Analysis of Students' Cognitive Presence and Perception in a Custom-Designed Virtual Problem Based Learning Assignment

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Abstract—All the teaching and learning activities except laboratory-based practicals remained conducted virtually during the transition from the Covid-19 pandemic to the endemic phase. The problem-based assignment for Pharmaceutical Analysis was conducted virtually. This study aims to evaluate students' level of engagement and perception of virtual engagement to complete an online problem-based assignment on real situations using the cooperative Jigsaw model. Jamboard was used as an online communication tool to connect the students and facilitators. The content of the written discussion posted on the Jamboard and the questionnaire survey were analysed to establish the level of engagement. The student's perception of virtual engagement was based on a questionnaire survey using descriptive analysis. Analysis of the student's opinion posted on the Jamboard showed the presence of cognitive, social, and teaching components in the level of engagement during the virtual discussion. The information from the internet is borderless and the facilitators need to be knowledgeable to explain, guide, and stimulate higher-order thinking among the students. With careful course design, the Jigsaw cooperative activity on real problem-based questions could use to facilitate collaborative problem-solving skills among the students.

Keywords—virtual, engagement, Jigsaw, problem-based-learning

1 Introduction

Virtual distance learning was implemented in March 2020. The transition to the endemic phase reverted some teaching and learning activities to face-to-face delivery while the rest remained online. At present, the undergraduates have experienced studying through complete online distance learning for two years. McKenna [1] has reported that students in online distance courses felt isolated, restless and low motivation among their peers. Pedagogical approaches that spark the interest of students through collaboration and engagement can create a sense of community in the online environment as outlined in the Community of Inquiry (CoI) framework [2].

1.1 Theoretical framework

The Community of Inquiry (CoI) is a theoretical framework for the optimal design of online learning environments to support critical thinking, critical inquiry, and discourse among students and teachers [3]. The CoI framework is supported by collaborative constructivist educational assumptions, particularly in higher education [3], and encompassed the cognitive, social, and teaching presence. Teaching presence is the presence of a facilitative role provided by an engaging and trusting facilitator and conceptualized through instructional design and direct instruction. Social presence is the ability of learners to engage socially and affectively in a community of inquiry. Cognitive presence is defined as the degree to which "learners can construct and confirm meaning through sustained reflection and discourse in a critical community of inquiry" [4]. Teaching presence is essential for higher learning to occur, and the design of teaching and learning activities should encompass both the social and cognitive presence through student engagements. Thus, teacher-student engagement is an important element in a virtual classroom [5].

The process of developing cognitive presence was developed by Garrison et al. [6], based on Dewey's work on the reflection process. It involved four phases, namely, triggering, exploration, integration, and resolution [7]. The triggering stage involved students identifying the problem, exploration involved the collection and sharing of information, integration involved correlating the information and finally resolution involved the suggestion of a hypothesis or solution in solving the problem.

The Community of Inquiry Model highlights the need for learners to be engaged on social and emotional levels to achieve their desired learning outcomes. Indicators of social presence in course design included group collaboration, open communication, and problem-solving [8].

To avoid students feeling isolated and demotivated, cooperative learning was incorporated into the second-year undergraduate course. Cooperative learning is an established student-centered strategy, and the course instructor assumed the role of a discussion facilitator. This technique allowed students to engage in critical thinking, promoting active learning through discussion, improved problem-solving ability, development of communication skills, and resulted in higher satisfaction among students [9]. Students who participated in cooperative learning activities "move away from rote learning strategies and more toward meaningful strategies" [10]. In the Jigsaw Cooperative Learning, each student is a member of a base group and an expert group (Figure 1). The question assigned to a base group was further subdivided into sub-topics linked to the main topic. These base group members with similarly assigned sub-topics formed the expert groups. Upon completion of the expert group discussion, the students returned to the base group to peer-teach, allowing for the integration of individual and group accountability, with each expert having an essential role in conveying information that the base group members lack [11]. The Jigsaw model allowed between and within-group engagement in completing the task collaboratively. In addition, basic elements such as positive dependency, individual accountability and interaction are common in this model. It allows peer learning and working in a team that produces a tangible group product or project [12] and sustained learning [13]. Therefore, promoting student engagements through cooperative learning in distance education courses is important for setting up an online learning community.

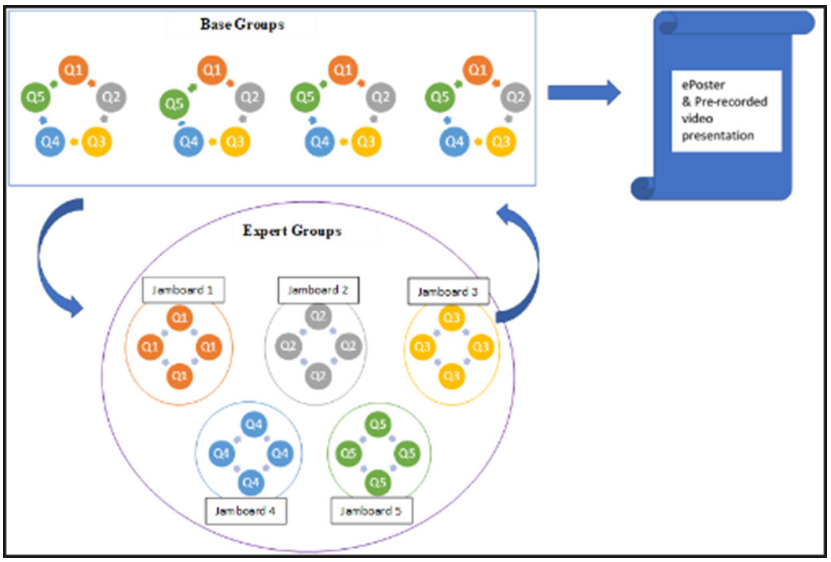

Fig. 1. Jigsaw base and expert groups

Student engagement plays a crucial role in students' learning and satisfaction in distance education. The concept of motivation and engagement is like "old wine in a new bottle" as reviewed by Parker et al., [14] which applies to online distance learning. According to Bandura's [15] social cognitive theory of psychological functioning, both human learning and behaviour occur in social environments. Engagement with others allowed people to learn knowledge, skills, strategies, beliefs, norms, and attitudes. The social presence was categorised into affective and behavioural engagement [16]. Student engagements have three interrelated dimensions, namely, behavioural, emotional, and cognitive. Student behavioural engagement relates to their participation in activities. Student emotional engagement refers to their emotional reactions to activities, peers, and teachers, and their sense of belonging to the course. Finally, cognitive engagement refers to mastering complex knowledge [17], and high engagement levels were shown to corroborate students' grades [18].

Very few studies relate to the digital native's perception in an asynchronous and synchronous virtual engagement to collaboratively complete a real situation problem-based assignment. This study incorporates two approaches involving jigsaw cooperative learning and problem-based learning in an online environment and, therefore, aims to evaluate the students on the following:

i) The level of virtual engagement (e.g. cognitive, social, teaching presence)
ii) Perception of cooperative learning in an expert and base group engagement.

2 Methodology

Pharmaceutical Analysis is a core pharmaceutical chemistry subject for second year undergraduates in the Pharmacy degree program. The rapid development of new

analytical instruments coupled with the stringent global regulatory rules governing the quality and safety of pharmaceuticals make this course challenging. The analytical instrumentation concepts are new concepts that most undergraduates enrolled in this Pharmacy program encounter for the first time.

2.1 Content of problem-based questions

An inquiry-guided problem-based question on real situations was designed and vetted by three senior academics whom are subject matter experts. The designed problem-based questions consisting of 5 sub-questions (Q1 to Q5) included the course content taught over the first five weeks of online distance learning (ODL). The topics included the fundamentals of pharmaceutical analysis, the theory of spectroscopy and the instrumentation used for molecular and atomic spectroscopy. The assignment questions were designed based on real applications to allow students to see the relevance of the equipment and analytical methods in their future profession as pharmacists. The outcome of the Jigsaw inquiry-guided problem-based learning was presented in a digital Poster with a fixed size poster template for all the base groups.

2.2 Formation of Jigsaw base and expert groups

The 169 students enrolled in the class were divided into 13 base groups with each group having 13 students. The students selected their base team members and subdivided their team according to the five sub-questions (Q1–Q5) (Figure 1) which were recorded in a shared Google Sheet. Therefore, 2–3 students were assigned to either of the five sub-questions. Students having the same sub-question from this base group were re-grouped into a new expert group. Discussion within the expert group and facilitators was done asynchronously using the Jamboard. There were 5 Jamboards created to accommodate the 5 sub-questions.

The discussion among the members in the base group was not monitored or facilitated. Those members from the five expert groups converged or returned to their base group and presented their findings during the expert group discussion. The base group members discuss and decide on the best solution for the real problem-based question based on the presentation from the members of the expert group.

The traditional jigsaw learning method was modified by assigning 2–3 people per sub-question instead of 1 student to a sub-question. This was done to increase the engagement frequency since these were new topics and were conducted virtually. Moreover, it was the first time the jigsaw cooperative problem-based learning method was introduced to them. The Google Classroom was the learning management system used as a communication base serving as a virtual notice board for course announcements.

2.3 Questionnaire survey and data analysis

All the students were subjected to a pre-survey and post-survey to evaluate their understanding of the pharmaceutical analysis topics. Included in the post-survey were demographic status and satisfaction in completing the digital assignment. The questionnaire

was developed on Google Form and distributed online to the students. The collected data were analyzed using descriptive analysis. The descriptive mean was calculated using the Microsoft® Excel® (Version 2107) spreadsheet. Both the mean score and standard deviation were recorded. Reliability coefficients, as estimated using Cronbach's alpha coefficient value. Reliability coefficients greater than 0.70 are generally acceptable, values greater than 0.80 are adequate, and values greater than 0.90 are good [19]. The qualitative evaluations were taken directly from the students' responses to the open-ended survey questions. The posting in Jamboard was thematically analyzed by two researchers to identify interesting patterns and themes in the data [20]. The collected data were thematically categorized into three levels of engagements, namely, cognitive, social, and teaching presence as these are the three main constructs.

3 Results

There were 169 second-year students enrolled in the Pharmaceutical Analysis course through online distance learning and the students studying from home were distributed throughout the country. The number of questionnaire survey respondents was 150 (88.8%) with 73% female and 27% male. In the pre-survey, 63.8 % of students opted to select their group members, and, 9.4 % preferred to be randomly assigned by the lecturer with the rest being neutral. Therefore, a Google Sheet was shared with the class to enable them to choose their base group members.

The students actively participated in the asynchronous discussion. The Jamboards for Q1–Q5 recorded 72, 88, 74, 102, and 33 messages, respectively. The messages in the Jamboard (Figure 2) showed critical thinking involved as students used the knowledge they were taught and applied it to the information they acquired from the internet and translated the result of their observation.

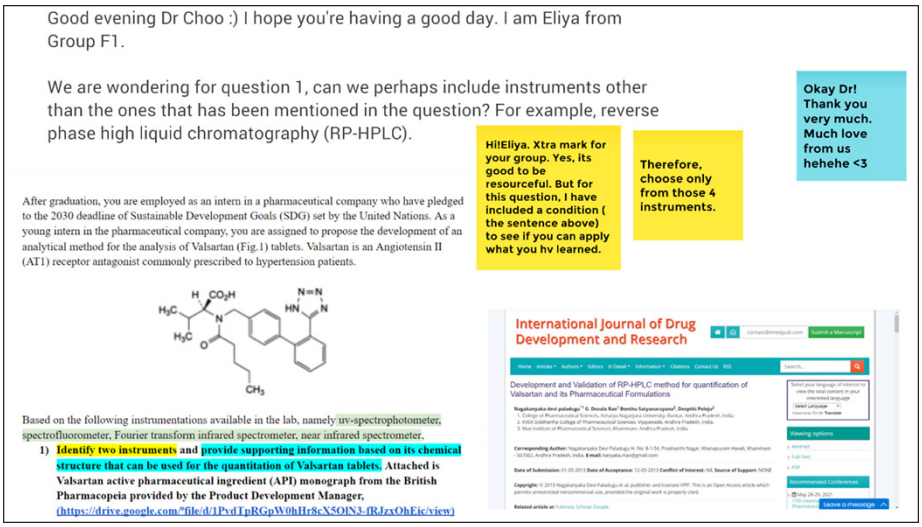

Fig. 2. An example of the asynchronous messages in the interactive Jamboard

Both the Jamboard messages and the questionnaire survey showed the student's level of engagement and were thematically grouped according to the three CoI presence, namely cognitive, social, and teaching presence (Table 1).

Table 1. Level of engagement

Cognitive	Social	Teaching
Hi! Friends! I am from C1. How about we summarize and discuss what main points that we suppose to include in our ePoster. So how about we listed it first? 1) mechanism and the principle of Raman, 2) any additional info of Raman, 3) advantages & disadvantages 4) maybe we can compare Raman with the instrument mention in Q3? (J4). Hi! Friends from C1, I am from E2, I agree with that. Additionally, I think maybe we should also include how we can overcome the limitation (J4). I would like to discuss with everyone about NDMA being susceptible to photolysis. NDMA from industrial processes contaminates the environment. It gets degraded by uv radiation at 225nm to 250nm. From the information gathered from the internet and image posted here, do you guys think this could potentially be the limitation of the instrument, uv spectrophotometer? I would like to hear your thoughts. Thank you in advance. (s8, J3) I do agree with you that it might hinder the detection. (s9, J3) "It gives me the knowledge and makes me think rationally to relate the concept of this lecture and real life." (s54)	"The assignment encourages student for teamworking" (s21) "Supportive whenever been asked the question." (s57) "LOL this is fun" (s3) "Let's enjoy!!" (J3). "This is the type of learning method is quite new for me such as the poster and the Jamboard but I loved it so far." (s59) "Like discussion in a large group" (s128) "Like working in a group"; (s147) "I like being able to discuss in jamboard with batch mates because I'm struggling to understand the concept alone" (s98)	"Lecturer always give support and keep answering our question even the little, tiny question." (s1) "The way I find more information when I do read due to question arises from the lectures." (s38) "I love how lecturers encouraged the student to ask a question even some not-so-good question or not not-so-clever question, so students can clear out their misunderstanding regarding certain topics." (s40)

The student's perception of engagement was tabulated in Tables 2 and 3 when the group discussed between experts and base group members. The student's perception of the expert group discussion (Table 2) recorded a Cronbach's alpha coefficient value of 0.819 indicating acceptable reliability of the questionnaire dataset. The mean score for students' perception of the expert group was between 4.34 to 4.64.

Table 2. Student's perception of engagement in the expert group

No.	Descriptions	Mean	Standard Deviations
1	The members in the expert groups were very supportive and provides prompt replies.	4.64	0.53
2	The discussions were stimulating and challenges the mind.	4.51	0.61
3	Other group members reply to my questions	4.41	0.71
4	I like using the interactive Jamboard for discussion in the expert group.	4.34	0.72
5	Discussion in Jamboard with lecturer	4.40	0.70

The mean score of students' perceptions of the base group discussion was between 4.63 to 4.88 (Table 3) and was slightly higher than the expert group. This may indicate a higher cohesiveness or teamwork among members of the base group as the group was formed based on their choice.

Table 3. Student's perception of engagement in the base group

No.	Descriptions	Mean	Standard Deviations
1	The leader is important to organise and delegate job tasks among members	4.78	0.51
2	I learned to be analytical from my group member	4.72	0.53
3	The presentation from different group members was clear and accurate	4.63	0.53
4	Everyone worked as a team to complete the digital Poster	4.83	0.39
5	The deadline was clearly informed by the facilitator	4.88	0.35
6	The group leader organised the various experts to collaboratively complete the digital Poster before deadline.	4.86	0.38

4 Discussion

Student engagement was by default conducted through virtual distance learning due to the movement control order imposed during the Covid pandemic and endemic phase. Internet connectivity disruption has been the main issue in achieving a smooth synchronous delivery during some of our live stream lectures. Communication is an indicator of social presence and smooth communication influences learning emotions [14] and affects learning outcomes [21]. Students' involvement and interaction were considered critical in maintaining a sense of belonging during the activities. According to Garrison [22], students must feel they belong if they are to form a cohesive community of inquiry to achieve the desired learning outcomes. The Jamboard app allowed students and facilitators to be creative to draw, copy, paste images, write directly onto it or post a colourful "sticky note" message which livens up their learning environment. The postings

on the Jamboard showed the presence of the student's level of cognitive, social, and teaching indicators as listed in Table 1. From Table 1, the students showed they enjoyed doing the virtual assignment as it encouraged teamwork and were able to understand the concepts better through discussion. The sense of community or social presence is cultivated since everyone in the group tries to be the first to respond to the queries on the Jamboards. According to Chakraborty & Nafukho [23], to maintain student online engagement, it is essential to create a positive learning environment, provide consistent feedback promptly, and use the right technology to deliver the right content.

During the first two days of the expert group discussion, the team members identified the problem and brainstorm to find solutions. This was similar to the first two phases, namely the trigger and exploration phase displaying cognitive presence as mentioned by Chen and Cheng [7]. The cognitive presence was seen in the Jamboard posting by student J4 (Table 1), indicating the need to summarize and discuss the main points and ways to overcome the limitations. Both students, namely, s8 and J3, provided extra information they acquire from the internet to overcome the limitation. Student s54 finds the virtual discussion was able to provide knowledge to think rationally and relate the concepts learned during the lecture to real life. In addition, peer facilitation is an important strategy to enhance cognitive presence [24] and it was observable in the asynchronous engagement (s98, Table 1). Peer facilitation is different from facilitator instruction as it grows out of a lateral relationship while instructor facilitation is based on a hierarchical relationship. Thus, peer facilitation has resulted in more posting and higher quality posts [25]. The asynchronous discussion has provided more time for reflective thought in facilitating deeper learning [26] and was observable in the Jamboard discussion messages which demonstrated the cognitive domain (Table 1) of the students exhibiting a better understanding of content and concepts that were taught to them for the first time. In addition, they were able to extract relevant information from the journals and establish a connection to their problem-based questions. Students were resourceful in getting information from the internet to answer the queries raised by their peers in Jamboard with guidance from the facilitator. Some were helpful to clarify certain concepts which their peers could not understand initially. The conversation recorded in the Jamboard was courteously executed exhibiting their collaborative and soft skills.

Throughout the brainstorming session in the expert group, the facilitator's role was to monitor the discussions and provide feedback, as needed, to ensure that students remained focused to find solutions to the real problem-based questions. The role of the facilitator or teaching presence is pivotal to the development of students' sense of community through the design and facilitation of both social and cognitive presences. Teaching presence can provide support or trigger students' thoughts (s1 & s40, Table 1) leading to higher learning order as students start to read and search for solutions (s38, Table 1). The facilitator's initial stage was to convince the students to initiate a conversation by encouraging reflection and confirming the learner's understanding and slowly progress towards students being independent to discuss amongst themselves. But at a certain point, they requested the facilitators to intervene to ensure the discussion was moving in the right direction. Thus, the asynchronous nature of online engagement allowed the facilitator to guide the discussion topic on the right track while eliminating wrong statements and limiting the conversation within the discussion topic.

Facilitators must be trained and knowledgeable to facilitate as students were resourceful in downloading information from the internet which does not limit them to the information from books or lecture notes. This allowed the students to explore and critically access the solutions to the questions and such processes can lead to the development of higher order thinking and collaborative skills. Through the design and facilitation of both social and cognitive presences, facilitators established a trusting relationship with the learners. Monitoring the student's progress online has indirectly increased the facilitator's monitoring time to provide consistent and prompt responses to the posts on the Jamboards. Teaching online has generally been acknowledged to be more time-consuming and labor-intensive than face-to face teaching [27].

After the expert groups completed the discussion, the members return to the base group and presented the findings to the base group. The communication between members in the base group was not facilitated by a facilitator as the facts they have collected from the expert groups were presented and discussed again within the base group. The finalised solutions to the five sub-questions were organized and merged into a fixed-sized digital Poster. This was similar to the process of developing cognitive presence involving the last two phases, namely, to integrating and resolving the solutions [7]. As the number of students in the base groups was smaller, they communicated using both WhatsApp and Google Meet (76.2%) within their base group for asynchronous and synchronous discussion to complete the digital Poster. Other means of communication were Telegram and email. Engagement between members of the base and expert group or peer community is an important psychosocial indicator or social presence indicating successful online student engagement [28].

In the questionnaire survey, the students rated highly between 4.34 to 4.64 (Table 2) on their perception of the expert group engagement. They like the support provided by their peers, e.g. replying to their questions, replying promptly, and stimulating or mind-challenging discussion which was similar to peer facilitating being an indicator of social presence. They rated highly on the use of the interactive Jamboard for the asynchronous discussion. Although asynchronous engagement was used, most of the students showed a high level of social and community presence.

The student's perception of the base group engagement was rated highly too between 4.63 to 4.88 (Table 3). The discussion within the base group was solely dependent on peer facilitation without the presence of the facilitator as it involved the student's creativity in producing the final product, the digital Poster. This was similar to the integration and resolution phase [7] where team members need to analyse their information and finalised the best solution. Communication or social presence was clearly shown during the base group discussion. Information regarding the submission deadline of their final product by the facilitator was rated the highest (4.88) while the leader's task to organise and collaboratively complete before the deadline scored the second highest (Table 3). This was probably due to the understanding the whole team will be penalised for a late submission. Students also rated highly the importance of the group leader to organise and delegate the job task. This has resulted in members experiencing high collaboration and teamwork among the base team members. The discussion between members of the base group has thought them to be analytical as well. From the survey, a total of 61.8 % of students have been exposed to jigsaw cooperative learning for the first time. Most students (71.7 %) enjoyed working in a bigger group of more than ten

members and 25.7 % of students were neutral regarding the group size. According to the review by Taft et al., [27], there is no fixed class or team size in an online course but should be on evidence-based pedagogical research. The majority (84.9%) of students liked the discussion between groups. This may have promoted a sense of community that is feeling belonging to a group of learners with a common goal and engaging learning materials with other learners and facilitators. This sense of community showing social presence is crucial in helping to prevent the sense of isolation studying in an online distance learning course [29].

5 Conclusions

The asynchronous online communication may be included and improvised post-Covid. This session during ODL has been convincing to see the students were able to cultivate CoI and collaboratively complete the virtual problem-based assignment. Verbal communication should be encouraged in the future when internet connectivity is stable. It is also observable that students could easily retrieve information from the internet and were able to relate to the taught theoretical knowledge and apply it to their present problem-based question through synchronous and asynchronous discussion between members in the jigsaw group. The information from the internet is borderless and the facilitators need to be knowledgeable to explain, guide, and stimulate higher order thinking among the students by designing quality problem-based assignments.

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