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Exploring the Behavioural Patterns of Knowledge Dimensions and Cognitive Processes in Peer-Moderated Asynchronous Online Discussions

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Abstract: Peer moderation has been used as a beneficial strategy in asynchronous online discussions to assist student learning performance. However, most studies in peer-moderated asynchronous online discussions (PMAOD) have focused only on learning effectiveness and perceptions of students rather than on students' knowledge dimensions and cognitive processing patterns. This study combined quantitative content analysis (QCA) and lag sequential analysis (LSA) to explore student knowledge dimensions and cognitive processing patterns in PMAOD. The participants were 84 students in an undergraduate blended course from University Putra Malaysia (UPM), Malaysia. The Revised Bloom Taxonomy (RBT) was used as the codification scheme to code the discussion transcripts of participants assigned the role of peer moderators in a reciprocal manner over seven weeks. Behavioural distributions and patterns of high- and low-quality discussion groups were compared. Results showed that students were primarily sharing knowledge dimensions and cognitive processes of metacognition and understanding, respectively. Additionally, it was found that there was a modest proportion of off-topic discussions. Nonetheless, by means of LSA, it was found that PMAOD exhibited a certain degree of self-sustainability in knowledge and cognitive process behaviours, with the exceptions of *procedural knowledge* and the cognitive process of *applying* and, in terms of diversity in knowledge dimension and cognitive processing, high-quality discussion groups outperformed low-quality groups.

Keywords: peer moderation, asynchronous online discussions, quantitative content analysis, lag sequential analysis.

Résumé : La modération par les pairs dans les discussions asynchrones en ligne a été utilisée comme une stratégie visant à favoriser la réussite des étudiants. Cependant, la plupart des études sur les discussions asynchrones en ligne modérées par les pairs (DALMP) se sont seulement centrées sur l'efficacité de l'apprentissage et les perceptions des étudiants plutôt que sur les schèmes caractérisant le partage d'éléments de connaissance et de processus cognitifs par les étudiants. Cette étude combine une analyse quantitative de contenu (AQC) et une analyse séquentielle d'écarts (ASÉ) pour explorer les schèmes de partage des éléments de connaissance et des processus cognitifs des étudiants dans un contexte de DALMP. 84 étudiants de premier cycle suivants des cours hybrides à l'université Putra Malaysia (UPM), en Malaisie, ont participé à l'enquête. La taxonomie révisée de Bloom (TRB) a été utilisée comme modèle de codification pour coder les transcriptions des propos tenus par les participants qui se sont réciproquement vus assigner le rôle de modérateur auprès de leurs pairs durant sept semaines. Les distributions comportementales et schèmes de qualité (élevée ou faible) des discussions de groupes ont été comparés. Les résultats ont montré que les étudiants partageaient tout d'abord des schèmes relatifs à des éléments de connaissance puis des processus cognitifs de métacognition et de compréhension. De surcroit, une petite part de discussions hors sujet a été relevée. Néanmoins, l'ASÉ a permis de mettre en avant que la DALMP fait ressortir un certain degré d'autosuffisance dans les comportements relatifs au processus cognitifs et à la connaissance, exception faite de la connaissance procédurale et du processus cognitif d'application. Les groupes de discussion de qualité élevée surpassent ceux de faible qualité en termes de diversité des éléments de connaissance et des processus cognitifs.

Mots-clés : Modération par les pairs, discussion asynchrone en ligne, analyse quantitative de contenu, analyse séquentielle d'écarts

Introduction

As an asynchronous tool, discussion forums have been used either as a main means for communication and interaction in distance education (Lee & Tsai, 2011) or utilized as a complementary method to face-to-face teaching (Zhan, Xu, & Ye, 2011). With few drawbacks, it offers many advantages including promoting self-regulated and active learning, facilitating collaborative knowledge construction, supporting critical thinking, and promoting reflective and thoughtful content in discussions (Wang & Woo, 2007; Wong & Bakar, 2009). However, advanced cognitive processing and knowledge construction in asynchronous online discussions (AOD) requires some sort of intervention (De Smet, Van Keer, & Valcke, 2008).

To assist AODs, various interactive instructional strategies can be used (Kanuka, Rourke, & Laflamme, 2007; Sung, Chang, Chiou, & Hou, 2005). However, as Hou (2011) suggested, instructors' real-time intervention is needed to enhance both deep and broad interactions in an AOD. Nonetheless, some researchers (e.g., Correia & Baran, 2010; Seo, 2007) have started to question whether an instructor is the most effective facilitator. Many instructors may not be able to dedicate the amount of time and effort needed for proper facilitation of AODs since it is very time consuming and tedious work (Correia & Baran, 2010). Moreover, a discussion facilitated by an instructor may result in an instructor-centred discussion (Seo, 2007). It is therefore a matter of controversy as to which strategy promotes more positive outcomes—instructor facilitated or peer moderation. Peer moderation can be an alternative to instructor moderation and be used as a potential solution.

Learning in a peer-moderated asynchronous online discussion (PMAOD) may be considered a specific type of collaborative learning in the form of computer-supported collaborative learning (CSCL) (Topping, 2005), where participants are assumed to negotiate meaning in small groups and one peer assumes the supportive role as peer moderator. Researchers investigating collaborative learning and peer moderation frequently refer to frameworks building on Vygotsky's social -cultural theory. Vygotsky (1978) emphasized that knowledge is interpersonal before it becomes intrapersonal, and in order to foster the construction of the former, social interaction is crucial. Consequently, peer collaboration and peer moderation can be regarded as an important benefit of collaborative learning. Furthermore, Vygotsky's theory on the "zone of proximal development" (ZPD) appears to support the effectiveness of peer moderation. The ZPD is "the distance between the actual developmental levels as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (Jaramillo, 1996, p. 139). ZPD pertains to peer moderation since this type of collaborative learning is characterized by the adoption of specific roles, where one partner clearly takes a direct pedagogical role by creating learning opportunities in the group through questioning, clarifying, and active scaffolding (Roscoe & Chi, 2008).

In recent years, researchers (e.g., Hung & Crooks, 2009; Ng, Cheung, & Hew, 2009) have investigated the advantages of adopting peer moderation strategy in AODs to support high quality collaborative learning. For example, Zha and Ottendorfer (2011) adopted a peer moderation strategy in an undergraduate basic immunology online course (N = 216) to investigate its effect on students' cognitive achievement. They used Bloom's taxonomy (Bloom & Krathwohl, 1956) as the framework to examine students' cognitive achievement. They found that peer moderators in online discussions outperformed respondents in terms of lower-order cognitive achievement. A similar peer-led strategy was used in a study in a graduate-level communications networks course delivered asynchronously to a cohort group of 17 adults (Rourke & Anderson, 2002). Results revealed that students' perceptions on PMAOD helped them gain higher-order learning objectives. These peer moderation studies emphasized the effect of peer moderators' role assignments on assigned students' behaviours. However, another view on peer moderation highlighted group process advantages resulting from the acts of peer moderators (Mudrack & Farrell, 1995). De Smet, Van Keer, and Valcke (2009) conducted an exploratory case study investigating evolution in support of nineteen pairs of fourth-year peer moderators over time, each tutoring one asynchronous discussion group of about ten freshmen. They noted that peer moderators could effectively model study skills such as concentrating on the materials, organizing work habits, and asking questions. In brief, assigning students to the role of peer moderator not only helps them to use higher-level cognitive skills for a specific domain and apply knowledge to a specific domain or context, but also supports other group members' activities during PMAOD (King, 2007).

However, the majority of PMAOD-related educational studies have focused on student perceptions (e.g., Hew, 2015), motivation (e.g., Xie & Ke, 2011), engagement and achievement (e.g., Xie, 2013), participation rate (Xie, Yu, & Bradshaw, 2014), and peer moderation techniques (Hew & Cheung, 2008). Little attention has been devoted to scrutinizing the process of interactions and students' behavioural patterns in PMAOD, particularly with various performance qualities (high achieving groups versus low achieving groups), which is considered as a crucial topic. Previous studies used different instructional strategies and communication tools. For example, Yang, Li, Guo, and Li (2015) conducted a study on 43 English as a foreign language (EFL) learners who were engaged in online cooperative translation activities and compared the behavioural sequences of knowledge construction between the high-score groups—characterized as higher graded groups based on the ranking order—and low-score groups- characterized as lower graded groups based on the ranking order. They found that different opinions in high-score groups proceeded further to the negotiation and co-construction knowledge phase, which was lacking in low-score groups. In another study, Hou and Wu (2011) compared students' online discussions between the high- and low-quality groups using a text-based instant messaging (IM) tool. They characterized high-quality groups as those with higher scores on clarifying a topic, collecting information, depth of analysis, and conclusion, and low-quality groups as those with lower scores on the four aforementioned dimensions. They found that students in high-quality groups performed better than the low-quality discussion groups in terms of knowledge construction, participation, and coordination. However, the extant research on behavioral patterns of knowledge and cognitive achievement between the discussions of high-quality PMAOD groups and low-quality PMAOD groups is rare. In this study, a high-quality PMAOD group discussion refers to the "depth", which contains the level of contributions and focuses on the discussion topics, and "completeness" which includes the length and richness of the discussion content.

To address the mentioned literature gaps, this study aimed to explore the understanding of the students' dialogic processes in PMAOD. To this end, quantitative content analysis (QCA) was employed to delineate the frequency of students' knowledge dimensions and the cognitive processes demonstrated in PMAOD. However, QCA alone did not show the relationship between threaded messages and how message sequence could affect subsequent discussions and cognitive outcomes. Jeong (2003), found that examining the relationship between messages is key to understanding interactions and group processes in computer-mediated communication settings. Hence, lag sequential analysis (LSA) was used to visually present the students' behavioural patterns exhibited during PMAOD. To understand the students' knowledge dimensions and the cognitive processes, the

Revised Bloom Taxonomy (RBT; Anderson & Krathwohl, 2001) was adapted as the coding scheme. Based on RBT, the knowledge dimensions are factual knowledge, conceptual knowledge, procedural knowledge, and metacognitive knowledge. Cognitive processes in RBT include remembering, understanding, applying, analyzing, evaluating, and creating.

By combining the results from the QCA and the LSA, a better understanding of the characteristics and limitations of knowledge constructions and cognitive processing in PMAOD could be achieved. Specifically, this study addresses the following questions:

1. What are the distribution of knowledge dimensions and cognitive processes exhibited by students in PMAOD?
2. What are the students' sequential behavioural patterns of knowledge dimensions and cognitive processes most likely to occur in PMAOD?
3. How do the frequency and observed patterns of knowledge dimensions and cognitive processes differ in high-and low-quality discussion groups?

Methods

Participants

This study was conducted in an undergraduate level blended course titled *Information Communication and Technology for Primary School* in UPM University. It was an eleven-week fundamental course offered during the 2013/2014 first semester, using the learning management system of the university (PutraLMS) and covered various instructional design models and the application of each model to educational practice. The course curriculum required students to engage in three face-to-face working sessions (9 hours) and online group discussions.

Eighty-four students participated in this study. Of the participants, 65 (77.38%) were females, and 19 (22.62%) were males, ranging in age from 29 to 51 (Mean = 44.15). The participants' ethnicity was: 76 Malays (90.48%), three Chinese (3.57%), three Indian (3.57%), and two others (2.38%). The participants' working experience varied from six to 31 years. When asked to describe their confidence level in the usage of PutraLMS to complete their coursework, more than half of the participants (f = 44) reported that their level of confidence was high. Thirty-eight participants (45.24%) perceived themselves at a moderate level, while only two (2.38%) reported their confidence level as low.

Procedure

In this study, peer moderation was employed in the aforementioned course. The participants were randomly divided into 12 groups seven members each. This assignment was completed using random number generator function in Excel ® 2007. Secret forum groups were generated for each group. After a trial session of one week, students participated in seven consecutive discussion topics in their constant groups, discussing theoretical concepts related to the course. Table 1 summarizes the discussion topics. Each topic discussion lasted for one week. Each student moderated a discussion topic for an assigned week within his/her own group. The nature of all seven discussion topics designed for each of the seven learning topics of the course was evaluated as the same by the course instructor. In this study, the peer moderation was reciprocal in nature (De Backer, Van Keer, & Valcke, 2012). In other words, the peer moderator's role was switched among the students, giving equal chance to all students to benefit from assuming a peer moderator's and responder's role (Falchikov & Blythman, 2001).

Each student in the study was assigned to the peer moderator role once and acted as a responder for the remaining six online discussions. The peer moderator's role was scripted and modelled by providing two guidelines instructing students on how to perform their duties. The first guideline was based on the 6-step peer tutor training approach by De Wever, Van Keer, Schellens, and Valcke's (2010); the other was based on the 5-step e-moderation model by Salmon (2000) and a set of sample sentences based on a body of literature (De Smet et al., 2008; Hew & Cheung, 2008). There were two types of evaluations to assess the content and face validity of the two functional guidelines: subject matter experts and pilot test. One week before the onset of each discussion, the moderators received an email containing discussion topics and two validated functional guidelines. They were also allowed to discuss activities with the instructor. To prevent any influence caused by the instructor's subjective interventions and to ensure the objectivity of observations, the instructor did not participate in or provide any guidance to the actual student discussions. While students were participating in the online group discussions, the data regarding learners' participation and online discussion activities were saved in the PutraLMS database and were used for the final QCA and LSA.

Table 1. Weekly Online Discussion Topics

	Topic
1	Analysis phase is the first phase in interactive multimedia development process. The Analysis phase sets the stage for the whole project. Discuss the steps that you have to go through in Analysis phase in developing interactive multimedia application.
2	Discuss Design phase in interactive multimedia development process and explain definitions related thereto.
3	Explain Development phase in interactive multimedia development process.
4	What is Implementation phase in interactive multimedia development process all about?
5	Explain how formative and summative evaluations are performed to evaluate the e-learning programs?
6	How to promote ICT integration at schools?
7	We are facing significant social and technological changes as well as changes in learners' behaviour due to access to social networking technologies. Describe the competencies necessary for an instructional designer in the current era.

Coding Scheme and Data Analysis

All student posts and comments in the discussion forum were retrieved in chronological order for subsequent analysis. The discussions between the 84 students over seven weeks yielded 2288 messages, which were used for the QCA. In the current study, the RBT coding scheme developed by Anderson and Krathwohl (2001) was used to analyze the learners' cognitive structures and knowledge dimensions in the PMAOD (see Table 2). RBT has two dimensions: a knowledge dimension and a cognitive process dimension.

Table 2. Knowledge and Cognitive Process Dimensions in RBT (Anderson & Krathwohl, 2001)

Dimension	Code	Content	Description	Example
Knowledge Dimension	K1	Factual knowledge	Knowledge including facts, definitions, or terminologies.	"ADDIE model has the sequential steps of Analysis, Design, Development, Implementation, and Evaluation."
	K2	Conceptual knowledge	Knowledge including concepts and constructs.	"Hierarchical Analysis is applied to intellectual, psychomotor and attitudinal skills NOT to Verbal Information."
	K3	Procedural knowledge	A series of procedures or knowledge procedures.	"To do content analysis, we need to go through…"
	K4	Metacognitive knowledge	Knowledge about cognitive tasks, including appropriate contextual and conditional knowledge, or strategic knowledge.	"Here is an example of content analysis diagram which is relevant to what we need to do…"
	K5	Off-topic/ irrelevant to the discussion topic	Other types of knowledge irrelevant to project topic.	"Thanks for your comments. I found it very useful."
Cognitive Process Dimension	C1	Remember	To access relevant knowledge from long-term memory.	"The model needs to be discussed separately as Prof. mentioned. For instance, the first stage refers to… ."
	C2	Understand	To make sense of acquired knowledge; to associate new knowledge with past experience.	"To my knowledge the second phase of the model is similar to what we do in our daily life as …"
	C3	Apply	To do a job or solve a problem through application (procedures).	"The steps that we can follow to finish this phase are listed in page 15."
	C4	Analyze	To break down and analyze each component of knowledge and note the relationship between the part and the whole.	"The problems that arise using this method are too costly, time-consuming, and not effective enough. The first problem refers to…"
	C5	Evaluate	To judge and evaluate based on criteria and standards.	"I agree with your categorization. Based on the coding scheme being provided for content analysis, this content is under the second category."
	C6	Create	To piece different elements together and form a complete and functional whole. To form a new structure by re-assembling elements through mental processes.	"So far the contributions seem to be focussing on… and it can be concluded that the solution to have a focused content analysis is designing a good codification scheme."
	C7	Off topic/ irrelevant to the discussion topic	Other types of knowledge irrelevant to project topic.	"Sincerely, if anyone still can't see it they can contact me."

The RBT coding scheme has been used in some studies (e.g., Hou, 2011; Jansen, Booth, & Smith, 2009) analyzing students' learning processes and outcomes in different contexts. Therefore, the validity of the coding scheme was ensured. The unit of analysis was each student message or reply made in the constant groups. To assess inter-rater reliability, the codification task was completed by a separate trained coder, who codified the entire messages based on the RBT coding scheme shown in Table 1. Note that each message was coded with one code from the knowledge dimension and one code from the cognitive dimension according to RBT. For example, when student A posted an off-topic message, it was coded as both K5 and C7 during the coding phase. Inter-rater reliability was calculated utilizing Cohen's Kappa (Cohen, 1960), which yielded a value of $\kappa = 0.86$ for the knowledge dimensions and $\kappa = 0.83$ for the cognitive processes, both of which reach the $p < 0.05$ level of significance, suggesting high inter-coder reliability (Neuendorf, 2002).

To compare the behavioural frequency and patterns of the high and low-quality groups, the teacher who was most knowledgeable on each discussion topic and the subject matter graded the discussion content of the twelve groups of learners on four dimensions: depth of analysis, clarifying a topic, collecting information, and making conclusions. Each dimension was graded from 0 to 5. To achieve a high-quality group grade, a high score (5) on all dimensions was needed. In other words, a score of 0 showed that the discussion content was off-topic and not relevant to the topic.

For the final comparison and analysis, the 12 groups were ranked according to their scores in descending order and the top four groups (i.e., G8, G4, G2, G6) and the last four groups (i.e., G1, G6, G9, G11) were selected as the "high-quality discussion groups" and the "low-quality discussion groups", respectively. Next, discussions in the high-quality groups and low-quality groups underwent QCA and LSA of behaviours. Using LSA for the QCA coding results, student online discussion behavioural patterns and sequential correlation with statistical significance were analyzed. LSA was applied in this study because many researchers have utilized this method (Bakeman & Gottman, 1997; Hou, 2011; Hou, Chang, & Sung, 2008; Lin, Hou, Wang, & Chang, 2013) and have stated that LSA could help to visualize the learners' overall behavioural sequences through the online discussion process, allowing researchers to recognize learners' knowledge constructions and cognitive process patterns.

Therefore, following the process noted by Bakeman and Gottman (1997), the coded data of QCA was arranged in chronological order, behaviour frequencies (transitional frequency matrix) were computed, and then the transitional probability (conditional probability matrix) and the expected-value matrix of each code were performed. Based on these matrices, the adjusted residuals table (*Z*-score table) was calculated for each possible behaviour pairing, to examine whether the appearance of one specific behaviour followed by another specific behaviour could reach statistical significance and hence determine statistically significant behavioural patterns. A Z score greater than 1.96 indicated the behaviour sequence reached the level of significance ($p < 0.05$). For example, when the sequence of C3 (apply) → C4 (analyze) reached a level of significance, the Z-value indicated students interpreted and demonstrated discussion tasks through procedures and in a new form, and then were able to immediately and easily make a connection between different parts of the procedure and appraise, criticize, distinguish or compare different parts.

The significant sequences were then converted into graphical illustrations (sequential transfer diagrams) to provide a visual representation of how students' knowledge dimensions and cognitive processes were sequenced in time.

Results

Results of QCA

The analysis of the 2288 messages demonstrated by the 84 students during the seven weeks yielded the code distribution shown in Table 3. Table 3 shows the frequency and distribution of knowledge dimensions and cognitive processes demonstrated by both high-quality groups per se, and low-quality groups.

As shown in Table 3, in terms of students' knowledge dimension ($N = 84$), the percentage of "metacognitive knowledge" was the highest (K4 = 43.62%), followed by "factual knowledge" (K1 = 21.46%), while "procedural knowledge" accounted for the smallest proportion of the learners' knowledge behaviour (K3 = 1.66%).

For the distribution of the cognitive achievement, as indicated in Table 3, students ($N = 84$) were mostly clustered around the "understanding" as their cognitive process (C2 = 54.41%), while other cognitive processes such as "remembering" and "applying" were found to be limited in the students' online discussions (C1 = 2.67% and C3 = 1.75, respectively). The cognitive process, evaluation (C5), was not observed in the coding results. In addition, irrelevant discussions (K5 and C7) accounted for a moderate portion of the students' online discussions for both categories (K5 = 22.47% and C7 = 24.30%).

Table 2. Distribution of the Quantitative Content Analysis of Codes Within the Two Dimensions

		Full Member		High-quality		Low-quality	
Dimension	*Category*	*Frequency*	*%*	*Frequency*	*%*	*Frequency*	*%*
Knowledge Dimension	K1	491	21.46	217	20.15	123	31.70
	K2	247	10.79	73	6.78	35	9.02
	K3	38	1.66	19	1.76	0	0.00
	K4	998	43.62	567	52.65	0	0.00
	K5	514	22.47	201	18.66	230	59.28
Total		2288	100.00	1077	100.00	388	100.00
Cognitive Process	C1	61	2.67	16	1.49	32	8.25
	C2	1245	54.41	620	57.57	123	31.70
	C3	40	1.75	15	1.39	2	0.52
	C4	132	5.77	28	2.60	4	1.03
	C6	254	11.10	180	16.71	0	0.00
	C7	556	24.30	218	20.24	227	58.50
Total		2288	100.00	1077	100.00	388	100.00

Note: C5 was not observed in this study

When comparing high- and low-quality groups, as shown in Table 3, the volume of messages in the high-quality discussion groups was more than in the low-quality discussion groups. This indicated that the students in the high-quality groups had more frequent and extended discussions and perhaps were more motivated to continue each discussion. Each individual code also occurred more frequently in the high-quality groups. For the aspect of knowledge dimensions, the high-quality groups showed numerous levels of knowledge dimensions and more K4 (metacognitive knowledge), with 19 episodes of K3 (procedural knowledge). The same type of discussion, however, was performed twice in the low-quality groups. In the high-quality groups, the knowledge dimension was primarily "metacognitive knowledge" (K4 = 52.65%), while in the low-quality groups, "factual knowledge" (K1 = 31.70%) was largely exhibited.

In terms of the cognitive processing discussions, the high-quality groups also exhibited more discussions. The results showed that notable students in the high-quality groups had more discussions and demonstrated more interactions in terms of higher-order cognitive processing, including "analyzing" (C4) and "creativity" (C6), than the low-quality groups. This suggested that in the high-quality groups, the students, to some degree, tried to move to a more in-depth process of task accomplishment after the tasks of understanding and comprehension. Overall, it was found that there is a correlation between active participation and learning effectiveness (the quality of discussion) in PMAOD. In the high-quality groups the "off-topic" discussions (K5 = 18.66% and C7 = 20.24%, respectively) were lower than the low-quality groups (K5 = 59.28% and C7 = 58.50%, respectively). This finding suggested that in the high-quality groups students tried to keep a balance between social presence and cognitive presence and could reorient their focus of attention from off-topic discussions to task-related discussions. Interpretations and discussions are stated in the conclusion and discussion sections.

Results of LSA

Results of QCA were further analyzed using LSA. Results are shown in Tables 4 and 5. In both tables, "rows" refer to behaviours occurring earlier and "columns" to behaviours occurring later in time. The Z-score tests, revealed five behavioural continuities for the knowledge dimensions and nine behavioural transitions for cognitive processing in PMAOD that reached the level of significance. These significant sequences are shown in Figure 1. The circles represent the codes, arrows "→" indicate the direction of the behavioural transfer, arrow thickness represents the level of significance, and the numbers depict the Z-scores of the sequences.

Table 4. Z-scores (Adjusted Residuals) for Knowledge Dimension of Entire Students

Z	K1	K2	K3	K4	K5
K1	29.84*	-3.94	1.13	-12.76	-11.61
K2	-7.06	34.37*	-2.16	-7.85	-8.63
K3	0.34	0.47	0.47	-1.84	1.36
K4	-13.15	-12.18	-3.16	29.41*	-11.99
K5	-8.58	-7.35	4.10*	-15.99	31.67*

Note: $^{*}p < 0.05$

Table 5. Z-scores (Adjusted Residuals) for Cognitive Process Dimension of Entire Students

Z	C1	C2	C3	C4	C6	C7
C1	16.41*	1.51	-1.06	-1.96	-2.80	-4.48
C2	-2.65	35.73*	1.04	-11.13	-17.66	-21.83
C3	0.92	4.88*	-0.85	-0.90	-2.26	-3.61
C4	1.94	-12.04	-1.58	30.52*	2.38*	-4.61
C6	-0.73	-13.67	1.30	3.24*	19.86*	-0.57
C7	-3.88	-26.98	-0.64	-5.04	6.40*	31.05*

Note: $^{*}p < 0.05$

Although QCA showed "metacognitive knowledge" as the most prominent knowledge dimension in PMAOD, it was found that all types of behaviour under the knowledge dimensions exhibited behavioural continuity (i.e., K1 → K1, K2 → K2, and K4 → K4), except for "procedural knowledge" (K3), as shown in Figure 1. In other words, each coding behaviour was independent of the other four codes. An important finding was that during discussions in PMAOD, students tried to maintain a degree of constant focus (K1 → K1, K2 → K2, and K4 → K4). Moreover, students' "off-topic" discussions displayed iterative significant sequence (K5 → K5). The students' sequential behavioural patterns also transferred from "off-topic" discussions (K5) to "factual knowledge" (K5 → K1), meaning that students tried to change their focus of discussions to topic-related talks and thereby continued the discussions. Therefore, within the PMAOD, students' knowledge dimension sequences were relatively iterative.

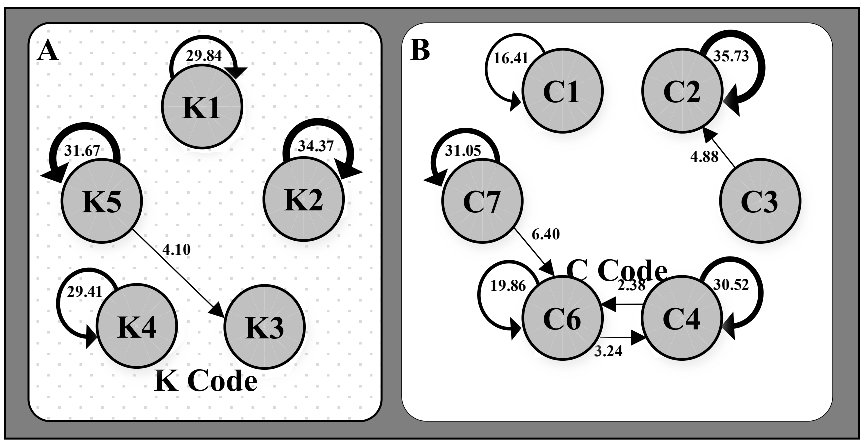

Figure 1. Behavioural transfer diagram for knowledge dimension (A) and cognitive process dimension (B).

When examining the pattern of codes in cognitive processing, the significant sequences were C1 → C1, C2 → C2, C3 → C2, C4 → C4, C4 → C6, C6 → C4, and C6 → C6. Furthermore, among these seven significant sequences there were bidirectional interactions between C4 (analysis) and C6 (create) (C4 → C6, C6 → C4). Except for the "apply" (C3) behaviour, the other five patterns of cognitive processes were continued and again participants maintained a constant degree of behaviours in PMAOD. C5 was not found in coding behaviours. It was also found that the "applying" behaviour (C3) was followed by "understanding" (C2) discussions. It showed that students were systematically demonstrating application and understanding during PMAOD (C3 → C2) while maintaining a degree of constant focus (C1 → C1, C2 → C2). Furthermore, after analyzing the components of a task (analyze), students often engaged in the creation activities such as forming a complete structure by putting elements together. The independence of "off-topic" discussions (C7) with other six coding cognitive behaviours suggested that learners were focused to a certain degree on learning-related discussions. For example, the scenario of students completing “remembering”, “understanding”, “applying”, “analyzing”, and “creating” behaviours and immediately deviating from topic discussions showed no significance sequencing pattern (C1→ C7, C2 → C7, C3 → C7, C4 → C7, C6 → C7), indicating that learners attained a certain degree of focus during the discussions. More importantly, even under the off-topic behaviour learners were still able to achieve a pattern of behaviours from “off-topic” to learning-related discussions (C7 → C6). Thus, a certain portion of “off-topic” discussions occurred independently and did not compromise the quality of the discussions but seemed to be beneficial in creating a knowledge-sharing atmosphere. An example of off-topic discussion is appreciating and encouraging people to contribute. It helps students to feel that their group members are willing to consider their opinions (Hew & Hara, 2007). One of the students (M22) said:

> I believe that you all have good views to share in the issue. So make it open to all.

Expression of appreciation is also helpful in creating a knowledge sharing atmosphere as found in one of the students’ (M49) dialogue:

> Thank you and congratulations on your advice and good reviews. It was a rapid response to the views and other friends’ suggestion. CONGRATULATIONS.

In terms of comparing high- and low-quality discussion groups, the results of the sequential analysis are shown in Tables 6 and 7. For this analysis 1077 messages from the high-quality groups and 388 messages from the low-quality groups determined through QCA were acquired. With respect to the knowledge dimension, seven significant sequences were found in the high-quality group, while in the low-quality groups only three significant sequences during online discussions were found. There were eight behavioural continuities in the high-quality groups with regard to the cognitive processing. Nonetheless, low-quality groups showed three behavioural continuities. The behavioural transition diagrams illustrated in Figure 2 are inferred from the data in Tables 6 and 7.

Table 6. Z-scores (Adjusted Residuals) for Knowledge Dimension in High- and Low-Quality Groups

	Knowledge Dimension									
	High-quality					*Low-quality*				
Z	K1	K2	K3	K4	K5	K1	K2	K3	K4	K5
K1	2.51*	8.54*	2.40*	-7.66	0.91	2.09*	-1.57	-	-	-1.06
K2	8.54*	0.99	-0.27	-5.21	-2.67	-2.62	9.97*	-	-	-3.33
K3	-0.37	0.74	-0.57	0.25	-0.21	-	-	-	-	-
K4	-7.97	-6.91	-2.32	18.86*	-10.73	-	-	-	-	-
K5	2.23*	-0.82	0.86	-12.99	14.61*	-0.47	-4.26	-	-	2.93*

Note: *$p < 0.05$.

Table 7. Z-Scores (Adjusted Residuals) for Cognitive Process Dimension in High- And Low-Quality Groups

	Cognitive Processing											
	High-quality						*Low-quality*					
Z	C1	C2	C3	C4	C6	C7	C1	C2	C3	C4	C6	C7
C1	22.40*	-3.68	1.76	-0.67	-1.12	-1.40	12.30*	-4.03	-0.43	-0.60	0	-2.88
C2	-2.66	9.96*	-3.30	-2.94	-5.66	-4.08	-2.45	7.72*	-0.97	-0.29	0	-5.72
C3	-0.46	-2.76	25.68*	-0.63	-1.68	-1.90	-0.43	-0.97	-0.10	-0.14	0	1.20
C4	0.92	-4.31	-0.62	18.03*	-1.37	-0.80	-0.60	-0.29	-0.14	-0.21	0	0.68
C6	-1.81	-4.58	-1.69	-1.44	5.06*	2.55*	0	0	0	0	0	0
C7	-2.03	-4.39	-1.90	-1.82	3.61*	3.93*	-4.38	-4.83	1.20	0.68	0	6.70*

Note: *$p < 0.05$.

As Figure 2 shows, the behavioural patterns indicated continuity when students in the high-quality groups discussed “factual knowledge” (K1 → K1), a part of “factual knowledge” discussions extended to “conceptual knowledge” (K1 → K2) and some to “procedural knowledge” (K1 → K3), the continual sequences that were lacking in low-quality groups. Moreover, the sequence of “metacognitive knowledge” followed by “metacognitive knowledge” (K4 → K4) was significant in high-quality groups. “Conceptual knowledge” (K2) and “procedural knowledge” (K3) were not significantly correlated with each other in the high-quality groups. Moreover, behavioural continuity was found between “off-topic” discussions (K5) and “factual knowledge” (K1) in high-quality groups, indicating that students switched their attention back to the discussion topics. It was discovered that the low-quality groups lacked K3 and K4, and only K1 → K1 and K2 → K2 were continued.

With regard to the cognitive processes dimension, in the low-quality groups, C4 and C6 were not significantly correlated with other codes and only lower-order cognitive processing was continued (C1 → C1 and C2 → C2). This finding indicated that the high-quality groups demonstrated numerous levels of cognitive process dimensions in their discussions and thereby exhibited more behavioural patterns. The findings also indicated that there was bidirectional sequential correlation (C7 → C6) between off-topic discussions (C7) and a higher-order cognitive process of creation (C6) in the high-quality groups – but lower than the students' overall sequential correlations. The low-quality groups, however, showed no such sequential correlations. Both groups showed behavioural continuity in "remembering" and "understanding" in terms of cognitive processes and "factual knowledge" from knowledge dimension. "Off-topic" discussions were also continuous in both groups.

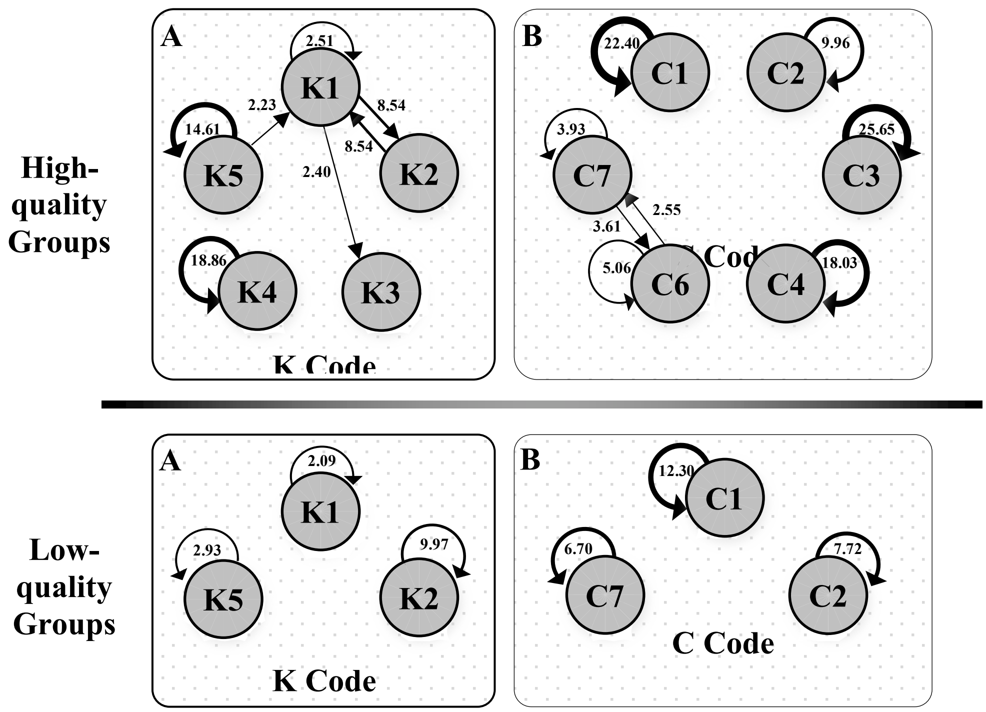

Figure 2. Behavioural transfer diagram for knowledge dimension (A) and cognitive process dimension (B) in high-and low-quality groups.

Discussion

Considering the results of QCA, "metacognitive knowledge" was the primary knowledge dimension in PMAOD (K4; 43.62%), whereas cognitive processes were performed largely at the level of "understanding" (C2; 54.41%). Regarding the distribution of cognitive process codes, many studies (e.g., Lin et al., 2013, 2014; Wang & Hou, 2014; Wu, Chen, & Hou, 2015) have also indicated that student cognitive processes in online discussions (synchronous or asynchronous) concentrate mostly in C2. Moreover, if focus were only on C1-C6 (excluding C2) by discounting "off-topic" discussions (C6), then the total percentage of C1-C6 (excluding C2) was 23.32%. In terms of cognitive diversity, when compared to studies that use RBT coding scheme, the total percentage of C1-C6 (excluding C2) of students on project-based activities using Facebook was 3.42% (Lin et al., 2013) and discussions with concept maps was 6.58% (Wu et al., 2015). The result of this study indicated that cognitive diversity in the PMAOD had a higher and better percentage (23.32%) outcome when compared to the other studies that used the RBT coding scheme and different strategies and tools.

Perhaps students in the PMAOD perceived themselves as having high expectations and greater responsibilities; hence, they demonstrated greater effort in utilizing different interventions and behaviours (Rourke & Anderson, 2002; Zha & Ottendorfer, 2011). However, the quality of their contributions focused more on lower-order cognitive achievements (C1, C2, and C3; 64.46%). These findings echoed results of empirical research focusing on knowledge construction processes in AODs, noting that learners' discussions were often limited to merely voicing opinions or sharing knowledge (Cheung & Hew, 2005; Hou, 2010; Hou & Wu, 2011). In general, higher-level knowledge construction behaviours such as analyzing, reaching agreement or creating new knowledge were difficult to achieve and students seldom moved into them (Chai & Khine, 2006; Cheung & Hew, 2006).

Despite the dominant adoption of "metacognitive knowledge" and the cognitive process of "understanding" in PMAOD, examined by using QCA, the results revealed significant behavioural continuity in all types of behaviours (i.e., K1 → K1, K2 → K2, K4 → K4, K5 → K5, C1 → C1, C2 → C2, C4 → C4, C6 → C6, C7 → C7, all significant ($p < 0.05$), except for "procedural knowledge" and "apply" cognitive behaviours (K3 and C3). Such behavioural transitions also maintained a degree of self-sustainability, showing a certain level of depth and focus in students' cognitive processing and knowledge dimension. Although there were continuous knowledge and cognitive behaviours represented in the students' online discussions, the transfer of other behaviours (e.g., K1 → K2, K1 → K3, K2 → K3, K3 → K4, C1 → C2, C2 → C3, etc.) were less apparent, with the exception of C4 → C6. It showed that in PMAOD, students stopped at the previously discussed knowledge or cognition. In terms of the sequential analysis, this study's findings were similar to those of sequential analyses in other studies of synchronous discussions (e.g. Lin et al., 2013).

Basically, the first step in knowledge sharing is "understanding" and judging the fitness of content to be incorporated for the discussion task (C2). Consequently, "metacognitive knowledge" and the cognitive process of "understanding" were expected to be the dominant dimensions. For instance, when a student collected and exchanged information in PMAOD with the group members, he/she had to first understand the content of the information (requiring cognitive processing such as interpretation, classification, and comparison of the information) and then judge its appropriateness to the discussion task (requiring exhibition of metacognitive knowledge). This finding fitted in with recent research that found evidence of high levels of "metacognitive knowledge" in reciprocal peer tutoring in natural settings (De Backer, Van Keer, & Valcke, 2012).

Prior research had suggested that peer moderation was a promising instructional approach to promote higher-levels of cognitive processing in AODs (Rourke & Anderson, 2002). However, findings from this study indicated that students did not reach higher-levels of cognitive processes utilizing the peer moderation strategy (i.e., C4 = 5.77%, C6 = 11.10%). Moreover, the cognitive process of "evaluate" (C5) was not found in this study and a relatively small proportion of procedural knowledge (K3 = 1.66%), was found in the coding results. This finding may be attributed to moderation techniques used by peer moderators. Challenging other people's ideas and asking thought-provoking questions are critical for promoting richer discussions in online discussions (Hew & Cheung, 2011).

Despite the few levels of cognitive processes (i.e., memorizing, applying, analyzing and creating) and knowledge dimensions (i.e., conceptual and procedural knowledge) in the QCA results, participation in the PMAOD, which provided a highly interactive environment, did not facilitate or promote students' higher-levels of cognitive process behaviours. Seo (2004) found similar results when giving students the role of peer moderators during AODs; it only had a positive effect on students' actual participation (measured through number of posts), but did not improve students' quality of knowledge construction. It may be perceived that students treated PMAOD as a place to simply share their knowledge, judge the appropriateness of the knowledge, and follow the patterns of discussions accordingly, as most of the sequential behaviours had continued deviation.

With regard to the lack of the "analyze" and "evaluate" cognitive processes involved in metacognitive knowledge, one plausible explanation might be the lack of training of peer moderators and relatively short-term nature of the PMAOD intervention. For example, Falchikov and Blythman's (2001) found that peer moderation is an unfamiliar intervention for some students. Thus, students needed time to adjust to new and different ways of interacting with one another. Similarly, the U.S. Department of Education (2001) noted that regular and frequent moderating sessions could lead to greater gains, suggesting that more positive results might be achieved when peer moderators spend more time in moderating activities. In other words, when peer moderators lacked task knowledge and skills, or failed to pass along critical information in ways that could help other members to pursue team goals, the performance of the group would likely suffer.

In addition, Seo (2007) argued that successful enactment of learners' higher cognitive processes in PMOADAS required student training. Moreover, it was noted that lengthening the duration of peer moderation provides students time to acquaint themselves with the required tasks. It could be assumed that the present RMAODs intervention was too short and did not provide adequate training. Hew and Cheung (2010) found that when students felt that the moderators' contributions were superficial and unhelpful they were reluctant to respond with high-quality knowledge. Since peer moderation is usually integrated with leadership and tutoring skills, training sessions prior to moderation supports increased effectiveness of moderators' facilitation skills.

Perhaps the topic of the discussion influenced the findings. To participate in online discussions, students must find the topic worthy of discussion and relate the topic to class learning goals (a construct similar to task value; Wigfield & Eccles, 1992). One student (M53), indicated, "I liked the fourth online discussion. It was more valuable for this course." Another student (M54) continued the conversation by agreeing with M53's view that the topic needed to be "connected" to the course learning objectives. Accordingly, higher-levels of cognitive process, such as "application" (C3), "analysis" (C4), "evaluation" (C5), and "creation" (C6), which are needed for further inquiry, were given less focus.

Prior studies have found different numbers of "off-topic" discussions in online discussions (e.g., Abedin, Daneshgar, & D'Ambra, 2012; Hou, Wang, Lin, & Chang, 2015; Koh, Herring, & Hew, 2010). According to QCA results, the percentages of "off-topic" messages were as modest as 22.47% for knowledge dimension and 24.30% for cognitive processing. Meanwhile, "off-topic" discussions showed behavioural continuity (K5 → K5; C7 → C7). Other studies (Hou, Chang, & Sung, 2009; Lin et al., 2013) have found continued "off-topic" discussions. The frequency of "off-topic" discussions was however; lower in this study than those in previous studies on project-based asynchronous discussions (Hou et al., 2009). As suggested by prior researchers, "off-topic" discussions (such as, greetings or encouraging group members) were beneficial in improving a sense of community among group members and not necessarily detrimental to the quality of the online discussions (Abedin et al., 2012; Veletsianos, 2012). Frequent and positive social interactions in online discussions were found to be helpful in forming a climate of knowledge sharing among group members (Bock, Zmud, Kim, & Lee, 2005).

Sequential analysis in this study found significant behavioural transitions from "off-topic" discussions to "factual knowledge" (K5 → K1) and the cognitive process of "creation" (C7 → C6). This finding, however, contradicted the sequential analyses in other studies of synchronous discussions (Lin et al., 2013; Lin, Hou, Wu, & Chang, 2014) where researchers found no significant sequences or correlation between "off-topic" discussion behaviours and the task-related discussions.

Students’ Discussion Behaviours in High- and Low-Quality PMAOD Groups

Overall, the frequency of posting messages in the high-quality groups was greater than that of posting messages in the low-quality groups. It appeared that messages from students in the high-quality groups reflected more of the knowledge dimension and cognitive processing behaviors in K4 (metacognitive knowledge) and C2 (understanding) than messages from students in the low-quality groups. The higher enactment of higher-level cognitive processing in the high-quality groups is worth noting. These groups significantly exhibited the following sequences: “metacognitive knowledge” (K4) → “metacognitive knowledge” (k4), “apply” → (C3) “apply” (C3), “analyze” (C4) → “analyze” (C4), and “create” (C6) → “create” (C6), which were lacking in the low-quality groups. Moreover, the results of the LSA revealed that the high-quality groups had bidirectional sequence between high-quality cognitive processes (C6 → C4). Overall, the high-quality groups displayed deeper knowledge and cognitive processing behaviors in the discussions. This result might be attributed to the PMAOD intervention, particularly the facilitation techniques enacted by peer moderators. Even though the peer moderators were not trained, they may have been generally familiar with task requirements and expectations concerning the role of peer moderators. When collaborating online with peers, students tended to simply share information, which resulted in confronting different viewpoints on the meaning of the learning content. Perhaps what fostered and optimized these discussions were effective facilitation techniques by the moderators, specifically their use of thought-provoking questions (Hew & Cheung, 2008; Roscoe & Chi, 2008).

The discussion content showed that members of the low-quality groups spent more time on “off-topic” discussions (K5 and C7). Topic familiarity may have affected the nature of students’ interaction. Group members who are unfamiliar with the content may be hesitant to contribute in return. As an example, one student (M30) shared the link of a website and then asked the other group members to respond. “I found this website informative. Please answer this question: how ADDIE model is applicable in designing materials mentioned in this website? Another respondent (M36) shifted the topic to off-topic discussion “Thanks for the link. Excellent website”. By looking at the above excerpts and many other similar cases from our protocol analysis, it is perceived that unfamiliarity with topic often led to sharing of feelings/or irrelevant information.

The findings of this study contradicted those by Hou and Wu (2011) who found that high-quality group projects employing instant messaging tools had a high proportion of “off-topic” discussions. In addition, members of the high-quality groups showed behavioural sequences from “off-topic” discussions to the “factual knowledge” dimension (K5 → K1) and “creating” cognitive process (C7 → C6), which were not observed in the low-quality groups. This finding was also in agreement with previous studies (e.g., Abedin et al., 2012, Bock et al., 2005; Kreijns, Kirschner, Jochems, & Van Buuren, 2004) that found the positive effect of "off-topic" discussions on meaningful discussions. Bock et al. (2005) stated that knowledge sharing is correlated with an organizational climate. This viewpoint may support the findings of this study. Specifically, the "off-topic" discussions among the high-quality groups may have fostered discussions that encouraged their knowledge sharing. However, failure in correlating "off-topic" and "on-topic" discussions probably resulted in low group performance.

In addition, students in the high-quality groups displayed significant sequences from "factual knowledge" to "factual knowledge" (K1 → K1), "factual knowledge" to "conceptual knowledge" (K1 → K2) and "factual knowledge" to "procedural knowledge" (K1 → K3). These continual sequences were lacking in low-quality groups. Similarly, significant behavioural sequences of blog usage by teachers from "factual knowledge" to "factual knowledge" (K1 → K1), and "factual knowledge" to "procedural knowledge" (K1 → K3), was reported by Hou, et al. (2009).

Implications

This study has the following practical implications for online teaching practices: (a) enable students to take turns as peer moderators, (b) train peer moderators, (c) be cautious about the duration of PMAOD, and (d) assign motivating discussion topics. Each implication is discussed in further detail below. Moreover, probing the potential differences between the high- and low-quality groups in terms of interactions and learning behaviours, positive factors were identified resulting in high-quality discussions and the latent limitations of low-quality discussions, which are explained below.

Enable students to take turns as peer moderators. When each student is provided with the opportunity to assume the moderator's role, a more engaging forum may be achieved. Similarly, as suggested and asserted by Zha and Ottendorfer (2011), "every student in class should have the opportunity to take the leadership role in group discussions" (p. 247).

Train peer moderators. It is critical to note that a well–trained moderator makes a difference. Many research studies have suggested that purposeful training sessions, moderation guidelines, and instructor modelling of moderation tasks should be considered to ensure successful online discussions (e.g., Hew & Cheung, 2008; De Smet et al., 2008; Xie & Bradshaw, 2008). Winograd (2003) emphasized the importance of training for peer moderators by stating that online conferences often failed due to lack of moderator training, which inhibited positive outcomes. Zha and Ottendorfer (2011) also reported that when the instructors devoted more attention to training the leaders, the students stayed on tasks and engaged in higher quality discussions**.** Lack of behavioural sequences from K1 → K1, K1 → K2, and K1 → K3 in low-quality groups supports the importance of appropriate peer moderators' intervention and guidance. One possible way to overcome the lack of these sequences is to train peer moderators to arrange discussion procedures into stages and ask group members to carry out discussions step by step, following the prescribed order. In such an arrangement, students do not skip through discussions and go straight to higher order knowledge dimensions.

Be cautious about the duration of peer-moderated discussions. A time stamp of the activity is critical when considering effective PMAOD. Several studies engaged in one-week discussions (Baran & Correia, 2009; Hew & Cheung, 2008; Xie et al., 2014). It has been suggested that two-week lengths be required in role-based online discussions to provide assigned members ample time to effectively internalize and exercise their role (Hancock, 2012).

Assign motivating discussion topics. Tasks need to be challenging, interesting, and stimulating. The course instructor assessed the topics discussed in this study in order to determine similarity in the level of difficulty. Only one week was allocated for discussing each topic. The result showed low-quality group moderators were not fully involved with stimulating higher-level cognitive processes compared to the high-quality groups. This may be attributed to the cultural background of the participants. Many Asian Pacific students report a face-saving cultural trait—being concerned with how others may perceive them (Zhao & McDougall, 2005). To overcome this cultural barrier, discussion topics should be of common interest and familiar to the discussants. According to Ng, Cheung, and Hew (2009), familiarity with topics was one of the main factors influencing peer moderators' participation in AODs.

Limitations and Suggestions

There were some limitations of this study that may have influenced the results and need to be addressed in future studies. First, this study urges caution in generalizing the results to other contexts, since all participants included in the study were undergraduate students majoring in Education. Moreover, the particular course being examined was a blended course, which contained both face-to-face and online components. With respect to course content and teaching strategies, the goal of the course involved the introduction of instructional design models. To develop better understanding of the relationships among course content, teaching strategies, and characteristics of project tasks, future research should investigate student discussions in PMAOD with varied discussion tasks, such as using project-based learning or incorporating ill-structured problem-based learning (Hou, 2011).

Secondly, the moderators in the current study did not receive training to facilitate group discussions. Subsequent research should also determine which types of training could have the best effects on both peer moderators' performance and those of their group members. Thirdly, for future research, it is suggested that the time allotted for PMAOD be examined and lengthened.

Conclusion

Although many questions remain unsolved in the emerging research on peer moderation during AODs, the current study adds valuable insights to the understanding of behavioural distribution and patterns in terms of knowledge dimension and cognitive processes in PMAOD. Generally, the findings showed that students in PMAOD made significantly more frequent use of "metacognitive knowledge" and cognitive process of "understanding". Despite a dominance of low-level cognitive processing, this study found sequential continuity in all cognitive and knowledge dimension when utilizing LSA. Sequential continuities in "procedural knowledge" and cognitive process of "applying" (K3 → K3 and C3 → C3) were, however, not found. In addition, results showed that using peer moderation in AODs can reduce the frequencies of "off-topic" discussions and help students focus back on the main discussion topics (K1; factual knowledge dimension and C6; cognitive process of create) from "off-topic" discussions.

Furthermore, students in high-quality groups were more likely to demonstrate high-level cognitive process behaviours. They exhibited the following sequences: K5 → K1 and C7→ C6 that were lacking in the low-quality groups. Even though this study did not examine the knowledge dimension and the cognitive processing behaviors at different levels of peer moderators and other group members, the study did show students' cognitive processing during CSCL. Accordingly, students' intention to participate more frequently and diversely in online discussions could be improved by incorporating various moderator strategies. However, currently they still tend to stop more at lower-level cognitive processes.

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