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An Autonomous E-Learning Discussion Facilitator: A Novel Approach

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This paper demonstrates a simulation that an autonomous discussion forum facilitator (AD Bot) framework using natural language processing and fuzzy logic can enhance student engagement in online discussion forums. This includes student to student, and student to instructor engagement as well as increasing knowledge attainment of subject matters discussed, where students receive timely feedback to their discussion post and exposure to relevant supplemental content.

Keywords: Autonomous, Discussion, E-Learning, E-Tutor

Introduction

As education continues to evolve, online learning continues to make strides in becoming a practical option for many students. Many educational institutions have required asynchronous learning to be the primary model for offering courses versus face-to-face learning due to the pandemic caused by COVID-19. A reduced classroom size has drastically increased the number of online learners, where teachers and professors must adjust their teaching pedagogical style to an approach conducive to asynchronous learning. In turn, an instructor's pedagogical style must promote student engagement where students interact with each other and the instructor. A core area where student engagement is critical to understanding and comprehending course material is participation in a class discussion forum.

In this paper, we introduce a model for an autonomous discussion forum facilitator (AD Bot). AD Bot is an asynchronous semantic-based fuzzy logic discussion forum facilitator that uses natural language processing (NLP) to interpret and associate text domains, which allows discussion post context comprehension by the system. Subsequently, providing an autonomous discussion forum facilitator gives instructors the ability to focus on targeting students who need more thorough assistance or more in-depth dialog.

AD Bot aims to evolve the traditional model of discussion forums by making forums more scalable, effective, and efficient for educators. Over the last decade, the class discussion model has evolved very little in online learning environments, where discussion questions are posted by an instructor every week that targets a specific topic from the course content. Class requirements mandate each student to post an initial response to the instructor's question and follow-up post to their peers. Berge and Muilenburg (2000) stated, "even in classrooms that do not use such teacher-centered approaches, question-asking is at the heart of understanding; online learning environments, web-based or otherwise, are often more learner-centered than traditional, brick-and-mortar classroom." Moreover, instructors face challenges achieving the intent of discussion questions in an asynchronous learning environment, which are outline by Borich (2010) and defined in table 1.

Using the work of Borich (2010) as a model to ensure a discussion forum serves its intended purpose. We can extrapolate the current weaknesses in online learning discussion forums include the lack of responsiveness from an instructor and peers; the lack of a sense of community and/or feelings of isolation (Song, Singleton, Hill, & Koh, 2004); and lastly, the student's inability to translate what he or she has learned from course content into a meaningful substantial discussion post. These weaknesses shows that online learning may not consistently fulfill its intended purpose.

Therefore, we define these weaknesses and challenges as "Impersonal Discussion", where an impersonal discussion is a lack of provocative question-asking to a student's post and timely responses from the instructor and other students. In addition, students may not receive an in-depth or related responses from a peer or/and instructor that directly expounds on what a student does not know and what background knowledge the student should learn as a prerequisite to understanding the discussion topic's context.

Table 1

Intent of discussion questions (Borich, 2010)

To arouse interest and curiosity
To focus attention on an issue
To stimulate learners to ask questions
To diagnose specific learning difficulties
To encourage reflection and self-evaluation
To promote thought and the understanding of ideas.
To review content already learned.
To help recall specific information.
To reinforce recently learned material.
To manage or remind students of a procedure.
To teach via student answers.
To probe deeper after an answer is given

This paper is structured as follows. Section II presents an extensive literature review on creating an autonomous discussion forum model that promotes user engagement and learning. Section III is the problem statement and hypothesis. Section IV presents our model, which contains the components of semantics and fuzzy logic. Section V presents an example of applying our model. Last, Section VI offers a conclusion.

Literature Review

In reviewing the various strategies used for online learning since 2000 it becomes clear that semantics, fuzzy logic, Natural Language Processing (NLP), and various forms of instructional material can be important in aiding the instructor in successful facilitation that yields knowledge acquisition and student engagement in online learning environments. Facilitation strategies in the online environment have been shown to be particularly influential in actively engaging students in their courses (Martin, Wang, & Sadaf, 2018). Listed in this section is a view on strategies for engaging students in online learning. This is an important topic due to the current teaching environments imposed by the 2020 COVID-19 Pandemic, where we found most learners from Kindergarten-College and working adults attending training classes forced to obtain knowledge through some form of online learning.

Leaners are interested in a particular lecture when they participate in the learning process. Due to the amount of information presented to learners, its essential that learners can comprehend the subject matter. Student engagement in online discussions is often difficult to perceive as students may only read posts rather than actively engage by posting; referred to as pedagogical lurking (Dennen, 2008). Learners have a need to incorporate their everyday lives into their learning process. Carroll and Morton (2017) suggest including current media in the learning process. This includes Ted Talks, Podcasts, News Feeds, Movies, Music, Political Speeches as well as graphic and moments of daily inspiration to spark conversation and dialogue from students.

Martin et al. (2018) identified twelve different facilitation strategies to enhance instructor presence and instructor connection while improving learning and engagement. To better understand how the structure of discussions affected the virtual learning community, the authors discovered that the format of the discussions altered the patterns of discourse, affected student engagement, and contributed differently to the development of learning communities. They suggest that learning strategies align with social, managerial, pedagogical, and methodological aspects of measurements.

Discussion boards in online courses/units typically are used to facilitate interaction between learner and instructor, learner and learner, and learner and content. Even if the educator has immense experience both in academia and the business world, the online learner may not be swayed simply by that experience. The instructor must present a fresh opinion on a particular subject to attract the learner's attention. Otherwise, the online learner will never feel the need to attend the class or curriculum. However, for that purpose, the educator should have immense knowledge of their subject and the curriculum. Our work proposes automated facilitation that ensures students are engaged with current and related content that adapts to a particular student's interest. This continual engagement promotes increased attendance and content comprehension.

The use of interactive discussion boards in online learning suggests they can be important tools to foster student engagement (Sabry & Baldwin, 2003), but students and facilitators have been critical regarding the structure of forums

and the quality of interaction and content (Thomas & Thorpe, 2019). Without much knowledge, the instructor has difficulty altering their methodologies which could serve as a detriment for themselves as well as their learner base. Another factor that should be addressed by an institution or an educator is the cultural difference between each learner. Cultural barriers can serve as a restriction in the academic process. This is because the student's learning style and the ability to grasp knowledge stems from their cultural roots. Interactive discussion boards differ from our model because discussions are deemed impersonal in situations where the quality of discussions is not consistent for each student, especially in large online classes where the student-to-instructor ratio is not conducive to a personal relationship that fosters direct consistent quality engagement.

Ragusa and Crampton (2018) found that "the quality and timeliness of lecturer feedback was the most valued form of learning communication identified by students regardless of course." Suppose the learner has gained education in a particular language or assesses information based upon the ideologies of their native culture. In that case, they might not be able to contemplate specific subjects or the curriculum. As a result, the learner will filter all the lectures and course materials according to the culture and family background they belong. This substantiates that our model, AD Bot, autonomous facilitation of communication in a discussion forum, may encourage students to complete course materials.

Morton and Carroll (2017), suggest the Whole Person Model of Learning. The Whole Personal Learning Model (WPLM) builds upon another pivotal approach which is none other than Herrmann (2006) Whole Brain Model and offers the real solution to academic distress by combining thinking, learning, individual self-efficacy, intrinsic motivators, self-esteem, life coping survival strategies and the interconnection of each variable with technology. While understandings and definitions of engagement vary, they typically include a reference to behavior, cognition, and emotion, with a recognition that these domains are inherently interconnected (Fredricks, 2011). Moreover, this approach provides the educator with a foundation that can be applied to majority learners, where our approach incorporates this model as a means to provide a personable automated discussion.

Problem Statement and Hypothesis

Problem Statement

Discussion forums are a platform for students to actively apply what they have learned from course content by demonstrating their understanding in the form of a discussion post, which may not consistently serve its general purposes in asynchronous learning environments because of lack of engagement from untimely responses by peers and instructors and the lack of understanding about the discussion topic.

Hypothesis

An autonomous discussion forum facilitator model based on fuzzy logic to provide feedback to students in a discussion forum, where students receive responses to their post in a timely manner with recommendations to supplemental course material will increase student-to-student and student-to-instructor engagement, extend a student's knowledge domain for a discussion topic, improve the quality of a student's discussion post, and create a less impersonal experience for students in online discussions.

Methodology

The components of this model are natural language processing, fuzzy logic, and resource mapping. These components provide this model's ability to automate a discussion board's facilitation in an online learning environment, such that students are more inclined to participate in online discussions and reduce the identify of impersonal discussions.

This model first processes a discussion topic posted by an instructor. If the post is a video or audio recording, then a transcript is generated for natural language processing. Once the transcript is processed, a query is run to find related media associated with the discussion topic. These media may include videos, new and scholarly articles, and conference proceedings. Each post made by a student in a given online course is next processed, where the queried media is mapped to the post with the highest relevancy using fuzzy logic. Lastly, feedback is provided to the student along with recommendations to further discuss with peers in the forum that have similar ideas based on their post.

Algorithmically we can abstract the framework in the following pseudo code:

```
SET expectedNumberOfPost TO Total # of Students
SET actualPost TO 0
SET highest_weight TO 0
SET highest_category TO 0

Interpret the context of the discussion topic
media[] = Perform query of media relevant to the discussion topic
While (actualPosts    < expectedNumberOfPost)
        Process Student Post
        FOR ( i = 1; i < media.count; ++i; ) DO
weight = Compute media[i] weight
IF weight is > highest_weight
SET highest_weight TO weight
SET highest_category TO i
END-IF
END
        Provide Feedback with related media resources based on weight
        Match Post to Peers with related context
END
```

Natural Language Processing

Natural language processing (NLP) is used to analyze the context of a sentence. As students post a response to the instructor's discussion topic, semantics generated build an association between the students' and instructor's post. Moreover, these semantics are used in determining which relevant media are best suited as supplemental reading for the student. For example, if an instructor posts the discussion topic, "What is involved in collecting requirements for a project?" Using Microsoft's cognitive services, natural language processor, we extract key phrases "requirements", "project", and "collection". A cognitive search is then performed on the key phrases, in which an array of resources are created that relates to the topic. Using the semantic term weighting model defined in (Morton & Qu, 2013), we are able to weigh the relevancy of the resources returned from the cognitive search.

$$TF - IDF\left(t_i d_j\right) = \frac{\sum_{i=1}^{c} count(t_i d_j) \times |\, log \frac{corpus\_count\_doc(t_i, corpus)}{count\_doc(t_i, corpus)}|}{corpus} \quad (1)$$

where count (t_i, d_j) refers to the frequency of term t_i in document d_j, also known as term frequency (tf); corpus refers to the number of documents in the corpus; c refers to the total number for terms in a query; count_doc (t, corpus) refers to the number of documents in the corpus that contains a term in set *t*.

Using the calculated weight from (1) we can determine a membership value for each resource returned by the cognitive search and for each post made by the student. The relevance of each input uses these thresholds where Low is TF <= 0.4, Medium is 0.4 < TF <= 0.7, while High is 0.7 < TF <=1.

Fuzzy Logic

According to Khettab, Bensafia, Bourouba, and Azar (2018), fuzzy logic systems address the imprecision of the input and output variables directly by defining them with fuzzy numbers (and fuzzy sets) that can be expressed in linguistic terms (e.g., small, medium and large). Fuzzy logic allows the model to distinguish what content is most relevant to the student based on their discussion post. Therefore, using the formula in (1), we can determine what relevant information needs to be provided to the student as the best relevant feedback when comparing a student's post to determine relevancy, given the fuzzy rules defined in table 1, which consists of an if-part (antecedent) and a then-part (consequence). These fuzzy rules have multiple conditions combined using conjunction (AND), which is also explained as $\mu_{A\wedge B}(x) := \min\{\mu_A(x), \mu_B(x)\}$. Min defines the conjunction of two fuzzy sets as the minimal of degrees of membership of the two fuzzy sets.

Using the membership value of the resource from the cognitive search and membership function in fig 1 for fuzzy

matching with the membership function in fig 2, along with the matching degree, we can apply deduction using relevant rules to determine a result.

Table 2

Fuzzy Rules

Rule		Operator		Consequence
R1	User_Input is Low	AND	Resource_Confidence is Low	Result is Low
R2	User_Input is Low	AND	Resource_Confidence is Medium	Result is Low
R3	User_Input is Low	AND	Resource_Confidence is High	Result Result is Medium
R4	User_Input is Medium	AND	Resource_Confidence is Low	Result is Low
R5	User_Input is Medium	AND	Resource_Confidence is Medium	Result is Medium
R6	User_Input is Medium	AND	Resource_Confidence is High	Result is Medium
R7	User_Input is High	AND	Resource_Confidence is Low	Result is Medium
R8	User_Input is High	AND	Resource_Confidence is Medium	Result is High
R9	User_Input is High	AND	Resource_Confidence is High	Result is High
R10	Initial Input is Empty	AND	Initial Resource_Confidence is High	Result is High

$$f(x) = \begin{cases} Low, & x < .2 \\ Medium, & .5 \geq x \geq .3 \\ High, & 1 \geq x \leq .6 \end{cases}$$

Figure 1. Membership function for User_Input and Resource Confidence

$$\mu_{A \wedge B}(x) \coloneqq min\{\mu_A(x), \mu_B(x)\}$$

Figure 2. Membership function for result confidence

Application of the Framework

To present this model's application, we have provided a simulation of a use case to support its validity, where the instructor and student are fictional actors in this model. In this simulation, as a use case, an instructor posts the discussion topic: "How can technology be used as a competitive advantage?".

The discussion topic is then processed, and key phrases are extracted, which are displayed in table 3. The extracted key phrases are used in a cognitive search where a list of media is returned as results. This list is reduced using fuzzy logic, where membership values are created for each media resource using the formula defined in (1). Table 4 illustrates the weight of each media resource after processing. The system identifies the top relevant media resources and will use them as feedback to students whose discussion post corresponds to the associated media resource.

Therefore, as a student makes their first post "When I think of technology being used as a competitive advantage, I immediately think of Amazon. In our text, Haag and Cummings
state companies "create a competitive advantage by making it more attractive for customers to buy from them than from their competition". Amazon continues to take its use of technology to further levels, creating an edge over additional companies. A customer of Amazon Prime, for example, gets free shipping on clothes and products.

Customers can download television shows, movies, and music for free. Amazon has partnered with Whole Foods to offer grocery delivery. Many other retailers and grocery stores have added free delivery service in an effort to compete with Amazon. The competitive advantage for Amazon versus Price Chopper or HyVee, for example, is they provide other services besides grocery delivery. However, Wal-Mart and Target provide groceries and additional products, which reduces Amazon's advantage in those areas. Consumers will soon be able to purchase any product and service from Amazon, all without leaving their home or interacting with anyone."

The system recommends real-time feedback based on the resources queried from the cognitive search, which allows the student to improve their discussion post before submission. When a student submits their discussion post the system provides a "feedback post", which engages the student immediately, allowing the student to respond as if he or she were having a conversation with an actual instructor. This dialog in the form of feedback promotes a more personal engaging discussion.

Using the results membership function in figure 2, we can determine what resources to use as feedback using the membership functions in figure 1, where one resource was recommended as real-time feedback and two resources was recommended as post submission feedback to the student, which is displayed in table 5. Figure 3 illustrates the ability to provide real-time feedback to a student based on their progress made on their discussion post. Figure 4 demonstrates how autonomous feedback is provided to a student based on their submitted post. In the illustration the student made their post and a reply way made by AD Bot suggesting supplemental resources to encourage the student to expand their scope of learning. The selection of feedback and supplemental resources by AD Bot is determined by selecting the highest degree of relevance or weighted confidence value. This simulation demonstrates that the quality of a discussion forum can be improved, as feedback can be provided in a timely manner which allows the online discussion forum to become a less impersonal discussion and a catalyst for engagement.

Table 3

Extracted Key Phrases

Key Phrases
Competitive advantage
Technology
Technology be used as a competitive advantage

Table 4

Weights for media resources compute against instructor's post

Resource Type	Link to Resource	tf	TF-IDF (Weight)
Video	https://www.ey.com/en_gl/consulting/how-you-can-turn-emerging-technology-into-a-competitive-advantage	13	.9
Website	https://hbr.org/1982/01/technology-as-a-competitive-weapon	11	.75
Article	http://search.proquest.com/openview/0376a7735f37fc59543a5f8f443fa78f/1?pq-origsite=gscholar&cbl=1821485	7	.73
Website	https://www.jmark.com/4-ways-technology-can-give-you-a-competitive-advantage	3	.52
Video	https://www.jmark.com/4-ways-technology-can-give-you-a-competitive-advantage/	1	.103

Table 5

Weights for media resources computed between the student's post and media resource

Feedback Type	Resource	TF	TF-IDF (Weight)
Real-Time	https://hbr.org/1982/01/technology-as-a-competitive-weapon	24	.8
Post-Submission	https://www.jmark.com/4-ways-technology-can-give-you-a-competitive-advantage	19	.78
Post-Submission	http://search.proquest.com/openview/0376a7735f37fc59543a5f8f443fa78f/1?pq-origsite=gscholar&cbl=1821485	17	.76

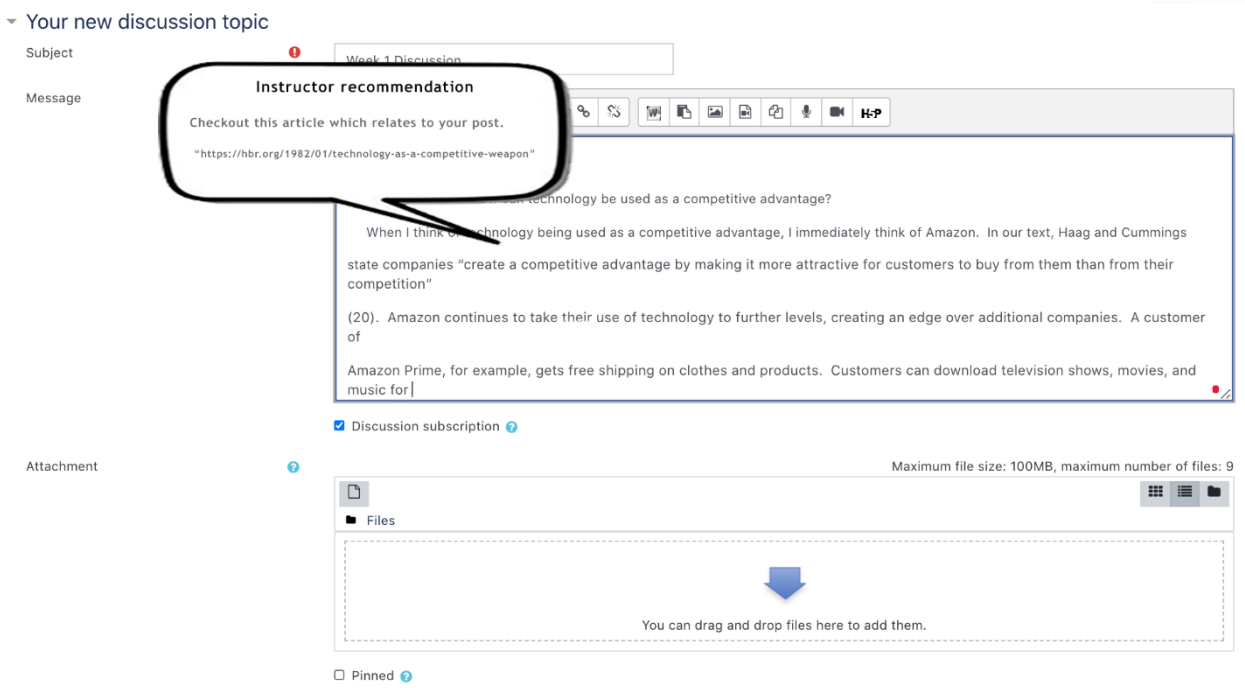

Figure 3. Real-Time Feedback from autonomous facilitator bot

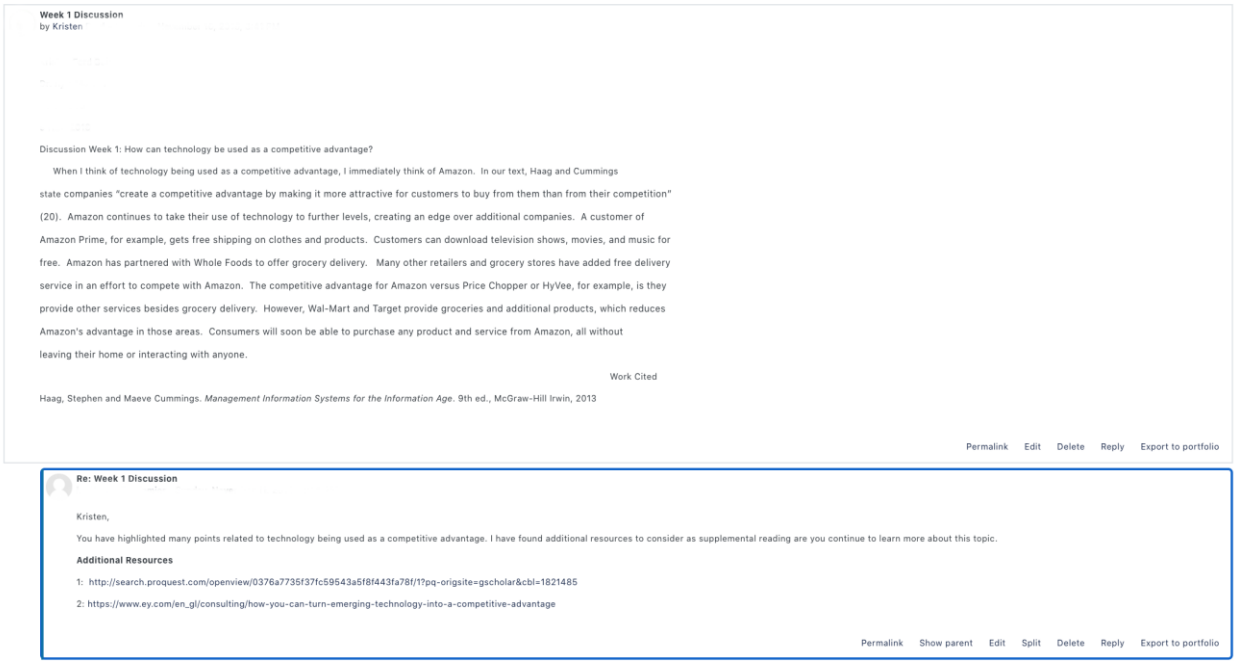

Figure 4. Example of Post-Submission feedback provided by facilitator bot.

Future Work

Based on the evidence provided by our simulation, which demonstrates that feedback can be provided autonomously to a student in a discussion forum, our future work entails implementing AD Bot into a real asynchronous learning environment. This approach would be implemented in two phases, where the first phase is a partial implementation of AD Bot, and the second phase would include full automation — using AD Bot. The partial implementation of AD Bot includes a professor moderating the feedback generated by AD Bot, where the professor approves feedback before posting. This phase aims to gather data that allows the determination of the effectiveness of feedback generated by AD Bot. These analytics may drive improvements to the AD Bot algorithm. For example, students may not want to receive feedback from a bot for every post, which may frustrate the student. Therefore, AD Bot could be refactored to act as a tool for instructors and not as a direct line of communication to the student. This may promote a more personal relationship between the student and instructor.

The second phase of implementing full automation allows the instructor to spend time with students in a one-on-one setting, where an instructor could provide low performing or poor attendance students with the attention, they need in an online learning environment. Full automation of discussion facilitation allows instructors to direct their attention more critical areas in the classroom.

Moreover, AD Bot may be improved to assist instructors in providing feedback on students' assignments. This feature would be beneficial in large online courses where the class size affects how efficiently a professor can provide effective feedback to every student. In addition, AD Bot has the ability to act as an aid in searching a knowledge domain more efficiently than a human professor, which prevents the instructor from spending an enormous amount of time looking for supplemental content for assisting students.

Conclusion

In reviewing the various strategies used for online learning since 2009, it becomes clear that an autonomous discussion forum facilitator, AD Bot, using semantics, fuzzy logic, and NLP to process discussion post made by instructors and students, and various forms of instructional material may be important in aiding the instructor in successful facilitation of a discussion forum that yields knowledge acquisition and student engagement in online learning environments. This paper provides a view of an autonomous discussion facilitator bot that when used properly could enhance student engagement in online discussion forums and address the challenges of a discussion forum, which includes impersonal

discussions.

The primary weaknesses of this model are associated with student engagement, where a student may choose to not fully engage, triggering the bot to explore additional ways to prompt engagement, where the student may think they already fully understand the topic and do not want to further interact with the automated facilitator. This may result in over student-to-facilitator engagement and cause adverse effects for the model to meet the intentions of an online discussion board.

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