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Cognitive and social interaction analysis in graduate discussion forums

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***Abstract*— Discussion forums play a key role in building knowledge repositories in an education institute. Asynchronous discussion forums enable part-time graduate professionals to have a better learning experience. This paper reports how a carefully curated discussion forum enhances the cognitive and social interactions among students in a graduate information systems course. In particular, we analyse the cognitive and social interactions and their impact on the student grades. To our surprise, the graduate students with their limited time resources, have higher order cognitive contributions and reasonable amount of social posts. We present the discussion forum design, cognitive and social behaviour analysis, grade analysis, and social network analysis. We use statistical methods and qualitative analysis to present our findings. Our findings provide useful insights that can be used in designing and implementing discussion forums in graduate business-technical courses.**

Keywords— Interaction analysis, Online Discussion Forums, Cognitive analysis, Social network analysis

I. INTRODUCTION

Interaction, as suggested by educational research, is one of the most important components of teaching and learning experiences [1]. As sociological researchers suggest, instruction ideally occurs in an environment where learners use socially mediated intellectual tools to achieve cognitive development [2].

Online discussion boards are advantageous when they provide an equitable space for all students. These spaces "allow participants who do not speak in classes an opportunity to have a voice and no one dominates the discussion" [3]. This equality prompts more meaningful discussions, increased participation and sense of community [4].

Researchers working in the area of asynchronous discussion boards have called for more studies to examine higher-order thinking and overall effectiveness [5]. They have argued that there is a missing gap in the research of how individuals experience online asynchronous discussions, citing the importance of the connection between the engagement of the interaction and meaningful learning. An important aspects of asynchronous discussion boards is that it gives students more time to interact and reflect before responding [6].

Wiesenberg and Hutton [8] observed some of the challenges related to computer-mediated communication (CMC) experienced by learners in graduate level courses. These included the amount of time involved in participating in online conversations and the challenges of communicating without visual cues. On the contrary, the millennial graduate students who are mostly in university on a part-time mode find discussion forums to be a critical platform that helps them engage with the fellow classmates and peer learning process. The platform also enables them to create a knowledge repository and improve their learning process. In our research work, we would like to study the interactions among graduate students and analyse its impact on the social, cognitive and learning aspects of the graduates. To answer this question, we formulate three research questions:

1) How the design of a discussion thread that is challenging, impacts the interactions among graduate students?
2) What types of interactions exist among the graduate students engaged in the online discussion forum?
3) How does the student interactions in discussion forum affect their grades?

We use data from an online discussion forum in a masters course, “Text Analytics and Applications” taught at the School of Information Systems, in our university (anonymised for the blind review). A study conducted by Burge, on a group of Master of Education students enrolled in a web-based distance program reported a number of challenges that related to peer interaction when dealing with handling and managing large quantities of information in an uncontrolled discussion forum leading to discussion fragmentation [7]. Therefore, we design our discussion forum in a controlled manner using challenging discussion threads so that the students are able to appreciate and participate in the organized discussions. The challenging discussion threads are designed so that that knowledge generated from student response to such posts can be applied to their project and help them prepare for exam.

This paper is structured as follows. Section 2 will review the background of interaction analysis in online forums and other relevant research in this area. Section 3 describes the context of our research problem. Section 4 describes the research approach with details of the dataset and tasks. Section 5 focuses on findings, analysis and answering our research questions, and we conclude in Section 6.

II. BACKGROUND

A. Interactive Learning Environment

Several researchers have studied interactions in the classroom since the 1960s, to quantify verbal behaviour. Applications of interaction analysis include improvement of teaching style and pupil achievement through reflection on classification of interaction type [9]. Additionally, an adapted form of Flanders' system of Interaction Analysis was used to understand and provide feedback on teaching behaviour in a foreign language classroom, for future classroom planning and improvement in content delivery [10]. Both papers use a human labeller to classify the on-going interactions into three categories – teacher talk, student talk and silence or confusion. The interactions are further classified based on whether the interactions are indirect or direct.

Another application of interaction analysis is through Walsh's Classroom Interactional Competence (CIC) framework, applied to help learners self-assess their interaction and conversation strategies to increase learning opportunities in the classroom [11]. The focus of the analysis is based on learner's contribution behaviour in terms of overlap of concept, pauses to assimilate and form ideas, echoes to clarify and support information, and repairs to correct, refute and disprove concepts. In our paper, we study the forum design components that can create an engagement and high level interaction among graduate students.

Lively online discussions can be facilitated by requiring participants to not only post their own work, but also comment and respond to each other's submissions. As a result, the discussions become more than just an assignment; students learn from each other and become more engaged in the learning process. Bruyn (2004) defined social, cognitive and system responses identified in student postings [16]. Garrison proposed a framework based on cognitive and social presence to study the interactions in online discussion forums [15]. In our work, we use the insights from the above research works and some the proposed frameworks for studying the interactions among graduate students and the impact on their learning.

B. Social Network Analysis

Social Network Analysis (SNA) is a useful tool for studying relations [17]. It is a collection of graph analysis methods that researchers developed to analyse networks in social sciences, communication studies, economics, political science, computer networks, and others. A "social network" is defined as a group of collaborating (and/or competing) entities that are related to each other. Mathematically, this is a graph (or a multi-graph); each participant in the collaboration is called an actor and depicted as a node in the graph. Valued relations between actors are depicted as links between the corresponding nodes. Actors can be persons, organizations, or groups—any set of related entities.

Garton, Haythornwaite and Wellman suggested using SNA methods for analysing online networks, in particular learner networks. Several authors have demonstrated the applicability of SNA to specific learning situations [17]. In these studies, the collaborating persons (students, tutors, experts, and so) are the actors. Links between a pair of actors represent the amount of communication between them. Most researchers concentrated on analysing the distribution of power (or centrality) in the resulting network. In our interaction analysis, we use networks to depict the social interactions in terms of social presence-mentions network.

Network Analysis techniques stem from graph theory wherein all relationships are in consideration of time and dependencies. Consisting of nodes and edges, the networks that we drew are directed, that is they consist of a source and a target. Network Analysis techniques are made use of to understand the interactions network in the classroom. The layout algorithm applied to a network can be of multiple types. The ones applied in this paper is based on Fruchterman Reingold Layout. The Fruchterman and Reingold layout is a force directed algorithm that assigns forces (attractive and repulsive forces) according to the edges connecting the vertices. The position of a specific node is defined by the sum of all the repulsive forces to unconnected nodes and all the attractive forces to all the connected nodes. [12]. We use the Circular Layout of the python networkx package that allows placement of all nodes in a two-dimensional circle. However, it does not minimize edge crossings [13].

III. RESEARCH PROBLEM STATEMENT

Our research problem statement is defined based on the interactive analysis frameworks. Garrison proposed a framework based on the types of responses that has several integrated components useful in our study [15]. Firstly, it is designed to analyse online interactions. Secondly, it includes the categories for analysing both social and cognitive behaviour of participants. Finally, it is widely used in asynchronous discussion analysis. Since this framework focuses on different aspects of student involvement in the discussion and how the student expresses his/her thought process in the postings, to suit our research problem, we developed a framework by adapting the Garrison framework.

To describe the research problem, we use the dataset from the graduate student discussion forum. A sample data is depicted in the Table1. The course, "Text Analytics and Applications" is a 13 week course with weekly topics and discussion threads. Table 1 shows the week, course topics and the thread posts under column, body. The details of the complete forum design is described in Section IV.

Cognitive presence focuses on higher order thinking. It includes; recognizing a problem or beginning the dialogue, making suggestions, searching for clarification of the problem, creating solutions to the problem and applying their new ideas and solutions. From Table 1, post from Student 1 is the personal experience that shows the skills of creating solutions. Post from Student 2 is detailed explanation for the problem. Post from Student 3 is on the discovery of the problem with detailed explanation. Post from Student 4 is about the suggestions. Post from Student 5 is the search for clarification or concept in the thread question.

Name	Week	Course Topics	Body
Student 1	1	Text Mining Introduction	I work In IHIS, a healthcare IT provider. I have come across two applications of text analytics here in IHIS.1. predicting whether the patient is a diabetic or non diabetic from the clinical notes. The model will also predict whether other habits of the patient, for eg smoker or a non smoker, does the patient jog regularly or not, etc.2. Using medication data and n-gram method we come with the most probable sequence, for example what is the sequence in which medicines are prescribed to a patient and is there any anything that can be inferred from it.
Student 2	1	Text Mining Introduction	Aside from what everyone else has mentioned above e.g. use by medical staff to keep abreast of fast moving research, I thought one impt use of text analytics was to be able to track the occurrence of illnesses/diseases and detect epidemics quickly. Of course, this would only work where the healthcare system is digitalized and interconnected i.e. what the government is try to achieve today. Assuming there is integration though, text analytics when applied to the diagnoses at a systems level, could yield results in respect of the occurrence of common illnesses e.g. flu, HFMD, and allow prevention measures to be taken to prevent further spread of the diseases.
Student 3	1	Text Mining Introduction	Student 10, Can you please explain more on your first part if you get more data insight of the clinical notes to do other activities because below things can also be done manually.
Student 4	2	Text Classification	Hi all,There are many industries to use text classification.For example, the service industry (restaurant, hotel, Booking.com) will use text classification to do the Sentiment Analysis.With sentiment analysis, usually you may have a comment, tweet or review from a user or customer and you want to programmatically detect the sentiment (if they are talking positively or negatively about something): In the case of hotels, you may classify opinions to know if they are talking about the service, location, price, etc.Thanks
Student 5	2	Text Classification	Generally, there might be drugs that must not occur together in the same prescription, but due to manual digital entry by a doctor, they might have been mixed. When text classification methods are used, they can be classified accordingly through machine learning methods. This kaggle data set on identifying attributes of a doctor https://www.kaggle.com/roamresearch/prescriptionbasedprediction is another interesting way in which text classification can be used.

Table 1: Example posts from discussion forum. The underlined phrases indicate the presence of cognitive and social presence

Social presence includes three categories; 1) emotional expression, such as humour or sharing feelings about the educational experience, 2) open communication including anything to show awareness of the other participants, such as referring to others' comments or quoting someone, and recognition of each other's contributions, such as expressing agreement or complimenting, and 3) group cohesion is anything that reinforces the group dynamic and builds participation, such as greetings, addressing interlocutors by name, personal questions, and "good-byes". The polarity of the post is not considered in this study. From Table 1, we observe posts from Student 3 and 4 depict social presence. Student 3 mentions, "Student 10" in the post while Student 4 exhibits group cohesion by addressing the class with greetings. Based on the above data analysis, we propose the Cognitive-Social Interaction framework for interaction analysis as described in Table 2.

In our proposed consolidated framework, cognitive presence is identified by four components; explanations, applications, search and suggestions. Social presence is identified by two components; mentions and group presence. Our research problem is to apply the framework described in Table 2 to the IS graduates' discussion forum in order to analyse the cognitive and social behaviour. The goal of the framework is to answer the three research questions proposed in Section I.

Table 2: Cognitive-Social Interaction Analysis Framework

Interaction	Component	Posts
Cognitive	Explanations	The explanation posts should be detailed on the topic. Bruyn's approach is to look into the length of the post [16].
	Applications	Past experience of the student is an indicator of his/her application skills.
	Search	The http links or references in the source indicate the search cognitive skills of the person. They exhibit the skills of exploration and information exchange.
	Suggestions	Suggestions indicate the higher order cognitive skills of analysing, evaluating and creating.
Social	Mentions	Quoting directly or referring to the person in the posts indicate the open communication in the discussion forum. Complimenting others is a recognition of the contributions and also indicates social presence
	Group Cohesive	Greeting to the class in a post depicts the presence of group commitment and collaborative communication.

IV. Research Approach

A. Course Discussion Forum design

Student discussion forums showcase three levels of participation

(1) "Lurkers", who read the messages and do not participate. They may learn by reading the posts and incorporating the ideas into their assignments or projects [18].

(2) Students who treat the forum as a notice board, posting their own position and having limited interaction.

(3) Students whose participation is interactive and used to its full potential [19].

The development of a collaborative learning environment is not simply a matter of employing the software to facilitate a communication place and informing the students of its availability and telling them to use it at will. This will result in students not using the communication opportunity at all or dropping out of communication after a very short time [20]. Therefore, the better participation is achieved by designing the forum which is well structured and challenges the students intellectually.

The current studies in discussion forum design are more directed towards design for case study discussions or programming discussions. However, the Information Systems graduate courses are business-IT courses. The graduates exhibit reservations if the forum is redundant and is a mere repetition of the course content. This drives the need for the unique discussion forum design. Moreover, in our experience, we also observed that the questions related to topics not covered in the class are more interesting to the students. Table 3 shows the discussion forum settings for the course. Note that the questions are a mix of business and technical components which align with the course objectives.

Table 3: Discussion forum design with focus on out of class learning. Underlined phrases are the topics. Each thread has questions posted by instructor.

Week	Discussion Forum Thread. (Title is underlined)
0	<u>General discussions</u> General discussions including concepts, labs, class etc.
1	<u>Text Mining Introduction</u> What are applications of Text mining in education domain?
2	<u>Text pre-processing and Natural Language Processing (NLP)</u> How search engines (Bing or Google) use NLP? What are examples of applications of chatbots in different industries?
3	<u>Document Similarity</u> Explain the differences between bag of words & vector space model.
4	<u>Text Classification</u> What are examples of text classification in industry (Government, healthcare, banks etc.)? What are various evaluation measures for text classification?
5	<u>Text Clustering</u> What are visuals for the cluster results - Free draw and upload? Explain one clustering evaluation measures with an example.
6	<u>Information Extraction</u> What are applications of HMM models (Or any Sequence Models)? What are examples of information Extraction in Industry (Finance, Retail, Travel, Healthcare, Media, Education etc.,)
9	<u>Sentiment analysis</u> Discuss technique to handle negation in opinions. Discuss technique to handle sarcasm in opinions. Discuss technique to handle suggestions in opinions.

We further motivate the students by posting the summaries of the posts for each question thread by the end of

the week. Thus, the goal of the discussions was to engage students in interactive reflection of class material, its practical applications and researching beyond classroom learning. To address our first research question, we designed the forum to incorporate such aspects in the thread questions. The discussion forum threads that were created for each week are described in Table 3. We also ensured that the question is broad enough so that the students have the possibility to discuss, research and share their own experiences.

B. Participants and Task

The study was conducted in 2018 on a graduate course, "Text analytics and Applications", offered by School of Information Systems. The course extends for 14 weeks with a break week, study week and an exam week with no class. Out of the 55 students enrolled in the course, 37 students participated in the discussion forums. More than 50% of the students have past industry experience or are currently working in the industry. To motivate the students, every week, the instructor collected the data from the discussion forum and used it as recap slides in the classroom. A total of around 200 student responses were received across all the discussion threads.

C. Data Analysis Methods

Statistical data drawn from the online learning management system, was derived from the standard teaching process. This information includes: the name; grades and posting threads. Aggregated and de-identified data sources were used for this paper, assuring anonymity and confidentiality. One researcher analysed the data and categorised the themes of the posts as described below.

(1) Explanation

Explanation refers to the posts which are lengthy, i.e. more than 20 words.

(2) Application

Application refers to the posts which describe user's personal experiences and uses the phrases that relate to experiences. "As I know", "In my experience", "I work ", "My friend works in" etc., are the phrases that express skills relevant to applications.

(3) Search

Search refers to the posts which consists of http links or APA references. Some students may not explicitly specify the links or references in the posts but use words such as "I found on the net", "I researched", etc.

(4) Mentions

Mentions refers to the posts that mentions other students' names in the post. Refer to the Table 1 for example. "Acknowledgements" are also examples for the social mentions as shown below.

"Thanks Student 10 that was a helpful read."

(5) Group Cohesive

Group cohesive refers to the posts that has words such as "Hi all", "Hello all", "Hi everyone" etc.

To examine our research questions from a more objective standpoint, descriptive statistical methods were adopted to test the statistical association between these relationships. Discussion postings and final results are obtained from the Learning Management System (LMS) and were analysed using statistical measures. The data was categorised into groups in order to determine cognitive and social participation in the discussion forums, as well as their final results. To assist with the exploration of these relationships, and to determine the degree of relation between the variables examined in the study, Pearson Correlation Coefficient procedures were carried out in order to explore the relationship between interactions in the discussion forum and their final results [14]. The results and findings of this process are reported in the following sections.

V. FINDINGS

A. Overall Health of Discussion Forum

Exploring the discussion forum at the high level answers our first research question, "How the design of a discussion thread that is challenging, impacts the interactions among graduate students?"

Figure 1 shows the distribution of discussions by topic. The figure shows the proportions of posts over topics.

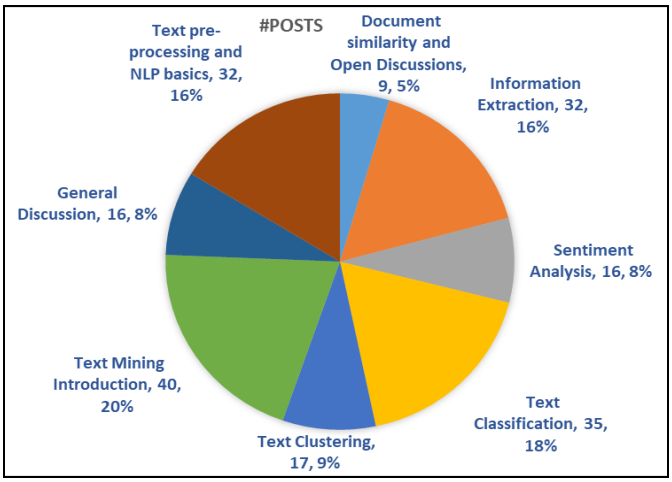

Figure 1: Overall participation across weeks/topics.

We observe that all the topics have similar contributions except for the topic, "document similarity". This is the most challenging topic hence the interactions are lower. From the perspective of the type of questions, the different types of questions namely understanding, analysis and discuss, received similar number of posts from the students. The average number of words per participant is 676, which is quite high, thus indicating students' interest in proving detailed explanations.

B. Cognitive and Social Presence Results

In this analysis, we answer our second research question. "What types of interactions exist among the graduate students engaged in the online discussion forum?" Table 4 shows the overall statistics of cognitive and social presence.

Table 4: Overall statistics of the cognitive and social presence in the discussion forum

Interaction	Component	Statistics
Cognitive presence	Explanations	93.2%
	Applications	11.5%
	Search	37.4%
	Suggestions	10.5%
Social presence	Mentions	26.8%
	Group Cohesive	10.5%

From Table 4 we observe that graduate students tend to exhibit higher order cognitive skills in the forums. The statistics of posts for application, search and suggestions are higher. This may be attributed to the design of the forum and the professional background and experience of the master students. To further investigate the cognitive behaviour over time, we further drill down to the individual topics. Figure 4 shows the cognitive behaviours over the weeks and we choose "cognitive presence-applications" for our study.

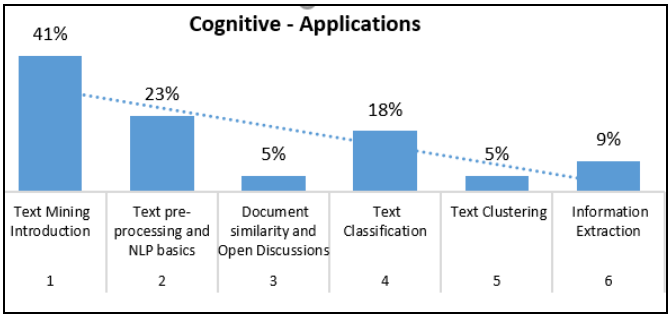

Figure 2: Cognitive Presence-Applications statistics over weeks. 1-6 are the weeks.

From Figure 2, we observe that the posts related to experiences start to reduce over the weeks as the content becomes more complex. To understand this behaviour we need to analyse the other cognitive components such as cognitive-search and cognitive-suggestions. As there are fewer Cognitive Presence-Suggestions compared to Cognitive Presence-Search, we focus on the search component of cognitive skills. Figure 2 shows the Cognitive Presence-Search statistics over time.

From Figure 3, we observe that the Cognitive Presence-Search postings increase over the weeks. The course content in the early part covers basics and over time, the content becomes more complex and the topics are more challenging. Hence, the graduate students might have little to share from their work experiences but they have to spend more time on researching to respond to the posts in the later weeks of the course. From this behavioural observation, we also deduce that the effective design of the discussion forum helped to sustain the interest in students.

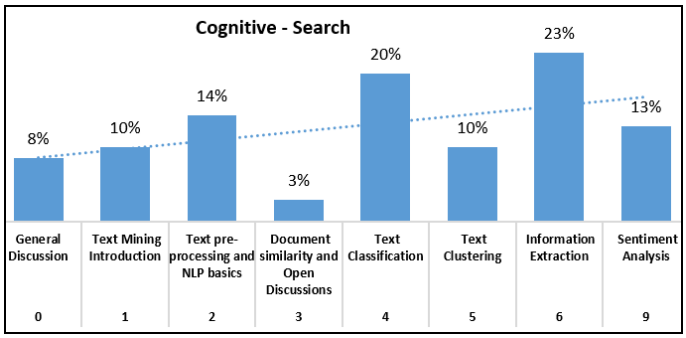

Figure 3: Cognitive Presence-Search skills statistics over weeks. 0-9 are weeks

Similarly, to further investigate the Social Presence, we drill down to the individual topic level and focus on the "Mentions". Figure 4 depicts the Social Presence-Mentions behaviour by weeks.

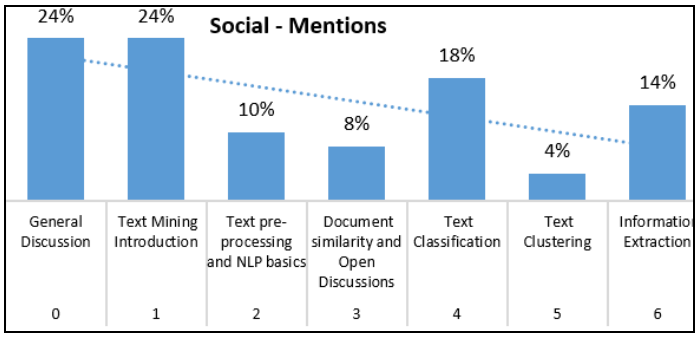

Figure 4: Social Presence-Mentions statistics over weeks. 0-6 are the weeks.

From Figure 4, we observe that the "Mentions" reduce over weeks. This also aligns with the increase in the cognitive search skills in the students. Since, students focus on doing their own search for difficult topics. Furthermore, we also wanted to analyse the Social Presence distributions among the students. Recall that social network analysis can be generated using circular layout in python. We wanted to identify the students who were very social. Figure 5 depicts the social networks of mentions.

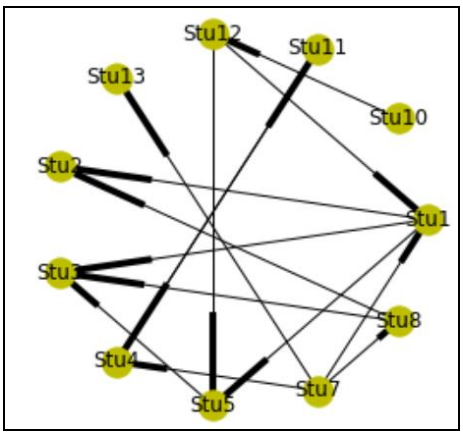

Figure 5: Social Network analysis for mentions.

From Figure 5, we observe that the social network involves only a small group of students. In our analysis, though 38 students participated, only 11 students were socially active identified through the Social Presence-Mentions. The thick line indicates the number of mentions received by the students. For example, Stu7 had not received any mentions which Student 3 received most number of mentions. The other students in the discussion forum were only direct participants and this behaviour was consistent across all the weeks.

C. Impact of Interactions on Grades

An early indication of the impact of postings on the grades through the discussion posts and class participation scores is shown in Figure 6.

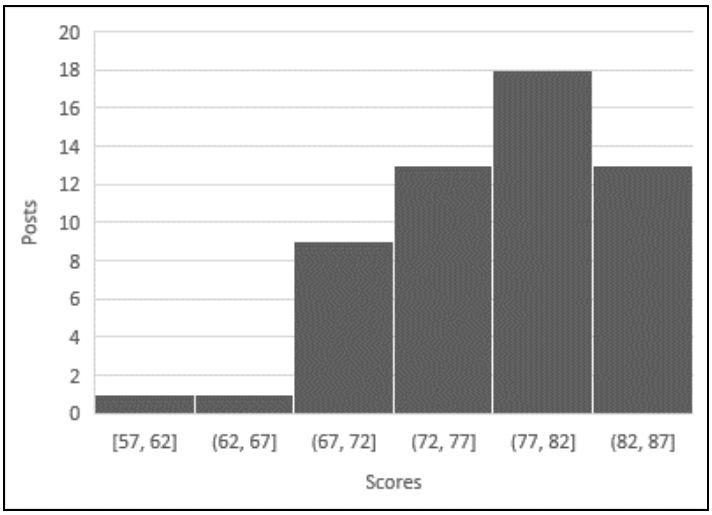

Figure 6: Students' discussion participation and scores. X-axis shows the range of grade scores for each bin.

From Figure 6, we observe that students with higher participation in the discussion forum tend to score high class participation scores. The lowest grade score is 57 on 100 and we bin the histogram with 5 points. Though the positive correlation trend is observed, there is also a small group of students who don't participate but gain higher grades. This needs to be further investigated by analysing the cognitive and social behaviours of these students in the forum.

In this analysis, we study the impact of the discussion forums on the grades. This answers our third research question, "How the student interactions affect their grades?"

Table 5: Correlation scores for the cognitive and social behaviour on grades.

Interaction Type	Total postings	Correlation Score	p-value
Cognitive – Search	71	0.193073	0.157
Cognitive overall	**177**	**0.38**	**0.004**
Social - mentions	**42**	**0.228623**	**0.093**
Social - overall	62	0.255076	0.325

From Table 5, we observe that there is a positive, small to medium correlation between overall cognitive presence and grades, which was statistically significant ($r = .38$, $n = 55$, $p < .004$). However, for overall social presence and grades, we observe a weak positive correlation which was mildly significant. From these results, we can infer that the cognitive behaviour has an impact on the score but social behaviour may not be a strong factor to affect the grades. Further, we also observe that the social presence is lower than the cognitive presence.

We also received qualitative feedback from the graduate students on the discussion forum. All students agree that the forum is very time consuming and tedious. However, the quality of the posts enabled them to learn and apply the knowledge in assignments and projects. To evaluate our discussion board design, we use the open survey questions for students. We received the feedback as shown in Figure 7 from the students on the design of the discussion forum. We handpicked few posts that depict the characteristics of the forum such as quality of questions and topical alignment of questions.

It motivates me every week to reflect upon the learnings of previous classes and also helps to attain knowledge outside the classroom learnings.

Enhance my understanding of a specific topic through posts from other people.

spurs me to do research and understanding the topic

Questions sometimes can be hard to answer and cost a lot of time to search online to get an "unique" answer among all posts.

Figure 7: Sample qualitative feedback of the discussion forum design

To study the social and cognitive presence, the qualitative feedback received depicted in Figure 8 shows that the knowledge and social interactions are motivating the students' participation.

I think it's interesting to see other people's post and what you have they have come up with

sharing ability and learn from peers

the professor gives a summary of the discussion points posted in the forum

Seeing others' discussion encourages me to search more about the questions and their sources are very useful for me.

Figure 8: Sample qualitative feedback of the social and cognitive presence in discussion forum.

We observed that several students agreed that the posts from the fellow participants motivated them to research further and contribute to the discussion. They see the value of out of class learning in the discussion forum rather than mere repetitions and redundant knowledge. Some dislikes/improvements to the discussion forum are "*No notification/ Don't have enough time to think about it*" and "*Knowledge gained there is not systematic enough*." Based on this feedback we can further improve on the design of discussion forum on organizing the content and sending reminders to the students.

VI. CONCULSIONS

In this paper, we presented the analysis that can provide more insights on the cognitive and social interactions among students in an online discussion forum within a graduate information systems course. In particular, we analysed the cognitive and social interactions and their impact on the student grades. We observe that challenging and non-redundant discussion threads encourages better online participation among IS graduates. The prior experience of the graduate students has an impact on their cognitive presence skills. Graduate students with their limited time resources, have higher order cognitive contributions and reasonable amount of social posts. For the future work, we could like to develop the automated classification techniques and generate the user profiles based on the discussions.

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