunities for the use of online learning brought about by COVID-19 [1] have led to the awareness of the vast differences between online learning and traditional learning [2–5], which has prompted more and more researchers to focus on the performance of online learning [6]. Vygotsky pointed out that language and conversation promote the development of thinking and cognition [7], so

in the learning process, discussion and collaboration between people are particularly important to improve learning performance, which means online collaborative learning is an important way of learning.

Learning engagement represents the learners' engagement in cognitive, behavioral, psychological, and other dimensions during the whole learning process, which can reflect the characteristics of the learning process [8], and is a key indicator of the quality of online learning [9]. Thus, focusing on students' learning engagement is vital to improve online collaborative learning performance.

Self-regulated learning is the strategic adjustment of learners' metacognition, cognition, behavior, etc. which can well reflect the behavioral mechanisms of learners during the learning process [10, 11]. When the context is extended into a collaborative learning environment, the concept of Socially Shared Regulation of Learning (SSRL) emerges, which mainly refers to the relevant adjustments carried out by the collective to achieve the common goal [12]. SSRL directly affects the collaborative learning process. In addition, research has shown that regulation of learning behaviors can positively predict group learning performance [13]. Therefore, students' SSRL behaviors should be used as an essential factor to enhance students' online collaborative learning performance.

There have been studies pointing out the commonality between regulation of learning and learning engagement [14], as well as studies pointing out that students who use more regulation behaviors are more engaged in learning [15]. However, there are still fewer studies on the relationship between SSRL behaviors and group learning engagement in the context of the learning process.

Therefore, this study conducted empirical studies to explore the characteristics of SSRL behaviors and the relationship between SSRL and group learning engagement in online collaborative learning activities. The study aims to enrich the research of exploring the relevance of SSRL and learning engagement and to provide guidance for improving online collaborative learning performance.

II. LITERATURE REVIEW

Learning engagement consists of behavioral, affective, and cognitive engagement [16], describing learners' positive behaviors of learning, cognitive commitment to learning and strategy use, and affective responses in learning [17]. As a characterization of the state of learning, learning engagement is associated with some important outcomes like grades, persistence, and college completion [18]. In addition to these variables, related researches have focused on modeling learning engagement to conduct prediction [19] and multimodal analysis [20]. Meanwhile, there have been researches found that learning engagement has a positive relationship with active collaborative learning [21] and collaborative activity can also prompt students' engagement [22].

SSRL is a shared regulation activity in the process of collaborative group learning to achieve common goals and maintain common cognition. The subject is all members of the group, and the content of regulation is the groups' shared task understanding, task knowledge, strategy use, and task evaluation, etc. [13] Previous researches about SSRL focus on a variety of directions. Researches may aim to explore mechanisms [23], focus on process [24], and develop instruments [25, 26]. The relevant variables are goals, feelings of difficulty, content processing, performance, and so on [27]. The researches are usually conducted in collaborative learning environment [23, 25, 28] even computer supported collaborative learning environment [24, 26, 29].

Some researchers have pointed out the self-regulation has commonality with individual learning engagement [14, 15]. In recent years, there have been several researches confirmed that SSRL and learning engagement have a "mutually reinforcing relationship" [30]. However, few studies explore such relationship in the context of dynamic collaborative learning processes and in groups.

In this research, we focused on the important elements above of conducting SSRL, including online collaborative learning, working in groups, exploring dynamic processes, and integrating with learning engagement. Therefore, the following research questions are posed:

(1) How do learners socially regulate their learning during online collaborative learning activities?

(2) What differences can be found in the patterns of SSRL behaviors between the high- and low-learning engagement groups?

III. MATERIALS AND METHODS

The study is based on a collaborative problem-solving course with a focus on mathematical modeling, which was divided into 6 sessions. The purpose of the course was to improve students' mathematical modeling ability and real-world problem solving ability by completing a mathematical modeling task, and it was hoped to improve students' scientific writing. A total of 54 students aged around 20 years old participated in the experiment. The students were all from a university in Beijing, China, and formed the collaborative learning groups of 3 members, totaling 18 groups. At the beginning of the course, each group was informed about the problem and was provided with related materials and assistance from the teacher. Students had to collaborate to solve the given problem and complete a report on their research. The course was conducted entirely online.

To obtain the characteristics and patterns of the SSRL behaviors during the collaborative learning process, this study used Tencent Meeting and WeChat to record all the discussion messages (including voice and text) during the group's collaborative learning process. We transcribed them all into text messages. Referring to the coding scheme for SSRL proposed by Kwon *et al.* [31], the regulation behaviors appearing in the text were coded. The coding scheme is shown in Table I. The coding units in this study were divided into time intervals, with 30 seconds per unit. The study coded each of the six sessions of each group's discussion in chronological order, and their statistical characteristics were calculated for analysis.

TABLE I. CODING SCHEME FOR SSRL BEHAVIORS

Behavior	Code	Definition
Scheduling	R1	Organize the group's work process according to the deadline for task completion
Dividing labor	R2	Discuss the division of labor or clarify the tasks and responsibilities of each group member
Task	R3	Identify tasks to be accomplished by recognizing project goals and requirements
Strategy	R4	Explore effective methods for coordinating the group process and achieving goals
Open-self	R5	Share individual strength, weakness, preference and situation to enhance teamwork
Monitoring the process	R6	Acknowledge group progress by checking and sharing the completed work
Group agreement	R7	Solicit feedback from other members to reach group agreements and establish group norms
Evaluation	R8	Evaluate group products or group processes

IV. RESULT AND DISCUSSION

To explore the relationship between learning engagement and SSRL behaviors, we collected learning engagement data from all groups and used k-means clustering algorithm to classify all groups into either low- or high-engagement groups. Then, we analyzed the statistical characteristics (i.e., frequency and percentage) of regulation behaviors for low- and high-engagement groups separately. To further explore the different sequence patterns of regulation behaviors, we used the GSEQ 5.1 software to conduct a lagged sequence analysis which is a method to test whether there is a statistically significant probability of the occurrence of one behavior followed by another in the overall behavioral sequence.

A. Overview of Students' SSRL Behaviors

Table II demonstrates the total frequency and mean of each type of regulation throughout the online collaborative learning activity. This analysis suggests that students are most concerned with monitoring the process (R6),

followed by strategy (R4), group agreement (R7), and evaluation (R8), with the behavior of open-self (R5) being overlooked.

TABLE II. THE STATISTICAL CHARACTERISTICS OF EACH TYPE OF REGULATION

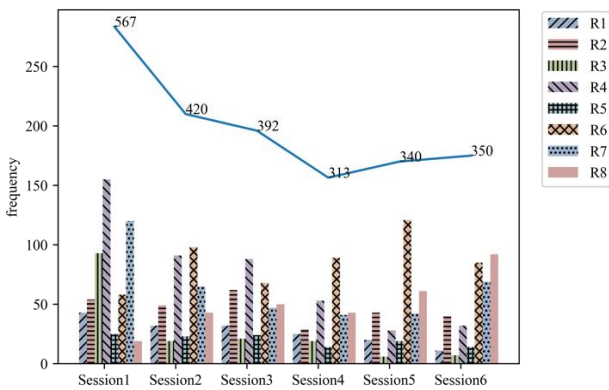| Regulation type	Total frequency	Mean (N = 18)
R1	163	9.06
R2	277	15.39
R3	165	9.17
R4	447	24.83
R5	119	6.61
R6	519	28.83
R7	384	21.33
R8	308	17.11

Fig. 1. The frequency of each type of regulation in 6 sessions of learning activity.

Fig. 1 presents the frequency of each type of regulation, with the top broken line representing the total frequency of SSRL behaviors occurring in each session. Overall, the frequency of SSRL behaviors showed a decreasing trend followed by a small increase. In the first session of the collaborative learning process, the highest frequencies of all behaviors occurred in strategy (R4), group agreement (R7), and task (R3). The peak frequencies of scheduling (R1), task (R3), strategy (R4), group agreement (R7) occurred in this stage of process. As the collaborative learning process progressed, the frequency of scheduling (R1) and open-self (R5) remained relatively stable, the frequency of task (R3) and strategy (R4) continued to decrease overall, and the frequency of monitoring the process (R6) and evaluation (R8) increased slightly. It can be seen that at the beginning of collaborative learning process, learners usually engaged in regulation behaviors for the task itself, and gradually shifted to regulating the learning process and group outcomes as the process developed.

B. Comparison of Percentages of Regulation between High- and Low-Engagement Groups

The statistical characteristics of regulation between high- and low-engagement groups are shown in Table III. Overall, the high-engagement groups had a higher average frequency of regulation. The regulation frequency characteristics of the high- and low-engagement groups were relatively consistent with the total frequency characteristics. It is worth noting that, the low-engagement

groups showed a higher proportion and mean of the regulation behaviors of strategy (R4) and evaluation (R8) on the premise that the low-engagement groups had a lower average regulation frequency, which shows that the low-engagement groups carried out strategy development and evaluation more frequently than the high-engagement groups.

TABLE III. THE STATISTICAL CHARACTERISTICS OF REGULATION BETWEEN HIGH- AND LOW-ENGAGEMENT GROUPS

Type	High			Low		
	Frequency	Proportion	Mean	Frequency	Proportion	Mean
R1	109	7.14%	9.91	54	6.31%	7.71
R2	189	12.39%	17.18	88	10.28%	12.57
R3	104	6.82%	9.45	61	7.13%	8.71
R4	263	17.23%	23.91	184	21.50%	26.29
R5	82	5.37%	7.45	37	4.32%	5.29
R6	344	22.54%	31.27	175	20.44%	25.00
R7	254	16.64%	23.09	130	15.19%	18.57
R8	181	11.86%	16.45	127	14.84%	18.14

C. Comparison of Behavioral Sequence Patterns of SSRL between High- and Low-Engagement Groups

To further analyze the differences between the high- and low-engagement groups in their sequence patterns of SSRL behaviors, we performed a lagged sequence analysis on the data of regulation behaviors, and explored significant behavioral sequences in different sessions as shown below in Fig. 2.
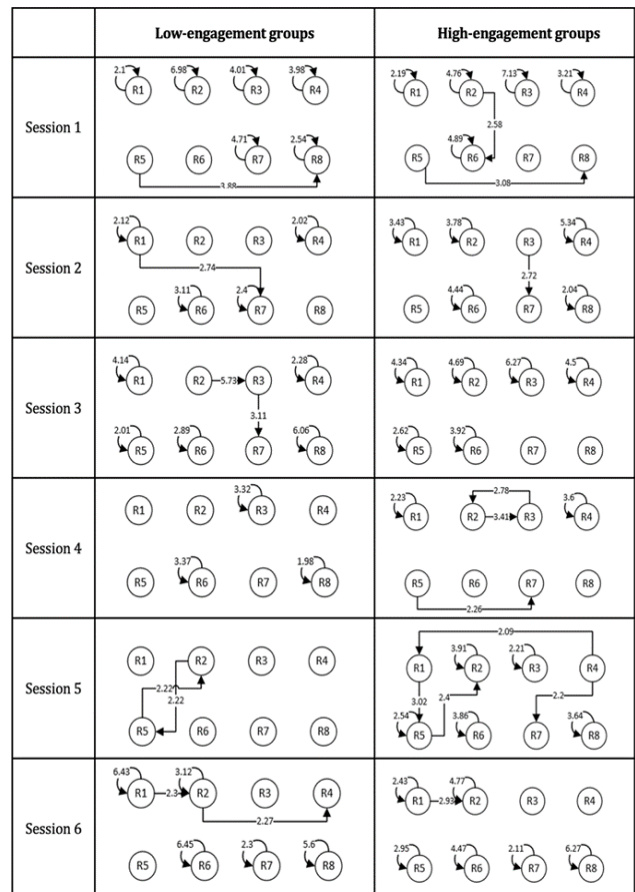

Fig. 2. The significant sequences of sessions 1–6.

The comparison between the groups shows that there are observable differences in the significant behavioral sequences of regulation. In the first half of the learning activity (sessions 1, 2, and 3), the low-engagement groups had more significant behavioral sequences about group agreement (R7) and evaluation (R8), whereas the high-engagement groups had more about dividing labor (R2) and monitoring the process (R6). This means that the low-engagement groups paid more attention to members' opinions in the early stage, while the high-engagement groups paid more attention to the task itself and its progress.

In the second half of the learning activity (sessions 4 and 5), the low-engagement groups had fewer significant behavioral sequences of regulation, whereas the high-engagement groups, in contrast, appeared to have more significant sequences. This implies that there is a relative lack of regularity in the behavioral sequence patterns of the low-engagement groups at this stage and there are not many significant behavioral commonalities between groups. On the contrary, the increase in variety and number of significant sequences implies that there is a large amount of behavioral commonality among all the high-engagement groups.

In the last session of the activities, the low-engagement groups had more behavioral sequences of dividing labor (R2) $\mapsto$ strategy (R4), while the high-engagement had more of open-self (R5) $\mapsto$ open-self (R5). This reflects that the low-engagement groups remained focusing more on the behaviors directly related to task completion, i.e., dividing the labor and developing strategies to solve the problem in the last stage, whereas the high-engagement groups more actively shared their competencies.

D. Discussion

There are some common features of SSRL behaviors throughout the online collaborative learning process. Regulation behaviors are more frequent and concentrated in the beginning and ending sessions of the learning process, such as scheduling, task, and strategy in the beginning stage, as well as monitoring the process and evaluation in the ending stage. Through the analysis of the whole process, it can be understood that at the beginning, the group tended to do more reading, discussion, and overall strategy development to ensure the effective promotion of the group's learning tasks. With the deepening of the discussion, the frequency of regulation declined due to a clearer division of labor and the identification of strategies to move forward in a structured manner. In this process, monitoring the process was used more often. In the final stage of finalizing and presenting the results, there was more discussion around the results among the team members, and since the initial results had already been generated at this stage, there was a higher frequency of group agreement and evaluation.

The significant behavioral sequences have a large number of repetitive behaviors which means the same regulation behavior repeats many times. It is mainly because the division of the unit of analysis in this study is 30 seconds per unit, and the regulation behaviors occurring in the online collaborative learning process required group members to participate together, thus their duration was mostly longer than 30 seconds. And since they are in the online collaborative learning environment, it is really common for multiple people to perform a regulation behavior such as formulating a strategy several times in a discussion. In addition, discussion about dividing labor was very frequent in the significant behavioral sequences, which can be seen as learners attach more importance to dividing labor.

The characteristics of regulation behaviors showed significant differences among different learning engagement groups. The high-engagement groups had more scheduling and dividing labor in the early stage of online collaborative learning process than the low-engagement groups, and maintained higher frequency of group agreement behaviors throughout the whole process, with a slightly higher frequency of open-self behaviors. And they had more behavioral sequences of dividing labor and monitoring the process than the low-engagement groups. This pattern of regulation behavior is more reasonable, meaning that the high-engagement groups have a smoother collaborative flow throughout the process: scheduling, dividing labor, discussing strategies in the early stage, completing the task in the later stage, and consistently asking for the group agreement throughout the process, sharing the range of their competence, as well as updating the group's progress on the task promptly.

The low-engagement groups, on the other hand, strategized and evaluated more frequently than the high-engagement groups throughout the process, with the significant behavioral sequence of successive asking for group agreement and evaluation in the early part of the process, and an additional discussion of dividing labor (R2) $\mapsto$ strategy (R4) in the last session. This implies that the low-engagement groups spent a significant amount of time discussing and developing strategies rather than practicing them. The significant sequence of behaviors related to the group agreement and evaluation means a repeated discussion of the solution, which reflects the lack of clarity of the strategies within the group. This resulted in insufficient learning engagement in the group, with members unable to fully and explicitly engage their cognition, behavior, and emotion in collaborative learning activities. In addition, the sequence of dividing labor (R2) $\mapsto$ strategy (R4) in the last session also proved that the group collaboration process did not result in a complete solution and the work of each member of the group was not clear enough, which prevented the group from moving to a higher level of learning engagement. Through the above data analysis combined with the review of the whole learning process, it can be seen that the frequency and sequence patterns of the group's regulation behaviors clearly show and even determine the current learning state of the collaborative group. The poor state of the task directly affects the learning engagement of the group. On the other hand, in the high-engagement groups, timely and appropriate regulation behaviors can ensure the smooth progress of the whole collaborative learning process. Learning engagement also can be maintained at a high

level and can be improved as the learning progress advances.

According to the results, if we hope to improve the quality of online collaborative learning, we can analyze the current situation of collaborative learning by focusing on the characteristics presented by their SSRL behaviors. It is necessary to guide students to carry out timely and appropriate regulation behaviors to promote the collaborative learning process. Attention should also be paid to guiding students to monitor the process, conduct evaluation, and implement other regulation behaviors timely. What's more, additional attention should be paid to the time when the regulation behaviors occur. As in this study, the low-engagement groups consistently showed significant behavior of developing strategies throughout the entire process, which should be intervened.

V. CONCLUSION

In this study, we conducted empirical studies to explore the characteristics of Socially Shared Regulation of Learning (SSRL) and the relationship between SSRL and group learning engagement in online collaborative learning activities. We found that the frequency of regulation behaviors in online collaborative learning firstly decreased and then slightly increased, and there was a significant difference between the early and later stages in terms of regulation types. In the early stage, more regulation behaviors were carried out for the task itself and members' work, such as scheduling, task, and strategy, while in the later stage, more feedback regulation behaviors were carried out for the progress and results of the group, such as monitoring the process and evaluation. When exploring the relationship, we found the high-engagement groups have significant characteristics in the frequency and sequence patterns of regulation behaviors with appropriate timing, while the low-engagement groups have repetitive and disordered sequence patterns of regulation behaviors due to the lack of clarity of strategies and division of labor, which is not efficient enough. Although we confirmed the relationship between SSRL and learning engagement, the internal mechanism of the relationship is not explored, which should be further examined in future studies.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Yaqi Zhao: Formal analysis, Data Curation, Writing – Original Draft; Yaqian Zheng: Writing – Review & Editing; Mingze Sun: Visualization and Investigation; Yanyan Li: Writing – Review & Editing, supervision; all authors had approved the final version.

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