Message Responsiveness During Online Discussions

Gaowei Chen, University of Hong Kong, gwchen@hku.hk
Chung Kwan Lo, Education University of Hong Kong, chungkwanlo@eduhk.hk
Liru Hu, University of Hong Kong, liruhu@connect.hku.hk

Abstract: Students are increasingly learning via online academic discussions, posting messages in an attempt to discuss their learning problems. However, many messages often do not receive responses. This paper aims to understand the relationship between the characteristics of message content and the corresponding message responsiveness. We randomly sampled 140 topics from a high school mathematics online discussion forum and analysed 1,559 reply messages using multilevel logistic regressions at the topic and message level. It was found that a message that either expressed a disagreement, a correct idea or a wrong idea or asked a question was more likely to receive a response. Time was another significant predictor of a message's responsiveness, in that messages posted earlier in a discussion or users that responded more promptly were more likely to receive a response. The findings contribute to the understanding of the discourse processes and students' learning behaviour in online academic discussions.

Introduction

Online discussion forums have been used to support student learning in various education contexts (e.g., Aloni & Harrington, 2018; Wise & Cui, 2018). One research focus of online academic discussion is message responsiveness because this is central for sustaining online discussions and developing online communities (Anderson, 2006; Tsai & Pai, 2013). Message responsiveness increases the lifespan of a discussion, the participants' sense of belonging, and their engagement in online communities (Lee, Reid, & Kim, 2014; Lewallen, Owen, Bantum & Stanton, 2014; Tsai & Pai, 2013). Also, receiving feedback can reinforce knowledge contribution in online communities (Jin, Li, Zhong, & Zhai, 2015; Kim & Sundar, 2014; Tausczik & Pennebaker, 2012). The participants can gain a deeper understanding of learning materials through reviewing and commenting on others' online messages (Aloni & Harrington, 2018; Tsai & Pai, 2013). Therefore, it is important to identify factors that affect message responsiveness in online academic discussion communities.

Content-related factors of post-replying behaviour in online communities are relatively less explored (Fang, Chen, Wang, & George, 2018). Studies have identified some psychological factors that affect online participation and knowledge-sharing behaviour across a range of online communities (e.g., Jin et al., 2015; Joyce & Kraut, 2006; Kim & Sundar, 2014; Lee et al., 2014; Wang & Lai, 2006). For example, the study by Lee et al. (2014) provided evidence that higher levels of online authors' sense of belonging would lead to higher levels of knowledge-sharing activities in an online community of travellers. However, we currently know far less about the factors of a message per se that drive post-relying behaviour in online academic discussion communities. What characteristics of a message will increase or decrease the likelihood of its responsiveness? This study aimed to address this question by analysing the messages in an online academic discussion forum.

Research model and hypotheses

In this study, we adopted the theoretical work of cognitive-social theorists, such as Festinger (1957) and Heider (1946), which affirms that cognitive dissonance and imbalance generate a motivational tendency to resolve these contradictory cognitions. We also used the theoretical model of helping behaviour as proposed by social psychologists (e.g., Latané & Darley, 1970; Yalom, 2005) to approach message responsiveness. We developed a research model with hypotheses about message responsiveness derived from the literature on online discussion. Referring to some existing analytical frameworks for online discussion (Chen, Chiu, & Wang, 2012a, 2012b), the research model was established with five dimensions: (1) evaluations, (2) knowledge content, (3) invitational form, (4) emotional expression, and (5) other factors.

Evaluation

The first dimension, evaluation, is concerned with whether online authors (or e-authors) expressed agreement, disagreement or neutral responses towards another e-author's message. According to Rooderkerk and Pauwels (2016), controversiality of the content is one of the key factors that drive others to react and comment on online messages. Leveraging Festinger's (1957) theory of cognitive dissonance, the researchers explained that the discovery of dissonance arouses cognitive conflict and initiates peer interaction to reduce such conflict. Consistent with the survey result of Tausczik and Pennebaker (2012), in this study, disagreement significantly encouraged

participation in an online mathematics community. Therefore, an expression of disagreement is presumably more likely to get a reply (H-1a). In contrast, the study of Joyce and Kraut (2006) suggested that an expression of agreement did not influence the probability of whether a message received replies or not. In the context of academic discussion, an expression of agreement tends to bring minimal new input to be further discussed. Tausczik and Pennebaker (2012) also suggested that agreement in comments was not related to participation. Therefore, we hypothesise that messages expressing agreement are less likely to receive replies (H-1b). We thus arrive at the first set of hypotheses.

- H-1a. Messages expressing disagreement will increase the likelihood of receiving responses.
- H-1b. Messages expressing agreement will decrease the likelihood of receiving responses.

Knowledge content

The second dimension is the knowledge content of a message to be (or not to be) responded to. In addition to instances of repetition (repeating ideas that have been mentioned earlier) and non-academic content, a message can be classified as expressing correct ideas, wrong ideas or justifications (Chen et al., 2012a, 2012b). Here, justification is an action that supports a new idea by linking it to data using a warrant or backing (Toulmin, 2003). We hypothesise that messages expressing correct ideas (H-2a), wrong ideas (H-2b) and justifying previous ideas (H-2c) are more likely to receive a reply. These claims are supported by the theoretical work of cognitive-social theorists. More specifically, any new ideas (no matter correct or wrong) are likely to create cognitive conflict with other e-authors because one may have different conceptualisations to approach a problem. Such cognitive conflict can lead e-authors to respond to the message to reduce the conflict (Festinger, 1957; Heider, 1946). Messages containing wrong ideas may trigger helping behaviour from other e-authors (Latané & Darley, 1970) to provide feedback and correct the mistakes. Thus, we derived the second set of hypotheses.

- H-2a. Messages expressing correct ideas will increase the likelihood of receiving responses.
- H-2b. Messages expressing wrong ideas will increase the likelihood of receiving responses.
- H-2c. Messages expressing justifications will increase the likelihood of receiving responses.

Invitational form

The third dimension is invitational form, namely, whether the message has explicit invitations for further discussion. During online discussions, messages could be classified into three major categories: (1) questions, (2) commands or (3) other statements without invitation (Chen et al., 2012a). According to Joyce and Kraut (2006), messages in a question format are more likely to receive responses in a newsgroup setting. Through the lens of the helping behaviour model by Latané and Darley (1970), questions may increase the likelihood that other e-authors will notice an appeal for help. Therefore, it is reasonable to expect that an e-author who explicitly asks for help is more likely to receive a response in online academic discussion (H-3a). Davidson-Shivers, Muilenburg, and Tanner (2001) regard commands in online discussion to be part of a broader category of soliciting. In their class of 14 graduate students, they found that the students generally provided substantive responses to these kinds of messages. If e-authors perceive the messages in a command format as solicitation, such messages are likely to receive responses (H-3b). Thus, we formulated the third set of hypotheses.

- H-3a. Messages in a question format will increase the likelihood of receiving responses.
- H-3b. Messages in a command format will increase the likelihood of receiving responses.

Emotional expression

The fourth dimension is emotional expression, concerning the affective experience induced in the messages of online discussion. The expression of affective experience can be positive, negative or neutral. In their study, Jin et al. (2015) examined the effect of positive feedback on knowledge-contribution behaviour in an online social Question & Answer community. They found that e-authors who received more positive feedback would contribute more knowledge to the community. From the perspective of behaviourism (Skinner, 1974), the positive affective experience might have reinforced post-replying behaviour (H-4a). As for the messages expressing negative affective experience, Lewallen et al. (2014) drew on the research of altruism (see Yalom, 2005, for a review) to explain post-replying behaviour. The result of their study supported that negative emotional expression was associated with higher responsiveness from peers. Besides, Ma and Chan (2014) found that altruism had a direct and significant effect on online knowledge sharing on a social media platform. Therefore, we anticipate that the messages expressing negative affective experience are more likely to receive responses (H-4b) and arrive at the fourth set of hypotheses.

- H-4a. Messages expressing positive affective experience will increase the likelihood of receiving responses.
- H-4b. Messages expressing negative affective experience will increase the likelihood of receiving responses.

Other factors

Referring to existing studies of online discussion (e.g., Chen et al., 2012a, 2012b; Fang et al., 2018; Tausczik & Pennebaker, 2012), we considered five other factors that may affect message responsiveness: (1) e-author's number of past posts, (2) topic initiator, (3) message length, (4) message number, and (5) time interval between a message's posting-time and its reply's posting-time. For example, the influence of message length was examined in the study of Fang et al. (2018). The researchers found that there was a positive relationship between message length and the number of replying posts in an online community of travellers.

Method

Online discussion forum and data

In this study, we collected and analysed data from an online discussion forum for high school mathematics. The forum is hosted by Art of Problem Solving (AoPS) Incorporated (http://artofproblemsolving.com) in the US. We chose this forum for the study because it is one of the largest mathematics communities on the Internet. We randomly selected 140 mathematics topics distributed in the year of 2016, excluding those topics that received less than four reply messages. The topics belonged to the three major domains of high school mathematics, namely algebra ($N = 73$), geometry ($N = 29$), and number theory and counting ($N = 38$). At the end of the data collection period (early 2017), the 140 topics had received 1,559 reply messages by 383 e-authors. As a side note, because the provision of personal information is optional in the forum, further analyses on the e-authors (e.g., age, race, and gender) were not feasible. Figure 1 shows an example of a discussion on an algebra problem called 'quadratic 2', including the first few reply messages.

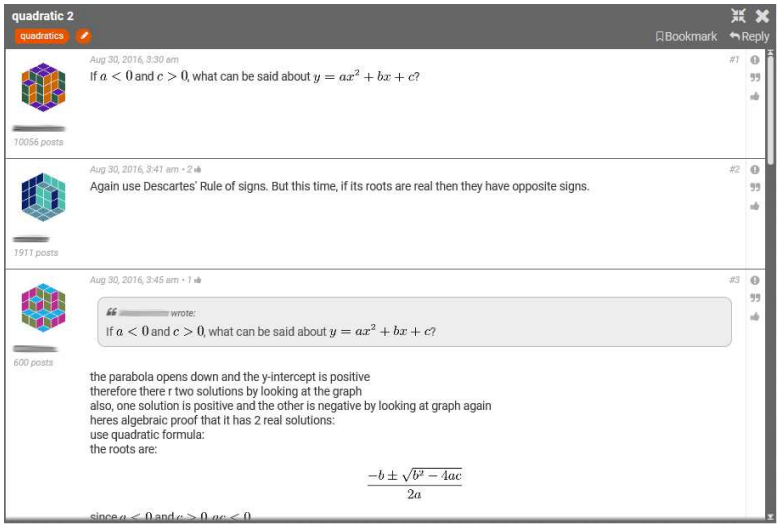

Figure 1. Screenshot of an online discussion and the first few reply messages.

Variables

Table 1 summarises the variables involved in this study. This set of variables was adopted and modified from Chen et al. (2012a, 2012b). There were three main categories: outcome variable (i.e., responsiveness), independent variables, and other factors. All the outcome and independent variables were binary-valued variables with '1' and '0' representing true and false, respectively.

Table 1: A summary of variables and corresponding descriptions

Category	Variable name	Description (values)
Outcome variable	Responsiveness	Whether a message was responded to or not in an online discussion (1 = received response, 0 = received no response)

Independent variables		
• Evaluation	Agreement	Agree with a previous message (1 = true, 0 = false)
	Disagreement	Disagree with at least one point in a previous message (1 = true, 0 = false)
• Knowledge content	Correct idea	An idea that is both correct (consistent with both mathematics and problem constraints) and new relative to the discussion (1 = true, 0 = false)
	Wrong idea	A new idea that is inconsistent with at least one mathematics or problem constraint (1 = true, 0 = false)
	Justification	An action that supports a new idea by linking it to data using a warrant or backing (1 = true, 0 = false)
• Invitational form	Question	Reply as a form of a question (1 = true, 0 = false)
	Command	Reply as a form of a command (1 = true, 0 = false)
• Emotional expression	Positive	Words, symbol or emoticon expressing positive affective state (1 = true, 0 = false)
	Negative	Words, symbol or emoticon expressing negative affective state (1 = true, 0 = false)
• Other factors	Number of past posts	The number of past posts (integer) by an e-author
	Topic initiator	An e-author who initiates the current topic (1 = true, 0 = false)
	Message length	Total number of words in a message (integer)
	Message number	The position of the current reply message in a topic (percentage of the current message's number divided by the total reply messages)
	Time interval	A log transformation of the time interval (minute) between a reply message's posting-time and its predecessor's posting-time along the same thread

In addition to the current-message variables, the present study also examined the variables describing earlier messages in the same thread as past studies showed that recent messages may create a local context that affects the ongoing discussion (Chiu, Molenaar, Chen, Wise, & Fujita, 2014). Constrained by the design of the forum interface, one participant usually responded to the topic or to only one earlier message each time, which helped identify the relationships among the reply messages.

Coding

We used a multi-dimensional coding scheme to reduce the number of needed variables, increase inter-coder reliability, and thereby to capture the data's complexity. For example, the coding scheme has four dimensions: evaluation (agree, disagree, neutral), knowledge content (null academic content, repetition, new idea), invitation to participate (question, command, statement), and emotional expression (positive, negative, neutral). Because each dimension has three categories, this scheme can capture 81 different types of messages (81 = 3 x 3 x 3 x 3). By coding one dimension at a time, a coder chooses among only three possible codes (instead of 81). Thus, the multi-dimensional coding strategy reduces training time, reduces overall coding time, and likely increases inter-coder reliability. Two student helpers coded the data separately. All disagreements were settled through consensus. Krippendorff's α (2004) for each binary variable was above 0.80, indicating high inter-rater reliability.

Data analysis

There were statistical challenges facing the temporal analysis of the discussion process. The present study adopted statistical discourse analysis (SDA; Chen et al., 2012a, 2012b) to address these issues. SDA addresses the outcome issues (i.e., nested data, serial correlation, and discrete variables) with a multilevel analysis, an I^2 index of Q-statistics, and the logit/probit model. SDA models nested data (i.e., messages within topics) with a multilevel analysis. An I^2 index of Q-statistics tested all groups simultaneously for serial correlation of residuals in adjacent events. If the I^2 index shows significant serial correlation, adding the outcome variable value of the previous message often eliminates the serial correlation. Lastly, SDA uses a logit/probit model for binary dependent variables (i.e., responsiveness in the present study).

SDA addresses the explanatory variable issues (i.e., sequential nature of data, possible indirect effects, and false-positive effects). A vector auto-regression combines characteristics of sequences of recent messages into a local context to model how they may affect a current message. To consider indirect effects of explanatory variables, SDA uses multilevel mediation tests. Lastly, SDA uses the two-stage linear step-up procedure to reduce false positive effects (i.e., type I error rate), which has been shown to be more effective than other relevant methods in computer simulations (Benjamini, Krieger, & Yekutieli, 2006).

Applying SDA to the present data, a Logit model was built for the binary outcome variable responsiveness. First, we added topic-level variables as control variables: algebra topic, geometry topic, and

number theory or counting topic. Traditional likelihood ratio test is not reliable for the Logit model, so we used Wald tests to check for the significance of the explanatory variables (Goldstein, 1995). Non-significant variables were removed in subsequent steps. At the message level, we first added the control variables. The variables that describe surrounding properties of a message were added first, which were *message number*, *message length,* and *time interval* between consecutive messages along a thread. Then, the variables that describe e-author' characteristics were added, which were e-author's *number of past posts* and whether an e-author was the topic *initiator* or not. Likewise, non-significant variables were removed in subsequent steps.

We then entered the predictors in order of their temporal occurrence and theoretical importance. First, we tested the evaluation, knowledge content, invitational form and emotional expression hypotheses by entering a list of relevant variables: *agreement*, *disagreement*, *correct idea*, *wrong idea*, *justification*, *question*, *command*, *positive emotion*, and *negative emotion*. Then, we checked for interaction effects among pairs of significant variables. Non-significant variables and interactions were removed from the specification in subsequent analysis. Next, we checked whether the regression coefficients differed significantly at the topic level. If they did, we kept the additional parameters. Otherwise, we removed them. As past studies showed that variables belonging to the lagged messages might also affect the outcome variable belonging to a current message (e.g., Chiu et al., 2014), we then entered lag variables measuring the properties of earlier messages (*–n*), first at –1, then at –2, and lastly –3. An alpha level of .05 was used for all statistical tests.

We conducted additional path analysis to estimate the indirect effects of the significant explanatory variables separately. The explanatory variables were entered in temporal order into the path analysis. To increase the readability of the analysis results, we converted the effect (*E*) of each explanatory variable to an odds ratio, which was indicated by a percentage increase or decrease (+*E*% or –*E*%) in the likelihood of a dependent variable (see Chen et al., 2012b, for the computational details). Lastly, to check if the analysis results depended on the Logit distribution, we repeated the above procedure with a Probit model.

Results

Overall, the analysis results indicate that only the characteristics of a current message significantly predicted its responsiveness. In other words, the impact of its previous messages along the same thread (e.g., lag 1 and lag 2) on post-replying behaviour was not significant. Also, a variance components model showed that the outcome variable responsiveness did not differ significantly across topics, so single-level modelling (message level) was adequate. The corresponding Probit models produced similar parameter estimates. Furthermore, the final model's *Q*-statistics and I^2 index showed no significant serial correlation of residuals for the 140 topics. So, the time-series model was likely appropriate. Table 2 shows the significant effects of each explanatory variable on message responsiveness.

Table 2: Effects of each explanatory variable on message responsiveness (R)

Aspect	Explanatory variable (E)	P(R|E) (%)[a]	P(R|~E) (%)[b]	Effect (%)	Standardised parameter coefficients
Evaluation	Disagreement	67	59	+8	+.355**
Knowledge content	Correct idea	62	53	+9	+.381**
	Wrong idea	76	53	+23	+1.032***
Invitational form	Question	77	53	+24	+1.073***
Other factors	Message number	45	76	–31	–1.396***
	Time interval	64	70	–6	–.282***

[a] Probability that a message receives a reply given that the explanatory variable does occur.
[b] Probability that a message receives a reply given that the explanatory variable does *not* occur.
***$p < .001$; **$p < .01$.

Evaluation

When a message expressed disagreement with previous messages, its likelihood of getting a response would significantly increase from 59% to 67% (+8%; when a disagreement occurred, the message's likelihood to receive a response was 67%; when a disagreement did not occur, the likelihood was 59%; see Table 2), supporting hypothesis H-1b. The likelihood of responsiveness did not change significantly when a message expressed agreement with previous messages. Therefore, hypothesis H-1a was not supported.

Knowledge content

Messages expressing correct ideas or wrong ideas were likely to receive response. For correct ideas, message responsiveness would significantly increase from 53% to 62% (+9%), supporting hypothesis H-2a. As for wrong ideas, the increase was even greater and message responsiveness would significantly increase from 53% to 76% (+23%), supporting hypothesis H-2b. The likelihood of responsiveness did not change significantly when a message included a justification/explanation. Therefore, hypothesis H-2c was not supported.

Invitational form

When a message explicitly invited further response in a question format, its likelihood of getting a response would significantly increase from 53% to 77% (+24%), supporting hypothesis H-3a. For the messages in a command format, no significant effects on message responsiveness were found. Therefore, hypothesis H-3b was not supported. Very few messages included a command in the data set (1.6%). The low occurrence might have limited the generalisability of this result.

Emotional expression

There were no significant effects on the likelihood of responsiveness for messages expressing an affective state. Neither the positive ones nor negative ones significantly altered message responsiveness. Therefore, hypotheses H-4a and H-4b were not supported. It is worth noting that there were relatively few messages expressing emotions (positive = 11.2%; negative = 7.2%). In other words, affective state was not frequently expressed in the researched online discussion forum. The low occurrence thus might have limited the generalisability of this result.

Other significant factors

The analysis results show that the message number and time interval were two other factors that had a significant impact on message responsiveness. Specifically, the likelihood of a later message receiving a reply would decrease from 76% to 45% (–31%; when the message number exceeded the mean message number by 50%). Similarly, the likelihood of receiving a response would decrease from 70% to 64% (–6%) if the time interval between two consecutive messages was 50% longer than the average wait time.

Summary of results

Figure 2 summarises the path analysis of all significant explanatory variables of message responsiveness. The solid and dashed arrows indicate positive and negative effects, respectively. The corresponding value of each arrow is its standardised parameter coefficient. The thicker the line, the larger the effect size.

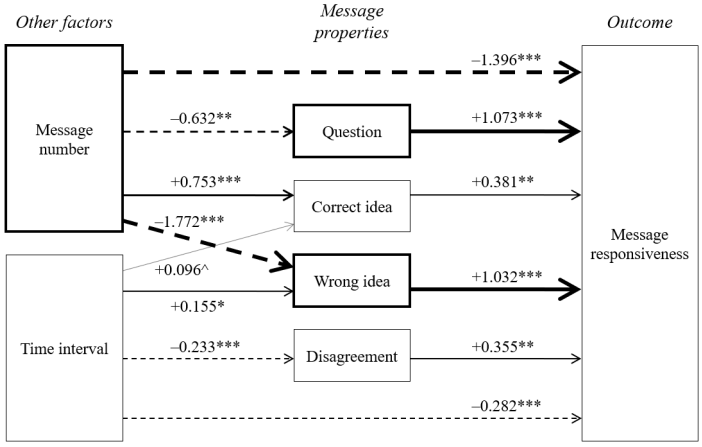

Figure 2. Path analysis of significant explanatory variables of message responsiveness. Corresponding value of each arrow is standardised parameter coefficient. Thicker line indicates larger effect size. ***$p < .001$; **$p < .01$; *$p < .05$; ^$p < .1$.

Discussion

In this study, we adopted statistical discourse analysis to examine how content-related factors of a message would affect the likelihood of the message's responsiveness in online discussion of high school mathematics. The results support the hypotheses about disagreement (H-1a), correct ideas (H-2a), wrong ideas (H-2b) and questions (H-

3a). Apart from content-related factors, the results also indicate that the message number and time interval affected message responsiveness. These results are discussed as follows.

First, messages expressing disagreement were linked to higher responsiveness. This result confirms the survey results of Tausczik and Pennebaker (2012). In online discussion, expressing disagreement with an idea makes visible the cognitive conflict between e-authors. As Heider (1946) comments on cognitive conflict, 'If no balanced state exists, then forces towards this state will arise' (p. 108). In other words, such a cognitive conflict created a momentum for the e-authors to contribute and resolve the problem. Resolving the cognitive conflict can be meaningful for students and eventually lead to a better understanding (Limón, 2001). Educators can encourage students to critically look back at the previous messages and to politely express their disagreement (if any) in online discussions.

Second, both correct ideas and wrong ideas were linked to higher responsiveness. These results can be explained using the theoretical work on helping behaviour (Latané & Darley, 1970; Yalom, 2005) and cognitive conflict (Festinger, 1957; Heider, 1946). The messages expressing correct ideas might elicit other e-authors' confirmation, whereas the ones expressing wrong ideas might trigger other e-authors to correct the mistakes. Both actions can be regarded as helping behaviour towards problem-solving. Given that there are a large number of members in the online discussion forum of this study, it is reasonable to expect that not all of the members would have the same approach to problem-solving. Therefore, any messages expressing new ideas (no matter correct or wrong) elicit the possibility of creating cognitive conflict between e-authors. As a result, the likelihood of receiving a reply increased. In particular, wrong ideas gave rise to greater controversiality leading to further discussions (Rooderkerk & Pauwels, 2016), and therefore, higher responsiveness, as our finding suggested. Educators can encourage students to express new ideas in online discussion. According to the analysis results, their ideas would likely be confirmed or corrected by other capable e-authors. Their learning would thus benefit.

Third, messages in a question format were linked to higher responsiveness. This result was consistent with the study of Joyce and Kraut (2006) in a newsgroup setting. Although altruism can lead to post-replying behaviour (Ma & Chan, 2014), e-authors might overlook others' need for help and take no action. Messages in a question format could increase the chance of others' noticing the need for help (Latané & Darley, 1970) and thus the higher responsiveness. Therefore, questioning is a desirable invitational form for students to ask for further feedback. Our result confirms the value of recent technological development of question prompts in online discussion forums (e.g., Aloni & Harrington, 2018) because posting a question may promote online participation. Educators can consider incorporating this kind of technology in their online discussion forums to scaffold students' discussion process.

Finally, message number and time interval affected responsiveness. The results indicate that later messages in a discussion and those delayed reply messages were less likely to receive responses. When multiple e-authors had contributed their ideas in an online discussion, the problem in question and cognitive conflict between e-authors might have been resolved. In the later stage of discussion, e-authors could find solutions by reading through the posts in the discussion. The momentum of post-replying behaviour was thus reduced. Also, as time goes by, it is reasonable to expect that e-authors might have resolved the problem via some other means (e.g., asking their teacher). Therefore, they no longer needed to revisit their discussion to seek help. Educators can encourage students to provide timely responses in an early stage of discussion. In this way, students can have a higher degree of involvement in online discussion.

Conclusion and implications

This study aimed to identify the content-related factors that affected message responsiveness in online academic discussions. The results suggest that how a message looks backward (i.e., showing a disagreement), posts knowledge content (i.e., adding a new idea that is either correct or wrong), and looks forward (i.e., asking a question) would affect the likelihood of receiving a response. Messages that respond slowly and messages that are posted in the later stages of an online discussion are less likely to receive responses. Based on the results of this study, several implications for online discussion were drawn to sustain and deepen online academic discussions. First, educators can encourage students to critically look back at the previous messages in the discussion of a topic. When students disagree with other e-authors, they can write up their response in a polite way. Expressing disagreement is likely to elicit further response. Such an idea-exchanging process facilitates e-authors to come to a consensus regarding the problem in question and eventually leads to a better understanding of learning materials. Second, educators can encourage students to post their ideas in online discussions. Regardless of whether the ideas are correct or wrong, they are likely to be confirmed or corrected by other e-authors. Third, questioning is a desirable invitational form for further participation. Messages in a question format can increase peer engagement and the potential to sustain online discussions. Finally, educators can remind their students to reply promptly to increase the likelihood of getting feedback from other e-authors.

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