Chapter 4
Analysis of Co-regulation Behavioral Patterns by Cluster and Sequential Analysis in CSCL

Abstract Computer-supported collaborative learning (CSCL) has been widely adopted in the field of education. Many benefits from collaborative learning have been well documented in the literature. Both collaborative knowledge building and regulation are very crucial for successful collaborative learning. This study focuses on how group members co-regulate each other in a CSCL environment. The online discussion transcripts of 24 groups were analyzed based on the coding scheme. The cluster analysis and sequential analysis method were integrated to analyze the behavioral patterns of co-regulation. It is found that students demonstrated different characteristics of co-regulation in terms of behavioral patterns and behavioral transitions. Few groups made adaptation during co-regulation. The implications for developers and practitioners are also discussed in detail.

Keywords Co-regulation · Co-regulated learning · Behavioral pattern · Cluster analysis · Sequential analysis · CSCL

4.1 Introduction

Collaboration with others has been considered as a central form of human activity (Barron 2009). A lot of the benefits of collaboration have been addressed in previous studies. For example, learning occurs through collaboration with others in school settings or in informal contexts (Barron 2009). Social communication skills can be fostered by collaborating with others during the processes of resolving discrepancies, negotiating issues, and achieving common understanding (Roschelle 1992). Constructive dialog during the process of collaboration can also promote conceptual development and social interaction (Barron 2009; Roschelle 1992). Therefore, collaboration is very crucial for human development.

Co-regulation is defined as an externally initiated regulatory process that promotes self-regulation and shared cognition (Zheng and Huang 2016). Previous studies have indicated that co-regulation is important for productive and successful collaborative learning (Winne et al. 2013). Group members have to co-regulate their

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tasks and social interactions through setting goals, making plans, selecting and enacting strategies, monitoring, as well as evaluating and reflecting. Co-regulation emphasizes the social interactions that occur between two or more group members in a collaborative learning context (Zheng and Yu 2016).

It has been found that co-regulation can support and promote self-regulated learning to a large extent (Chan 2012). Contemporary research has paid more attention to self-regulated learning, while little effort has been put into examining co-regulated learning in the field of education. Failing to consider the crucial role of co-regulated learning leaves a gap between co-regulation and collaboration. This gap must be addressed so as to provide researchers access to how learners conduct collaborative learning through the lens of co-regulation. This study aims to analyze how group members co-regulated their learning in a CSCL environment. This CSCL environment supports co-regulation through setting goals, making plans, online discussions, selecting strategies, evaluation, and reflection. The following section will describe this process in detail.

4.2 Literature Review

4.2.1 Regulated Learning

Regulated learning involves intentionally negotiating task goals, selecting and enacting strategies to optimize task performance, monitoring progress, as well as making adaptations (Järvelä and Hadwin 2013). Researchers posited that regulated learning is intentional and goal directed, meta-cognitive, and social (Hadwin et al. 2011). Usually, researchers only centered on knowledge building without focusing on how group members regulate each other in CSCL. In fact, regulated learning is more important than knowledge building to some extent. In addition, knowledge building is different from regulated learning in the following ways. First, knowledge building involves sharing information, transforming information, and integrating new information with prior knowledge through social interactions (Mayer 1996; Resnick et al. 1991). Therefore, knowledge building focuses on domain knowledge and task-related aspects, while regulated learning covers socio-cognitive and team related aspects (Fransen et al. 2013). Second, the target information of knowledge building and regulated learning are different. In terms of knowledge building, domain knowledge is constructed by group members. With regard to shared regulation, meta-motivation, meta-emotion, and meta-cognition knowledge is constructed during a collaborative learning process (Järvelä and Hadwin 2013). All in all, knowledge building and regulated learning interact with each other. Regulation of motivation, emotion, goals, plans, and strategies can promote knowledge building, and vice versa.

There are three forms of regulated learning, namely self-regulated learning, co-regulated learning, and socially shared regulation of learning (Järvelä and

Hadwin 2013). In a collaborative learning context, each group member needs to regulate his or her learning (self-regulated learning), other members' learning (co-regulated learning), as well as collectively regulate all members' learning (socially shared regulation of learning). Self-regulated learning is the process that promotes individuals to set goals, make plans, adopt strategies, monitor, and evaluate (Schunk and Zimmerman 2008). Winne et al. (2013) posited that successful collaborative learning required each group member to regulate his or her own learning well. However, researches also indicated that students are self-regulated but do not regulate each other (Winters and Alexander 2010).

As the expansion of self-regulated learning, co-regulated learning implies multiple self-regulating agents socially regulating each other's learning processes (Volet et al. 2009). Co-regulated learning requires every group member to be aware of one another's progress and be able to regulate each other. Co-regulatory abilities have been considered as important abilities for improving the quality of collaborative learning (Ucan and Webb 2015). However, productive collaborative learning requires more than self-regulated learning and co-regulated learning (Järvelä and Hadwin 2013), namely socially shared regulation.

Socially shared regulated learning implies the construction and maintenance of collectively shared regulatory processes, beliefs, and knowledge to achieve a shared understanding (Hadwin et al. 2011). Findings indicated that socially shared regulated learning plays a crucial role in collaborative learning (Rogat and Linnenbrink-Garcia 2011). Group members need to jointly negotiate and regulate their motivation, beliefs, emotions, goals, plans, and strategies to formulate shared outcome in CSCL.

4.2.2 About Co-regulation

Self-regulation is defined as an active and constructive process in which learners regulate their motivation, cognition, meta-cognition, emotion, and behavior (Pintrich 2000). Co-regulation extends self-regulation by socially regulating each other's learning (Volet et al. 2009). Co-regulation is fundamental for the establishment of joint understanding or mutual knowledge (Barron 2009). As a central process, co-regulation requires group members to coordinate each other's motivation, emotion, cognition, and meta-cognition by questioning, prompting, explaining, and restating (Järvelä and Hadwin 2013).

Co-regulation is grounded by Vygotsky's (1978) theory that higher psychological processes in individuals originate from social interactions. Co-regulation consists of emergent interactions mediated by goal setting, planning, monitoring, and evaluation (Zheng and Huang 2016). Co-regulation also describes interactions between two or more peers that coordinate self-regulated learning processes (McCaslin and Hickey 2001). For example, student A set his or her goal based on the task standard. Student B questioned the goal after discussion. Thus, student A evaluated and reflected his or her goal. Finally, if student A had the ability of co-regulation, he or she will make adaptation of the goal. In this scenario, co-regulation was mediated by social interaction between the two members. Therefore, co-regulation was externally initiated by others.

4.2.3 Co-regulation in CSCL

CSCL centers on how people can learn together with the help of computers (Stahl et al. 2006). Koschmann (2002) posited that CSCL is centrally concerned with meaning and the practices of meaning making in the context of joint activity. During collaborative learning, co-regulation can be achieved by interacting with other group members. Group members need to co-regulate each other to achieve common ground and shared understanding or outcomes. For example, group members can ask questions or explain reasons, relationships, or mechanisms during collaborative learning. If they have conflicts, they can negotiate with each other and find solutions. Finally, they will reach a shared understanding of the subject matter. Hadwin et al. (2011) posited that co-regulation occurred when individuals' regulatory activities were supported, guided, or restricted by others. Moreover, Volet et al. (2009) indicated that high-level co-regulation contributed to productive collaborative learning.

Previous studies have explored how group members co-regulated one another in a CSCL context. DiDonato (2013) suggested that co-regulated learning processes in a CSCL context may lead to increases in self-regulated learning and co-regulated learning. Lajoie and Lu (2011) examined the influence of an external tool on co-regulated learning activities. They found that an interactive whiteboard demonstrated better learning outcomes than a traditional whiteboard. So the interactive whiteboard served as an external tool to facilitate co-regulated learning.

However, previous studies put more emphasis on examining how students adopted strategies rather than the regulation of collaboration (Winters and Azevedo 2005). Few studies have investigated how group members co-regulated one another during collaborative learning. Furthermore, few tools to support co-regulation have been developed. The purpose of this study is twofold. First, it aims to develop a system to support co-regulation in a CSCL context. Second, it examines the behavioral pattern of co-regulation in the co-regulated learning environment to gain more insights into the nature of co-regulation. Thus, research questions are formulated as follows:

1. How many potential clusters can be formed based on co-regulated learning behavioral traits in a technology enhanced co-regulated environment?
2. What are the behavioral sequence characteristics of each cluster?

4.3 Method

4.3.1 *Participants*

The number of participants in this study was 96 undergraduates (73 female and 23 male) with an average age of 18 from a university in Beijing. They were freshmen in the departments of Law and Chinese Language and Literature. They were randomly assigned into 24 groups of 4 people. The collaborative learning task was to design a plan about how to set up a wireless network in the dormitory. All of the groups completed the same task for about 2 h.

4.3.2 *Procedure*

This study was conducted as part of a study course on the fundamental application of computers, a course worth three academic credits. The collaborative learning task was to design a plan to set up a wireless network in a student dormitory. In the study, 24 groups completed the same task within 2 h in two computer classrooms. All of them conducted online collaborative learning via a CSCL environment. Figure 4.1 shows a screen shot of the CSCL platform. This CSCL platform can support students whilst setting their goals, making plans, discussing online, submitting group products, as well as evaluating and reflecting. Before collaborative learning, the research assistant first introduced the platform and the operation method. Subsequently, every group conducted online collaborative learning for 2 h.

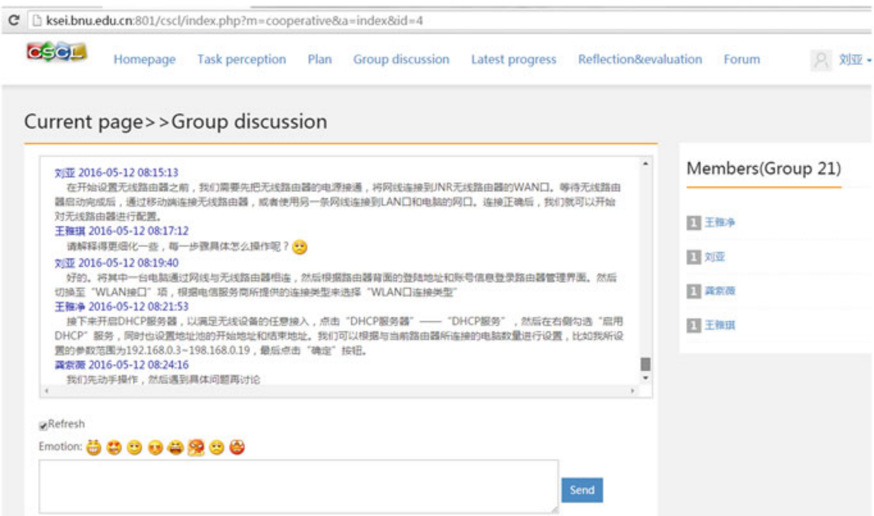

Fig. 4.1 A screen shot of online discussion

Members of the same group were located in different classrooms and were not permitted face-to-face discussion. Each group was uninterrupted unless they required help with use of the platform. All of the discussion transcripts were recorded automatically by the platform.

4.3.3 Data Analysis

This study integrated content analysis, lag sequential analysis (LAS), and cluster analysis to analyze the behavioral pattern of co-regulated learning in a CSCL environment. Table 4.1 shows the coding scheme for co-regulation that was developed by Zheng and Huang (2016). There were six kinds of co-regulated learning behavior, including goal orientation, making plans, enacting strategies, monitoring and controlling, evaluating and reflecting, as well as adapting meta-cognition. Off-topic was also considered because group members often discussed some topics which were irrelevant to the collaborative learning tasks. The analysis unit was the speaker's turn. Two graduates were trained to code the data by researchers, and independently coded all of the data manually. In order to ensure consistency, Cohen's Kappa was calculated using SPSS software. The result indicated that a Kappa coefficient of 0.81 was achieved, which demonstrated excellent reliability (Viera and Garrett 2005). Finally, all discrepancies were discussed and resolved.

Cluster analysis was then performed to analyze the students' coded behavior using SPSS 20.0. The cluster analysis process included two steps. First, hierarchical cluster analysis was conducted to determine the number of clusters. Second, *k*-mean cluster analysis was performed to analyze the characteristics of the behaviors.

Table 4.1 The coding scheme for co-regulation in CSCL

Dimension	Examples
Goal orientation (GO)	"This task requires us to set up wireless network"
Making plans (MP)	"We need to make a schedule in order to complete this task"
Enacting strategies (ES)	"I have an idea. We can search for information via the Internet, and then compare which one is better"
	"You needn't argue anymore. I think I can find out a solution"
Monitoring and controlling (MC)	"How is it going? We only have one hour left"
	"I think we will have trouble with this solution"
Evaluating and reflecting (ER)	"I think we need to reflect the current plan"
	"Overall, we have achieved the expected goal and finished the task successfully"
Adapting meta-cognition (AM)	"We need to adapt our plan and strategies immediately"
Off-topic (OT)	"We will have dinner after discussion"

In this study, LSA (Bakeman and Gottman 1997) was also adopted to analyze the behavioral transition of co-regulated learning. The sequential analysis was adopted in previous studies to analyze user behavioral patterns (Hou and Wu 2011; Hou and Li 2014). There were three steps during the LSA process. First, to calculate the frequency of each kind of behavior. Second, to analyze the transition matrix of behavioral frequency. Third, to calculate the adjusted residuals (Bakeman and Gottman 1997). Generalized Sequential Querier (GSEQ) software, version 5.1, was adopted to conduct LSA.

4.4 Results

4.4.1 Cluster Patterns of Co-regulated Learning Behavior

In order to examine the cluster patterns of co-regulated learning behavior, the hierarchical clustering Ward method was adopted. The results indicated there were three clusters in terms of co-regulated learning behavior patterns. Then *k*-mean cluster analysis was conducted to examine the characteristics of each cluster. Table 4.2 shows the cluster analysis results and the average frequency of each kind of behavior.

As shown in Table 4.2, the three clusters comprise 3 (12.5 %), 16 (66.7 %), and 5 (20.8 %) groups, respectively. It was found that co-regulated learning behaviors of Cluster 3 achieved the highest frequency in terms of making plans, enacting strategies, monitoring and controlling, evaluation and reflection, as well as adapting meta-cognition. While Cluster 1 achieved the lowest frequency with respect to goal orientation, making plans, enacting strategies, monitoring and controlling, evaluation and reflection, as well as adapting meta-cognition. The co-regulated learning behaviors of Cluster 2 achieved a medium level. In addition, the off-topic messages of cluster 1 accounted for the highest proportion, while the off-topic discussion of Cluster 3 accounted for the lowest proportion. Overall, goal orientation, making plans, enacting strategies, monitoring and controlling, as well as evaluation and reflection were the five main behaviors.

Table 4.2 Cluster analysis of group behavior

Behaviors	Cluster 1 (N = 3, 12.5 %)	Cluster 2 (N = 16, 66.7 %)	Cluster 3 (N = 5, 20.8 %)
GO	5	18	15
MP	2	11	18
ES	22	102	123
MC	23	97	151
ER	4	15	24
AM	1	1	3
OT	103	86	56

4.4.2 Sequential Patterns of Co-regulated Learning Behavior

In order to examine the sequential pattern of each cluster, sequential analysis of the seven behaviors codes (GO, MP, ES, MC, ER, AM, and OT) of all three clusters was conducted using GSEQ 5.0. Table 4.3 shows the adjusted residuals for the three clusters. The rows represent the initial behaviors and the columns represent the behaviors which followed the initial behaviors. If a *z*-score was greater than 1.96, it indicated that the connectivity of the sequence achieved a significant level (Bakeman and Gottman 1997). Figures 4.2, 4.3, and 4.4 demonstrated the behavioral transition diagrams of Cluster 1, Cluster 2, and Cluster 3, respectively.

According to the analysis results in Table 4.3, and Figs. 4.1, 4.2, and 4.3, it was found that students' co-regulated learning behaviors were significantly different. In terms of Cluster 1, only three behavioral sequences achieved a significant level

Table 4.3 The adjusted residual table for the three clusters' behaviors

Z	GO	MP	ES	MC	ER	AM	OT
Cluster 1							
GO	−0.41	−0.26	0.41	1.81	−0.41	−0.18	−1.19
MP	−0.26	−0.16	−0.57	1.55	−0.26	−0.11	−0.45
ES	−0.91	1.50	1.32	1.44	1.73	−0.40	−2.55
MC	1.66	−0.58	1.20	1.32	−0.93	−0.41	−1.87
ER	−0.36	−0.23	2.13*	0.71	−0.36	−0.16	−1.70
AM	−0.18	−0.11	2.51*	−0.39	−0.18	−0.08	−1.37
OT	−0.21	−0.43	−2.95	−3.19	−0.21	0.75	4.52*
Cluster 2							
GO	1.38	0.54	1.64	0.02	−1.02	−0.24	−2.08
MP	0.74	−0.63	1.59	−0.02	−0.79	5.39*	−2.03
ES	−0.94	−0.93	0.24	1.57	2.56*	−0.67	−2.21
MC	1.50	−0.16	2.21*	1.15	−1.64	−0.65	−3.24
ER	−0.87	0.74	−1.62	1.69	2.66*	−0.22	−1.20
AM	−0.22	−0.19	−0.69	−0.62	4.30*	−0.06	−0.60
OT	−1.15	0.79	−3.18	−3.57	−1.95	−0.59	8.24*
Cluster 3							
GO	0.65	−0.87	0.15	1.21	−1.01	−0.35	−0.91
MP	−0.84	−0.96	1.21	1.53	−1.11	−0.38	−1.82
ES	−2.00	−0.87	1.92	1.05	−0.26	−1.18	−1.93
MC	2.00*	1.50	−0.14	0.41	−0.99	−0.19	−1.59
ER	−0.98	−1.11	−0.26	−0.10	1.34	−0.45	0.85
AM	−0.34	−0.38	−1.18	−0.18	−0.45	13.11*	−0.73
OT	0.77	0.97	−2.69	−3.42	2.14*	−0.71	5.95*

*$p < 0.05$

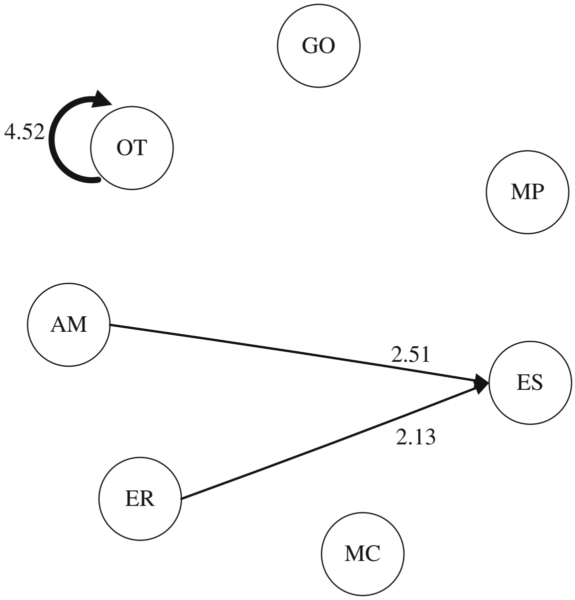

Fig. 4.2 The behavioral transition diagram of cluster 1

(ER → ES, AM → ES, and OT → OT). The behavioral path ER → ES showed that when group members evaluated and reflected, they tended to enact strategies. The behavioral path AM → ES demonstrated that when group members adapted

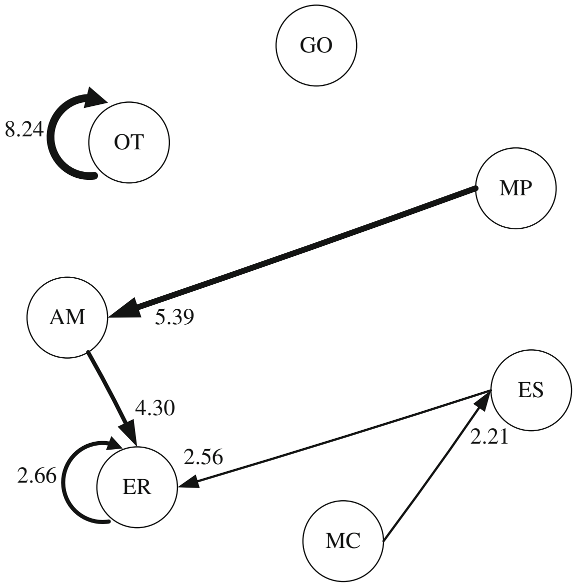

Fig. 4.3 The behavioral transition diagram of cluster 2

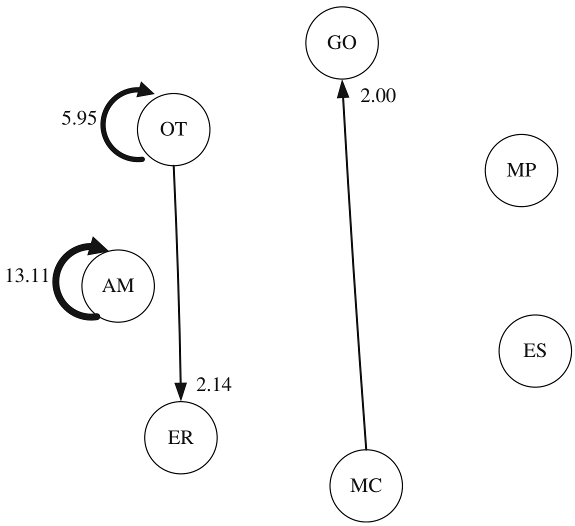

Fig. 4.4 The behavioral transition diagram of cluster 3

meta-cognition, they continued to enact strategies. These two paths should be encouraged because they can promote group members to co-regulate themselves. While the behavioral path OT → OT showed that when some group members talked about irrelevant topics, other students joined in with that chat. This means that the groups in Cluster 1 cannot co-regulate their learning. It also indicated that only a few behavioral transitions occurred in Cluster 1.

With respect to Cluster 2, six behavioral paths reached a significant level (MP → AM, AM → ER, ES → ER, MC → ES, ER → ER, and OT → OT). It was very clear that five different behavioral paths emerged in Cluster 2. The behavioral path MP → AM indicated that when group members made a plan, they tended to adapt meta-cognition. The behavioral path AM → ER demonstrated that when group members adapted meta-cognition, they continued to evaluate and reflect. The behavioral path ES → ER indicated that when group members enacted strategies, they continued to evaluate and reflect. The behavioral path MC → ES showed that group members enacted strategies when they monitored and controlled their learning processes. The behavioral path ER → ER revealed that when some group members evaluated and reflected, others continually evaluated and reflected. While the behavioral path OT → OT was the same as in Cluster 2. This indicated that group members of Cluster 2 also talked about some irrelevant topics. Furthermore, this kind of behavior continually occurred among group members of Cluster 2. Overall, more behavioral transition occurred in Cluster 2. This result indicated that the groups of Cluster 2 can better co-regulate one other.

With regard to Cluster 3, only four behavioral sequences reached a significant level (MC → GO, AM → AM, OT → ER, and OT → OT). The behavioral path MC → GO indicated that group members oriented their goals when they monitored

Table 4.4 Frequency and distribution of co-regulation behaviors

	GO	MP	ES	MC	ER	AM	OT
Frequency	38	31	247	271	43	5	245
Percentage (%)	4.3	3.5	28.1	30.8	4.9	0.6	27.8

learning processes. The behavioral path AM → AM showed that when some group members adapted their meta-cognition, others followed to adapt their own. The behavioral path OT → ER indicated that when some group members talked about irrelevant topics, other group members regulated to evaluate and reflect. At the same time, the behavioral path OT → OT also occurred. This result indicated that some groups cannot regulate themselves and off-topic discussion continually occurred in some groups. Among these four behavioral paths, the behavioral paths MC → GO and OT → ER were desirable and should be encouraged. Overall, Cluster 2 demonstrated the best co-regulated learning behaviors among the three clusters because more behavioral sequences occurred in Cluster 2.

In addition, the behavioral transition pattern of 24 groups were examined by the sequential analysis method. Table 4.4 shows the frequency and distribution of different co-regulation behaviors. It was found that monitoring and controlling accounted for the highest percentage, followed by enacting strategies, while making adaptations occurred the least. These results indicated that students could enact strategies and monitor learning processes. However, they seldom made adaptions of meta-cognition during co-regulation.

Table 4.5 shows the adjusted residual of co-regulation behaviors. Figure 4.5 shows the behavioral transition diagram of all groups. As shown in Fig. 4.5, there were eleven statistically significant behavioral paths. They were MP → ES, MP → AM, ES → MC, ES → ER, ES → ES, MC → ES, MC → MC, MC → GO, ER → ER, AM → AM, and OT → OT. Among these behavior transitions, MP → ES, MP → AM, ES → MC, ES → ER, MC → ES, and MC → GO were desirable and within expectations. However, five paths, namely ES → ES, MC → MC, ER → ER, AM → AM, and OT → OT, indicated group members could not regulate each other very well. This revealed that some group members repeated other members' behaviors continually.

Table 4.5 The adjusted residual table for the 24 groups

Z	GO	MP	ES	MC	ER	AM	OT
GO	1.32	−0.30	1.51	1.34	−1.48	−0.48	−2.50
MP	−0.19	−1.08	2.07*	1.91	−1.33	2.00*	−3.17
ES	−2.16	−0.69	2.53*	2.86*	2.05*	−1.40	−5.02
MC	2.85*	1.37	2.33*	2.45*	−1.69	−0.52	−5.67
ER	−1.35	−0.44	−0.45	1.44	2.64*	−0.51	−1.46
AM	−0.45	−0.43	−0.43	−0.48	1.49	11.76*	−1.41
OT	−0.57	0.15	−6.18	−7.39	−0.61	−0.39	14.24*

$^{*}p < 0.05$

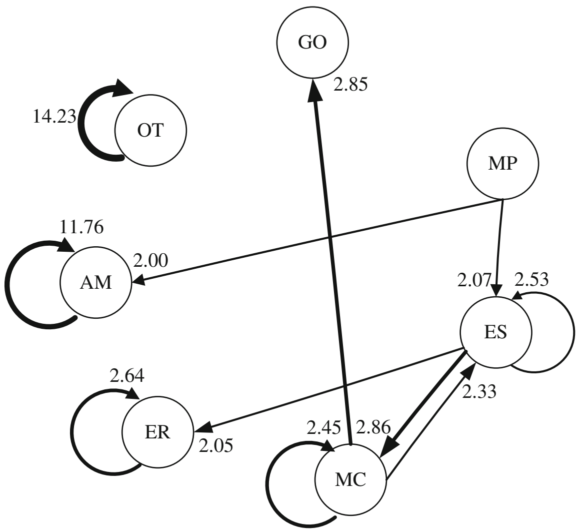

Fig. 4.5 The combined behavioral transition diagram of all groups

4.5 Discussion

In this study, cluster analysis and behavioral sequence analysis was conducted to examine the characteristics of co-regulated learning behaviors in a CSCL environment. The cluster analysis helped to identify the potential cluster patterns of group members' various behaviors. Sequential analysis of the behavioral patterns was adopted to examine learners' behavioral sequences in the field of digital learning (Hou and Wu 2011). This study considered both the behavioral frequency and sequential patterns in order to get a better understanding of group members' co-regulated learning behaviors.

It was found that Cluster 3 displayed the highest proportion in terms of co-regulated learning behavioral frequency and Cluster 1 demonstrated the lowest. Cluster 2 was characterized by a medium level of co-regulated learning behavior frequency. However, adapting meta-cognition occurred the least among all of these clusters. This means group members cannot make adaptations to their meta-cognition during learning processes. According to Winne and Hadwin (1998), learners need to make major adaptations by revising or restructuring cognitive conditions, meta-cognitive strategies, and operations to complete tasks. A lack of ability to adapt meta-cognition will hinder the processes of co-regulated learning. Overall, the following co-regulated learning behaviors achieved higher percentages: orientating goals, making plans, enacting strategies, monitoring and controlling, as well as evaluation and reflection. This result indicated that group members can regulate each other by establishing goals, making plans, selecting and applying strategies, monitoring their learning processes, as well as evaluating and reflecting upon learning outcomes.

The results of the analysis of behavioral sequence indicated that different clusters demonstrated different behavioral sequences. About 66.7 % of the groups could co-regulate themselves by behavioral transitions of making plans, enacting strategies, evaluating and reflecting, as well as adapting meta-cognition. These 16 groups displayed better co-regulated learning behaviors than other groups. Overall, the behavioral paths ER → ES, AM → ES, MP → AM, AM → ER, ES → ER, MC → ES, MC → GO, and OT → ER were desirable paths which should be encouraged, because group members need to co-regulate themselves via different behaviors. That is to say behavioral transitions are necessary for co-regulated learning.

In addition, the behavioral path OT → OT occurred in each cluster. This result indicated that students discussed some irrelevant topics and tended to fall into repetitive cycles. In fact, some off-topic discussion may smooth the collaborative-learning processes and serve the latent function of guiding group discussion (Chen and Wang 2009). For example, cheers, encouragement, or greetings can help to create a harmonious atmosphere. However, if group members continually talk about irrelevant topics, it can be considered a waste of time which may hinder the co-regulated learning processes.

This study has several implications for designers and developers in the field of education. First, the sequential analysis method can help instructional designers get a better understanding of the actual behaviors and co-regulated learning behavioral patterns of group members. The behavioral transition diagram visualizes different behavioral sequences, thus gaining more insight into how group members regulate each other in a CSCL environment. Thus, the interaction processes in collaborative learning were discovered through in-depth analysis of behaviors. Second, it was found that off-topic discussion occurred frequently during collaborative learning. Therefore, it is very necessary to adopt semantic analytical technologies to detect off-topic discussion and remind learners to return to collaborative learning tasks. Third, teachers should intervene when students show that they cannot co-regulate themselves based on their behavioral patterns and status. Therefore, developers can design useful tools to automatically analyze behavioral sequence transitions.

4.6 Conclusion

This study analyzed the behavioral pattern of co-regulation in a CSCL environment. Cluster analysis and sequential analysis methods were adopted to examine the characteristics of co-regulation. The results indicated that group members could co-regulate each other by setting goals, making plans, enacting strategies, monitoring and controlling, as well as making adaptations. However, making adaptations occurred the least among all of the kinds of co-regulation behaviors. Twenty-four groups demonstrated 3 clusters based on co-regulation behaviors. Every cluster displayed different traits of behavioral transition.

This study has several limitations. First, this study only analyzed the behavioral pattern of co-regulation. How group members regulated themselves and socially shared regulated joint learning activity has not been examined. Future studies will examine socially shared regulation in a CSCL context. Second, the study manually coded all of the discussion transcripts. This was very time consuming. Future studies will explore how to automatically analyze the data. Third, only one task was completed in this study. It may be that the task context influences how students co-regulated one other. Future studies will examine the traits of co-regulation in other task contexts.

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