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Construction and evaluation of an online environment to reduce off-topic messaging

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ABSTRACT

Online discussions have become more common as social network services have become more ubiquitous and complement various learning activities. However, studies investigating online discussions in recent years have shown that off-topic messaging has increased with the use of social network services. Thus, determining the design of a mechanism to reduce the frequency of off-topic messaging is an issue deserving attention. This study develops a Facebook-based system and employs two strategies (a filter reminder strategy and a self-reflection strategy) aiming to reduce off-topic messaging in comparative and empirical studies. The research questions are as follows: (a) Which strategy is more effective in reducing off-topic messaging? (b) What are the influences of the strategies on the patterns of students' cognitive processes? and (c) Does this influence occur during discussions? The results indicate that the filter reminder strategy can not only reduce off-topic messaging but also elicit more diversified cognitive behaviors. Finally, based on the findings, this study provides suggestions for future research and advice regarding instruction.

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Online discussion; off-topic; Facebook; cognitive process; lag sequential analysis

1. Background and motivations

With the launch of social media (e.g. Facebook), social network services have revolutionized online learning communities (Cruz-Benito, Borrás-Gené, García-Peñalvo, Blanco, & Therón, 2017; Wang, Woo, Quek, Yang, & Liu, 2012). In online learning communities, peer cooperative learning is often associated with the discussion-based instruction method, which is one of the most important instruction methods in many cooperative learning activities. Discussions not only help students develop cognitive skills and critical thinking abilities (Anderson & Krathwohl, 2001; Anderson, Rourke, Garrison, & Archer, 2001) but also foster a democratic outlook and enable them to accept different views and opinions. Furthermore, instruction that incorporates Internet technologies allows teachers to manage online discussions in real time (Sitzmann, Kraiger, Stewart, & Wisher, 2006).

Common methods for evaluating the learning effects of online discussions include quantitative research on the quantity or frequency of discussions and qualitative research to analyze discussion content, whereas lag sequential analysis (LSA) is frequently used to understand the cognitive process of students engaging in online discussions (e.g. Hou & Wu, 2011; Hou, Wang, Lin, & Chang, 2015; Wu, Hou, & Hwang, 2012). LSA aims to investigate which coding category could significantly follow the next coding category and to visualize the behavioral patterns among a series of coding categories in, for example, the process of an interactive online discussion. As shown by the results of Jeong's (2003) study on the interaction and critical thinking of grouped students during online discussions, conflicting views and opinions can instigate more discussions and critical thinking. Hou and Wu (2011) also investigated knowledge construction behaviors in synchronous discussions.

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The results showed that compared with low-quality discussions, high-quality discussions elicited more diversified behaviors related to knowledge construction and coordination.

Teachers specify topics for online discussions during instructional activities; however, as shown by the results of research on online discussions and lag sequence analyses, the quantity of messages that are irrelevant to the specified topic is high in online environments where teachers do not intervene in the discussions. Some studies have indicated that off-topic messaging represents a type of social talk. Discussions related to the course and social talk are intertwined. Social talk signifies the identity of grouped students. Thus, it can indirectly instigate learning behaviors and exert positive learning effects (Hou & Wu, 2011; Lehman, Cade, & Olney, 2010; Lipponen, Rahikainen, Lallimo, & Hakkarainen, 2003). However, what ratio of off-topic messages can be accepted? In the literature, Paulus's study (2009) indicated that over 50% off-topic messages would influence the quality of a course discussion. In addition, the present related study could not decide a consistent standard to determine what ratio of off-topic messages could be accepted. Table 1 shows that the off-topic messages observed in many studies are over 30% or even 50%. These excessive off-topic messages may influence the quality of online discussion. When the quantity of off-topic messages becomes excessive, it becomes an issue that teachers and researchers must confront (Paulus, 2009) and try to resolve.

Table 1. Research on the proportion of off-topic messages in online discussions in recent years.

Author(s)	Title	% of off-topic	Discussion mode
Lipponen et al. (2003)	Patterns of participation and discourse in elementary students computer-supported collaborative learning	42%	Internet-based asynchronous bulletin board system
Mcalister, Ravenscroft, and Scanlon (2004)	Combining interaction and context design to support collaborative argumentation using a tool for synchronous CMC	28%	Chat data
Paulus (2009)	Online but off-topic: Negotiating common ground in small learning groups	61%	Forum, chat and e-mail
Liang (2010)	Using synchronous online peer response groups in EFL writing: Revision-related discourse	31%–57%	MSN Messenger
Hou and Wu (2011)	Analyzing the social knowledge construction behavioral patterns of an online synchronous collaborative discussion instructional activity using an instant messaging tool: A case study	57.84%	MSN Messenger
Wu et al. (2012)	Exploring students' cognitive dimensions and behavioral patterns during a synchronous peer assessment discussion activity using Instant Messaging	34.6%	MSN Messenger
Wu, Hou, Hwang, and Liu (2013)	Analysis of Learning Behavior in Problem Solving-based and Project-based Discussion Activities within the Seamless Online Learning Integrated Discussion (SOLID) System	42%–54%	MSN Messenger and Facebook Group
Lin, Hou, Wang, and Chang (2013)	Analyzing Knowledge Dimensions and Cognitive Process of a Project-Based Online Discussion Instructional Activity Using Facebook in an Adult and Continuing Education Course	16%	Facebook Group
Wu and Hou (2014)	Exploring the process of planning and implementation phases in an online project-based discussion activity integrating a collaborative concept mapping tool	74.22%–88.85%	Concept mapping tool
Wang and Hou (2014)	Exploring Learners' Cognitive Processing Behavioral Patterns of a Collaborative Creativity Project Using Facebook to Support the Online Discussion	over 30%	Facebook Group
Hou et al. (2015)	Exploring the Learner's Knowledge Construction and Cognitive Patterns of Different Asynchronous Platforms: Comparison of an Online Discussion Forum and Facebook	12.01%–18.31%	Facebook Group and Discussion forum:
Wu, Chen, and Hou (2016)	Exploring the interactive patterns of concept map-based online discussion: a sequential analysis of users' operations, cognitive processing, and knowledge construction.	74%	Concept mapping tool

Some studies have analyzed excessive off-topic messages, but most studies have focused solely on online discussions. To promote student focus in online discussions, this study aims to investigate how off-topic messaging can be reduced with the least intervention.

Regarding how off-topic messaging can be reduced with the least intervention, two issues need clarification. Therefore, an analytical method is needed to explore the learners' performance when they are engaged in discussions held on an online platform. Thus, a lag sequential analysis (LSA) was employed to examine how the reduction in off-topic messaging via the system affected learning performance. Second, Bloom's taxonomy was used to evaluate the performance of learners through their online discussions.

Currently, studies concerning learning performance exhibited in online discussions can be divided into the following two categories: quantitative studies (e.g. number of times and frequency of discussions) (Nam, 2017) and qualitative studies (e.g. content analysis) (Kent, Laslo, & Rafaeli, 2016). Both types of studies possess good characteristics in conducting research. However, this study decided to adopt an LSA because this approach encompasses the two spheres of quantitative and qualitative studies, is able to obtain quantitative results and can identify the model of its operative behavior (e.g. Hou & Wu, 2011; Wu et al., 2012, 2013). LSA is an effective statistical technique that explores sequential coding categories (in an interactive process) by identifying the sequence of coding categories and then presenting visualization of the behavioral model. This analytical method has been recently employed by many researchers analyzing learners' behaviors via online discussions. For instance, Jeong (2003) discovered that conflicting viewpoints emerging in online discussions could facilitate these discussions and activate critical thinking in the group. In contrast, Hou, Chang, and Sung (2008) explored some possible constraints that might result in an asynchronous online discussion when a group of participants attempts to solve a problem through discussion and discovered that these participants can only attain a more satisfactory level of knowledge construction by improving their ability to acknowledge the main points, make a summary, and reach their conclusion by reminiscing about the discussion. Hou and Wu (2011) attempted to discuss the process of knowledge construction in an environment in which synchronous discussions occur. The research findings revealed that compared to a discussion held by low achievers, a discussion held by high achievers could lead to diversified outcomes of knowledge coordination and construction.

Regarding Bloom's taxonomy, Anderson et al. (2001, Anderson, 2006) presented a revision of the cognitive process dimension based on Bloom's taxonomy, which is often used to analyze the cognitive and skill-acquisition levels of all learning activities and has been widely employed to analyze the content produced by online discussions (Tao, 2016). Ng (2017) performed a clustering analysis to better understand the relationship between Bloom's taxonomy and students' performance during the online collaborative learning process, whereas Wu (2019) used Bloom's taxonomy to examine whether a redesign of the system could improve learners' cognitive level when they are engaged in online discussions. Bloom's taxonomy divides the cognitive hierarchy into the following six levels: remembering, understanding, applying, analyzing, evaluating, and creating. Please see the "section of the cognitive process" for details.

2. Reduction in off-topic messaging: current status, strategies and research purposes

Although Paulus (2009) noted that research on off-topic messaging was not mainstream. Some prior research results indicate that a reduction in off-topic messaging may contribute to better learning performance. Wu, Chen, and Hou (2015) compared being "focused on the synchronous discussion" (SD) and "the discussion model was balanced" (BD), they discovered that the off-topic frequency shown in the SD and BD groups was 61.11% and 80.89%, respectively. Their research results revealed that the SD group demonstrated a more diverse behavioral pattern and better user performance than the BD group. Hence, several studies have begun to explore this issue. For example, Paulus (2009)

studied off-topic messaging via the theory of common ground and computer-mediated discourse analysis, while Lipponen et al. (2003) investigated it via qualitative content analysis.

To address the long-unresolved issue of off-topic messaging, Mcalister et al. (2004) designed AcademicTalk based on structured dialogue and a designing context during the course of cooperative argumentation. They found that off-topic messaging was significantly reduced. Furthermore, Badri, Grasso, and Leng (2003) allowed teachers to first find pre-defined words and terms related to off-topic messaging via a filter mechanism for further analysis so that students could receive notices that displayed the quantity of off-topic messages and reminded them to stay on topic.

Other studies have investigated a variety of algorithms to enable filters to more accurately analyze the content of off-topic messages. For example, Van Mulbregt, Carp, Gillick, Lowe, and Yamron (1998) conducted the segmentation of text and topic tracking via hidden Markov models and classical language modeling techniques to identify the characteristics of off-topic messages. Agrawal, Rajagopalan, Srikant, and Xu (2003) established links-only algorithms to classify the content in news groups and analyze groups that contained off-topic messages. Cade, Lehman, and Olney (2010) identified sentences related to off-topic messaging via the Linguistic Inquiry and Word Count tool. Although the classification of off-topic messages via algorithms is characteristic of these studies, they noted a relatively low accuracy or weak ability to define and identify so-called off-topic messages (Cade et al., 2010).

These studies imply that the accuracy of identifying off-topic messages may be relatively low because the identification process is completely performed by algorithms that cannot always distinguish whether content is off-topic or on-topic. For example, students grouped for online discussions might often mention what they ate for lunch and dinner. Normally, these messages are off-topic. However, if the online discussion was about nutritional diets, these messages would be recognized as on topic. Therefore, both automatic and manual proofreading are required to correctly identify off-topic messages. After the features of off-topic messages are known, teachers can implement the *filter reminder strategy* (which is the first strategy adopted by this study) and establish some rules for the system to provide suggestions and reminders in real time.

Second, some studies have required students to select a proper tag for the messages and replies they post. For example, Tu, Blocher, and Gallagher (2010) investigated the differences between threaded and flat-structured online discussion environments for asynchronous discussion. In the flat-structured discussion forum, users were allowed to select a tag for the articles they posted. Research has shown that tags serve as keywords, and users favor them because they can use them directly. Users have to think about the content and attributes of relevant articles in order to select the proper tag, which might be considered an act of meta-cognition to some extent and thus may facilitate self-reflection. Thus, the second strategy adopted in this study to reduce off-topic messaging involved allowing the users to select a tag for their dialogues. We call this the *self-reflection strategy*.

In a literature review, we find that excessive off-topic messaging (e.g. off-topic messaging rates of more than 30%∼50%) often occurs in uncontrolled and unregulated discussion environments. Thus, this study develops a Facebook-based system that incorporates the filter reminder strategy and the self-reflection strategy for empirical research. This study aims to verify whether the design can reduce off-topic messaging. If it can, this study will further verify whether the design will influence the cognitive process (the revised Bloom's taxonomy) among the students. Thus, this study will investigate two major topics:

(1) Which strategy—the filter reminder strategy or the self-reflection strategy—will be more effective in reducing off-topic messaging?
(2) How will the strategies influence the patterns of cognitive processing among students?

3. System development

Figures 1–4 show the procedure followed in the planning and developing of the system and system screenshots. The teacher designs situational questions for the study units and course objectives and groups those questions based on learning objectives. When students join the pre-defined Facebook groups, the teacher can implement a collaborative problem-solving instruction method for online

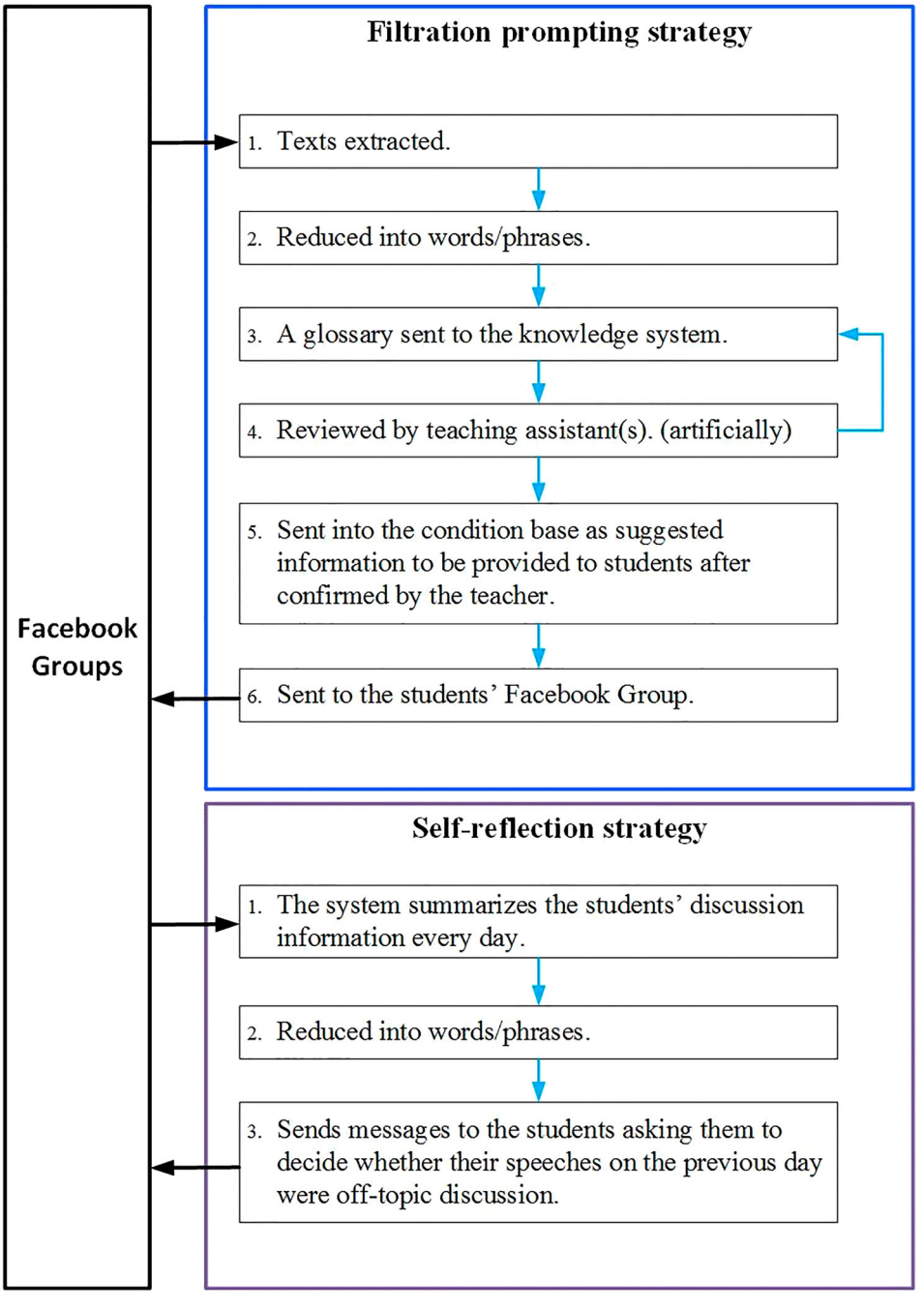

Figure 1. A schematic diagram of the combined off-topic discussion detection mechanism.

Figure 2. Off-topic word management.

discussions as originally planned so that students can engage in discussions concerning the planned content. The system can reduce off-topic messages during the discussion.

For the filter reminder strategy (see Figure 1 upper part), the discussion content extracted by the system via Facebook groups will be stored in the database to identify which students send relevant messages. Next, the system conducts text segmentation. When text segmentation is completed, the results are entered into the knowledge base for comparative analysis. The content extracted from more than ten thousand off-topic messages is stored in the knowledge base by the research team to form a library of common off-topic words and terms (Wu, 2016) (see Figure 2). When the comparative analysis is completed, manual proofreading is conducted to re-examine and fix the results identified by the knowledge base. Next, when the quantity of off-topic messages is determined, the system

Figure 3. Off-topic management mechanism.

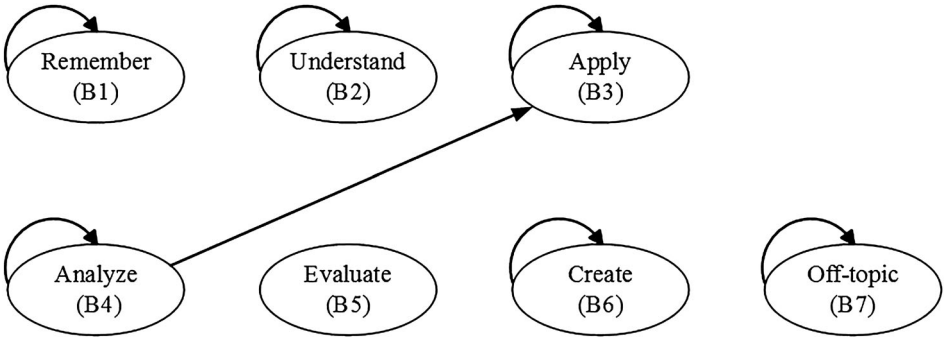

Figure 4. Behavioral transfer diagram for Facebook group only.

publishes the total message quantity and the total off-topic message quantity each day in the database with preset conditions. When the off-topic message quantity reaches a certain number, the system makes suggestions regarding specific messages that should be sent to individual students or all students in the group (see Figure 3). Based on the suggestions in the database with preset conditions, the teacher can send reminders to students.

As for the self-reflection strategy (see Figure 1 lower part), the discussion content extracted by the system via Facebook groups is stored in the database to determine which student sends the messages. Next, the system sends an email to the students each day and asks them to review each message they post. They have to differentiate off-topic messages on their own.

The discussions conducted by each student group are independent; students cannot view the discussion contents in other groups on Facebook. Furthermore, all of the discussion content and system operations are recorded in the database sequentially for post analysis.

4. Research design

4.1. Participants

The students in this course, Introduction to Computer Science, are sophomores. Twenty-eight students are enrolled, and we divide them into seven groups of four. This course was selected because the teacher arranges information-related topics with ethical dilemmas for discussion, and students discuss the topics online.

4.2. Procedures

The experiment flow is shown in Table 2. Based on the course content, the teacher designs topics for online discussions so that students can conduct group discussions and familiarize themselves with the discussion system and the discussion mode. When discussions are conducted, the teacher

Table 2. Experimental process.

Week (s)	Procedures	Topics concerning information ethics
1–2	Grouping practiced system	N/A
3–4	Facebook group	Is the consent of interested parties necessary when their pictures are to be posted in social networks?
5–6	Facebook group + Filter remind strategy	Should cyber-squatters be prosecuted?
7–8	Facebook Group + Self-reflection strategy	Can employees protect the right of privacy over their text messages?
9	Interview	N/A

randomly assigns information ethics-related topics (each topic includes a conditional statement of approximately 400 words) to each of the three activities, one with no off-topic reduction strategy, one with the filter reminder strategy and one with the self-reflection strategy. Each activity is conducted for two weeks. All students participate in the discussion topics under all three experimental conditions. During these two weeks, the teacher requires that students discuss topics concerning information ethics. After their discussions, each group reaches its own conclusions, and the group leaders post their conclusions and the reasons for their conclusions. After students are grouped, they must conduct discussions on Facebook and complete the assigned tasks. After the experiments are finished, interviews are conducted to understand the thoughts and suggestions of the students about the different modes.

4.3. Instrument

4.3.1. Off-topic words and terms

Due to language differences, this study references seven studies from Wu (2016) performed on the analysis of off-topic messages among college students in Taiwan, where 15,229 off-topic messages are used for content analysis. This study extracts 260 off-topic messages words and terms and imports these contents to the knowledge base of this study for comparative analysis. The method of induction is determined by the coder according to the discussion content.

4.3.2. The cognitive process

To understand the cognitive process patterns among students during the course of online discussions as well as the effects of strategies to reduce off-topic messages, this study encodes the cognitive processing dimension of the revised Bloom's taxonomy (Anderson, 2006; Anderson et al., 2001) for the quantitative content analysis and lag sequence analysis. The coding table is often used to analyze the levels of cognitive skills required for various learning activities. The cognitive levels are divided into six categories: remember, understand, apply, analyze, evaluate and create. Discussion content irrelevant to these six categories is classified as off-topic. Table 3 summarizes the details of the coding table, which has been widely used in analyses of online discussion contents (e.g. Johnson, 2008; Lubliner, Widmeyer, & Deek, 2009; Nasstrom, 2009).

4.4. Data analysis

When the experiment is completed, all discussion content is encoded as message units for the cognitive process, which may include several sentences and paragraphs. The first coder (with a professional background in psychology) encodes all of the discussion content. The second coder (also with a professional background in psychology) then randomly selects and encodes 50% of the

Table 3. The cognitive processing dimension of the revised Bloom's taxonomy.

Code	Dimension	Examples of the cognitive processes involved
B1	**Remember**: can the student recall or remember the information?	define, duplicate, list, memorize, recall, repeat, reproduce state
B2	**Understand**: can the student explain ideas or concepts?	classify, describe, discuss, explain, identify, locate, recognize, report, select, translate, paraphrase
B3	**Apply:** can the student use the information in a new way?	choose, demonstrate, dramatize, employ, illustrate, interpret, operate, schedule, sketch, solve, use, write
B4	A**nalyze**: can the student distinguish between the different parts?	appraise, compare, contrast, criticize, differentiate, discriminate, distinguish, examine, experiment, question, test
B5	**Evaluate**: can the student justify a stand or decision?	appraise, argue, defend, judge, select, support, value, evaluate
B6	**Create**: can the student create new product or point of view?	assemble, construct, create, design, develop, formulate, write
B7	Off-Topic	Discussions irrelevant to knowledge construction

discussion content to ensure consistency among raters. Next, the quantity and distribution proportion of each code as well as the lag sequence analysis are analyzed based on the coding results. Then, the codes are arranged in a time sequence to calculate the transition matrix based on the frequency of each code. After a series of matrix sequence calculations, we can infer the sequences that exhibit significant continuity (Bakeman & Gottman, 1997) and draw a sequential transfer diagram to understand the overall cognitive levels and the behavior sequences for knowledge construction.

Finally, in addition to performing quantitative content analysis on the cognitive process and analysis of the behavioral patterns related to the cognitive processes, we conduct qualitative text analysis on the discussion content and interviews to triangulate the results from the quantitative analysis and increase the validity of the study.

5. Results and discussion

In the following section, we investigate which strategy more effectively reduces off-topic messaging and examine the pattern of the cognitive process. We comprehensively discuss the differences between the strategies.

5.1. Quantitative content analysis on the cognitive process

This study adopts three types of discussion strategies. The total number of discussion messages is 2802 in Facebook Groups, 1656 in the filter reminder strategy and 1791 in the self-reflection strategy. Table 4 shows the quantity of messages related to the cognitive process, the quantity of off-topic messages and their proportions.

As indicated by Table 4, in terms of the total quantity of discussion messages, Facebook only generates the most messages, followed by the self-reflection strategy and filter reminder strategy. Interview feedback suggests that students are more used to conducting discussions in Facebook only and they are not used to reminders interfering with their discussions, which could also make them feel monitored. Additionally, in terms of the quantity of on-topic and off-topic messages, although students are not used to reminders that tell them to stay on topic, reminders in the self-reflection strategy and filter reminder strategy can indeed reduce off-topic messaging. Students also indicate that after they become used to the reminders, they can concentrate more on on-topic messages. In this regard, the system mechanism is helpful for reducing off-topic messaging.

Further investigation of the differences between the self-reflection and filter reminder strategy indicates that the proportions of off-topic messages for the two strategies are 33.57% and 31.21%, respectively; this indicates that the differences between the effects of the two strategies on off-topic messaging reduction are insignificant. Based the interview feedback, most students recognize that the self-reflection strategy functions to remind them of off-topic messages, and they think that this mode can indeed make them concentrate more on on-topic messages. For the filter reminder

Table 4. Quantitative content analysis on the three types of discussion strategies.

	Facebook group only		Filter reminder strategy		Self-reflection strategy	
	n	%	*n*	%	*n*	%
Remember (B1)	2	0.07	3	0.18	0	0.00
Understand (B2)	1506	53.75	992	59.90	1175	65.61
Apply (B3)	36	1.28	3	0.18	28	1.56
Analyze (B4)	33	1.18	36	2.17	10	0.56
Evaluate (B5)	1	0.04	5	0.30	0	0.00
Create (B6)	100	3.57	61	3.68	19	1.06
On-topic	1678	58.89	1100	66.41	1232	68.79
Off-topic (B7)	1124	40.11	556	33.57	559	31.21
Total	2802		1656		1791	

strategy, messages are sent to students every day, and they must distinguish between on-topic and off-topic messages on their own. Although it may help students review their own discussion messages, they are very often too busy with schoolwork or other affairs to review their own discussion messages.

Finally, the cognitive process investigation shows that the three groups exhibit no significant differences in their discussion content or cognitive processing. Understand (B2) has the highest proportion among the three groups as it might correspond to the nature of the discussion topics. As this study discusses topics related to information ethics, students must classify, describe, explain or identify relevant topics to a wider extent during the course of discussions.

5.2. The behavioral patterns related to the cognitive process

While the results of the previous section show that the self-reflection and filter reminder strategies reduce excessive off-topic messaging during discussions, it is also worthwhile to investigate whether the use of these strategies can influence the cognitive process of students during discussions. If these strategies could reduce off-topic messaging and influence the cognitive process of students during discussions, this study would go beyond the expectations of the researcher and the teacher. Thus, in the following section, we perform a lag sequence analysis to investigate the pattern of the cognitive process among students during the course of discussions when different strategies are used.

The previous section indicates that SR and FR are two effective strategies that can be used to reduce off-topic messages. However, this finding triggers the following question, which warrants our attention: Could these strategies affect students' cognitive processing? For researchers and instructors, it is undesirable for students' cognitive processing of the information to be negatively affected, even if the off-topic messages can be greatly reduced. Therefore, the following section employs a sequence analysis to explore how students exhibit their cognitive processing styles during discussions.

When we use the sequence analysis to understand the behavioral patterns, we first draw the behavioral transfer diagram based on the adjusted residuals table. The adjusted residuals tables and the behavioral transfer diagrams concerning the three types of discussions in this study are shown in Tables 5–7, and Figures 4–6, respectively. In the adjusted residuals table, the columns indicate the initial behaviors, and the rows indicate the behaviors subsequent to the initial behaviors. When the Z values are >1.96, it means that the sequence has reached significance.

Figure 4 exhibits the behavioral transfer diagram of the Facebook only group, as indicated by the results. Except for evaluate (B5), the Facebook only strategy reaches significance on each of the cognitive behaviors (i.e. B1→B1, B2→B2, B3→B3, B4→B4, B6→B6 and B7→B7). Evaluate (B5) does not reach significance, as the behavior appears only once (see Table 4). In addition, Figure 4 shows the significant behavior sequence of analyze (B4)→apply (B3). In this study, the discussion questions is as follows: "Is the consent of interested parties necessary when their pictures are to be posted on social networks?" Based on the discussion content, we know that students go online to choose and demonstrate relevant pictures as the basis of appraisal or comparison. This example represents application after the analysis.

Table 5. Adjusted residuals table of Facebook group only.

	B1	B2	B3	B4	B5	B6	B7
B1	26.47*	−0.07	−0.16	−0.15	−0.03	−0.27	−0.89
B2	−0.07	20.68*	−0.98	−1.59	0.63	−5.87	−20.2
B3	−0.16	−0.75	22.88*	0.89	−0.11	−1.13	−3.01
B4	−0.15	−1.59	2.43*	28.29*	−0.11	−1.08	−3.09
B5	−0.03	0.63	−0.11	−0.11	−0.02	−0.19	−0.63
B6	−0.27	−5.87	−1.13	−1.08	−0.19	40.02*	−5.1
B7	−0.89	−20.29	−3.01	−3.09	−0.63	−4.78	25.44*

*$p < .05$.

Table 6. Adjusted residuals table of filter reminder strategy.

	B1	B2	B3	B4	B5	B6	B7
B1	13.52*	0.16	−0.07	−0.25	−0.09	−0.33	−1
B2	0.16	14.79*	0.16	−2.06	−1.15	−4.09	−15.31
B3	−0.07	0.16	13.52*	−0.25	−0.09	−0.33	−1
B4	−0.25	−2.27	−0.25	25.19*	2.71*	−1.15	−3.19
B5	−0.09	−1.15	−0.09	2.71*	24.35*	−0.43	−1.29
B6	−0.33	−4.09	−0.33	−1.15	−0.43	25.27*	−3.65
B7	−1	−15.31	−1	−3.48	−1.29	−2.54	21.66*

*$p < .05$.

Table 7. Adjusted residuals table of self-reflection strategy.

	B1	B2	B3	B4	B5	B6	B7
B1	0	0	0	0	0	0	0
B2	0	16*	−2.65	−0.6	0	−2.68	−18.3
B3	0	−2.89	31.15*	−0.39	0	−0.54	−2.62
B4	0	−0.6	−0.39	20.97*	0	−0.32	−1.76
B5	0	0	0	0	0	0	0
B6	0	−3.25	−0.54	−0.32	0	19.64*	0.45
B7	0	−18.06	−2.96	−1.76	0	0.04	25.65*

*$p < .05$.

Figure 5 exhibits the behavioral transfer diagram of the filter reminder strategy. The results indicate that this mechanism has the most diversified behavioral patterns and reaches significance not only for each cognitive behavior but also for the sequence behaviors of analyze (B4)→evaluate (B5) and evaluate (B5)→analyze (B4). This result shows that the filter reminder strategy can more effectively enhance high-level cognitive thinking, which is found to be deficient in most other studies (e.g. Hou, Chang, & Sung, 2007; Wu et al., 2013). Based on the interview feedback and the quantitative analysis, we observe that the filter reminder mechanism is able to not only reduce off-topic messaging but also allow students to better concentrate on relevant topics for discussions. In addition, the cognitive behaviors discussed by the students are the most diversified.

Finally, Figure 6 shows the behavioral transfer diagram of the self-reflection strategy. The results indicate that this mechanism elicits the least behavioral patterns, and no significance is reached for the sequence behaviors (e.g. evaluate (B5)→analyze (B4)). Based on the interview feedback, we know that this phenomenon may result from the fact that students are less likely to respond because messages are sent every day, and they must distinguish between on-topic and off-topic messages on their own. When students are excessively discreet, their freedom to speak is hindered as the discussion environment is less liberal.

As we compare the cognitive processes and behavioral patterns elicited by the three discussion strategies (Facebook strategy, filter reminder strategy and self-reflection strategy), the cognitive

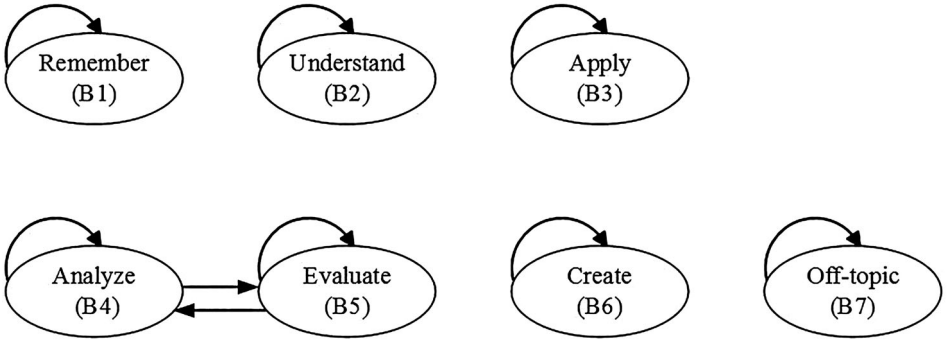

Figure 5. Behavioral transfer diagram for filter reminder strategy.

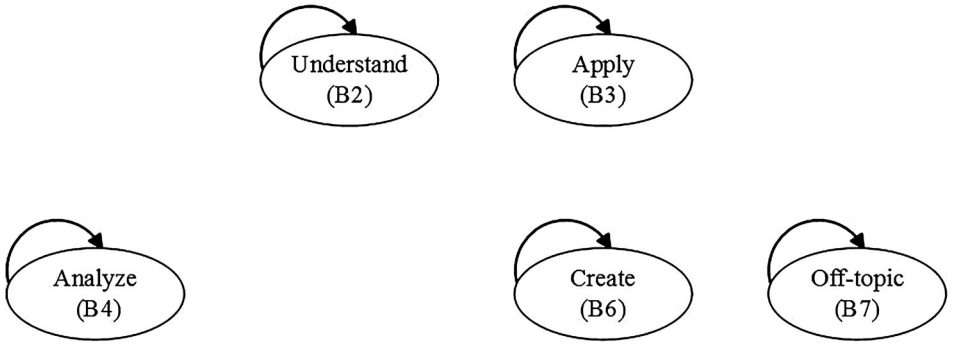

Figure 6. Behavioral transfer diagram for self-reflection strategy.

processing and cross-behavior interactions can be more clearly and diversely observed in the Facebook environment. We observe that the Facebook group strategy usually has positive effects on cognitive process; the quantity of off-topic messages is higher, but it still shows good learning effects. Although the filter reminder and self-reflection strategies can reduce off-topic messaging, they have significantly different learning effects, as we learn from investigating the cognitive process. The filter reminder strategy can improve and diversify the cognitive process, while the self-reflection strategy can limit it. Thus, in this study, the Facebook group only in coordination with the filter reminder strategy can most effectively reduce off-topic messaging and elicit better cognitive behaviors.

6. Conclusion and suggestions

This study was designed to investigate whether a filter reminder strategy or a self-reflection strategy could be used in a Facebook environment to help reduce off-topic comments and promote deeper cognitive strategies among students. To understand whether these strategies can influence the cognitive processing of students during discussions, we conduct a sequential behavioral analysis via the cognitive processing dimension of the revised Bloom's taxonomy.

The first research question seeks to ascertain which strategy can best reduce off-topic messaging. The results of the quantitative content analysis reveal that compared with Facebook only, the filter reminder and self-reflection strategies are better at reducing off-topic messaging. Although students say they are not used to messages or reminders interfering with their discussions (which makes them feel monitored), they still acknowledge the fact that these strategies helped them better concentrate on discussions. The second research question investigates the influence of these strategies on the patterns of the cognitive process among students and asks whether this influence occurs during the course of discussions. The sequence analysis results indicate that the Facebook group elicits good behaviors in terms of the cognitive process. The filter reminder strategy can improve and diversify the cognitive process, while the self-reflection strategy can limit it. Thus, in summary, the Facebook only strategy in coordination with the filter reminder strategy can more effectively reduce off-topic messages and elicit better behaviors in terms of the cognitive process.

Regarding the research limitations, this study investigates only a single case, and these research results need to be confirmed by more empirical studies in the near future. In exploring off-topic messaging, several potential influential factors include the discussed issues (interesting or not), personal factors (prepared knowledge, cognition style, habits of using information, etc.), group factors (degree of cooperation) and others. More case studies may be required to collect more evidence such that researchers can have more references when they investigate strategies for reducing off-topic messaging in online discussions. This study offers relevant suggestions based on research results and experimental findings.

This study provides the following two suggestions for instruction:

(1) How many off-topic messages can be considered excessive? This can be decided by classroom teachers. However, based on the results reported in the literature (see Table 1) and this study, the definition of off-topic messages could be affected by different types of discussions or the use of strategies or tools. This finding merits careful attention.
(2) Based on the number of discussions recorded in the system, when students engage in online discussions, they are usually on topic at the beginning and end of the activity, limiting the effectiveness of the filter reminder strategy. Thus, in the future, we suggest that teachers encourage students to conduct online discussions every day so that the filter reminder strategy can lead to a relevant analysis, and messages/reminders can be sent each day. Alternatively, a considerable amount of discussion among students can be achieved via system setup before the filter reminder is reset.

This study provides three suggestions for future research:

(1) As indicated by the results of this study, Facebook alone in coordination with the filter reminder strategy can both reduce the proportion of off-topic messages and also elicit more diversified cognitive behaviors. However, the filter reminder strategy uses the content prepared by the teacher as a reminder. Future research can further investigate the content of reminders.
(2) As off-topic words and terms differ based on the discussion topics, more and larger databases or new technology (e.g. latent semantic analysis (Landauer, Foltz, & Laham, 1998)) are required for analysis to reduce the verification workload of the teacher or the teacher assistant.
(3) Although the results of this study indicate that the self-reflection strategy is not favored by students, researchers can investigate how to improve it so that students can learn based on scaffolding.

Currently, no statistics regarding the off-topic/on-topic ratios or the percentages of different categories of cognition are available to compare the percentages among the groups, and future researchers could explore this topic.

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