Enhancing Adaptive Online Chemistry Learning: A Case Study on the Impact of QA tutor support

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Abstract— **This innovative practice full paper investigates the impact of using a Question Answering (QA) tutor to enhance an adaptive online chemistry course, specifically Chem Quest (CQ), at Singapore Institute of Technology. The study aims to examine the relationship between QA-immediacy and affective learning, cognitive learning, and motivation in an online learning environment. Two research questions are addressed: (1) whether online students who experience instructor-immediacy or QA-immediacy through synchronous communication have improved learning outcomes compared to a control group, and (2) whether QA-immediacy explains significant variance in student affective learning, cognitive learning, and motivation in online classes. The study hypothesizes that students who experience instructor-immediacy through synchronous communication via the QA tutor will demonstrate enhanced learning outcomes compared to those who do not, and that QA-immediacy will contribute to a significant variance in student affective learning, cognitive learning, and motivation in online classes. Quantitative results show that though there is no significant difference between the average CQ pre-test and post-test scores of students who engage with the QA tutor versus those who do not, there is an observed difference in terms of motivation, affective and cognitive learning. Students who interact with the QA tutor have a more positive attitude towards CQ. These same students also have a lower learning loss and have an overall more positive impression of the CQ course. These results show the promising impact that QA tutors can have on student learning.**

Keywords— Adaptive Learning; Educational Technology; QA tutor; immediacy

I. INTRODUCTION

At Singapore Institute of Technology, incoming freshman students are invited to complete various Quests before officially embarking on their university academic journey [1] [2]. Quests are independent, web-based courses in math, physics, and chemistry, enhanced with adaptive learning approaches to assist freshmen in revisiting foundational pre-university concepts at their own pace. Feedback from previous student surveys suggest that Quests have not only enhanced students' understanding but have also increased their confidence as they embark on their university education journey.

Chemistry Quest (CQ) is presently available for matriculated pre-freshmen in the Food, Chemicals and Biotechnology (FCB) cluster. This online course aims to address the diversity in chemistry knowledge among pre-freshmen and facilitate a smooth transition into chemistry-related modules during their initial trimester at the university. The goal of the Chemistry Quest is to provide pre-freshmen students with essential foundational knowledge in chemistry. Using the adaptive learning structure, learners with lower chemistry competencies go through a more vigorous course, while learners with higher chemistry competencies experience CQ as a refresher course. CQ has several essential features, including: (1) adaptive course flow feature that assesses the next evaluation based on the student's performance, (2) pre-test and post-test enabling students to measure their overall proficiency in chemistry, (3) supplementary resources that complements every topic including e-books and videos; and (4) detailed analytics that allow faculty to track students' progress and participation in real time. Fig. 1 shows some screenshots of CQ, depicting a practice question and relevant video resources provided for the question.

Launched in 2017, CQ operates on an adaptive learning platform designed for the creation of interactive and adaptive learning content. While effectively narrowing the knowledge gap among students with diverse chemistry backgrounds, CQ encounters challenges commonly faced by online courses, where completion rates often fall below 15% [1]. A significant factor contributing to these low completion rates and student frustrations in online learning is the absence of *immediate* assistance or response from instructors when students seek clarification or have questions [3]. Online learners prefer synchronous communication and value the availability of on-demand support from instructors [4].

Mere synchronous communication, however, is insufficient for online student satisfaction and learning outcomes. An instructor's understanding of interaction and immediacy dynamics affects the nature and quality of communication [5], and their use of immediacy behaviours is a stronger predictor of student learning than student demographic or course design [6].

Instructor's immediate behaviours (through computer mediated communication tools) includes posing questions, using students' names, employing inclusive personal pronouns (we, us), providing frequent response, offering praise, and expressing attentiveness [7]. These actions can (i) foster a feeling of co-presence with students, and consequently (ii) facilitate effective communication [8], enriching students' affective and cognitive learning experiences, motivation and overall engagement [9].

While an instructor can certainly display immediacy behaviours to enhance learning and student satisfactions in online classrooms, on-demand synchronous communication is clearly time-consuming and unfeasible. Machine learning-based artificial intelligence, on the other hand, would not find on-demand synchronous communication cumbersome. With an immediacy-equipped QA system taking over the role of an instructor during synchronous communications in an online learning environment, learners will have unlimited access to an 'instructor'.

The research described in this paper is designed to investigate the use of QA tutor to supplement an adaptive online chemistry course. The research study was designed to explore the impact of automated QA system on students' learning experience when engaging with the online CQ course. The study aims to determine how QA-immediacy is related to three criterion variables in an online learning environment: affective learning, cognitive learning, and motivation. Measurements include looking at the impact on students' engagement, completion rate and performance.

The research study addresses two main research questions:

RQ1: Do online students who experience instructor-immediacy or QA-immediacy through synchronous communication have improved learning outcomes compared to a control group?

RQ2: Will QA-immediacy explain significant variance in student affective learning, cognitive learning, and motivation in online classes?.

II. RELATED WORK

A. Instructor Immediacy and immediacy in online classroom

The theoretical framework for instructor immediacy as a form of interaction is based on two research areas in the field of communications: Moore's Transactional Distance (TD) theory [10] and Mehrabian's concept of communication immediacy [11]. Moore's theory of TD stated that the teacher and students in distance education are not only physically but also transactionally separated [12]. Such distance and lack of interaction create a sense of isolation and negatively impacts students' interest and motivation in online learning. To achieve effective learning, it is essential for online students to feel motivated and engaged, which can be achieved through instructors' communication and interaction with students [13] [14]. Immediacy was first introduced by Mehrabian [11], who defined this concept as "communication behaviors that enhance closeness to and non-verbal interaction with another.

Verbal immediacy applies to communication behaviors such as "calling students by names", "asking for students' feedback about the lessons", "referring to the class as we and our", and "engaging in conversations with students before and after class" [15]. Non-verbal immediacy refers to communication behaviors that include employing physical gestures, making eye contact, having a relaxed body position, directing body position toward students, and smiling . Liu [16] provided a systematic review of the available literature on different types of teacher immediacy and student motivation.

Gorham [8] explores the impact of teacher immediacy behaviors on student learning in the classroom. The authors identified a set of verbal teacher immediacy behaviors that results in a product of increased motivation, cognitive and affective learning. The importance of instructor immediacy when communicating in online classrooms has also been studied by Melrose [17] and Walkem [14], who found that students are more likely to see instructors as approachable as well as caring (of students as individuals and about students' learning) when instructors uses immediacy practices when communicating [17].

QA-immediacy in online learning has not been extensively studied thus far. Instructor immediacy research has generally been based on studies of asynchronous online classes, with less attention paid to synchronous interactions [18]. One exception is the case study of an online introductory psychology class [19], where it was found that learning was positively associated with greater participation in synchronous chat and greater use of some types of immediacy behaviours in the chats.

Although instructor immediacy can manifest through asynchronous communication channels such as email and discussion boards, the swift response of instructors to students is distinctly recognized as a component of instructor immediacy [14]. Timely response in synchronous communications demonstrate instructors' continual presence and accessibility, establishing a sense of closeness between instructors and students that students perceive as reassuring [20]. Other research has found that synchronous online sessions afford more immediacy than asynchronous communication alone [21].

Expressed in textual form, verbal immediacy is notably fitting for the online environment [22] and has been identified as a substantial predictor of perceived learning [23]. Specifically, studies have demonstrated that immediacy in teaching practices can impact students' learning outcomes [24], cognitive learning [25], motivation [26], and participation [27].

B. Chatbot in Education

In the absence of synchronous communication with an instructor, online students frequently take their questions to search engines such as Google or Bing. However, a studies show that despite growing up in the digital age, people aged 18–24 have reduced success in finding information online, resulting in students' frustration [28].

The rise of Generative AI in 2022 ushered in a new era and a transformative trend in education. Before that, implementations of QA were far from what is envisioned for integration into an online learning platform, especially where immediacy is concerned. Firstly, most QA systems did not support dialogue [29]. Furthermore, current QA systems are usually targeted at factoid questions, while learners' questions are usually long and open-ended [30]. A majority of QA systems also expect perfectly formulated questions [1], and hence are ill-suited to handle real student questions, which are often loosely formulated and peppered 19 grammatical and spelling errors. Additionally, the myriads ways in which students' questions are constructed leads to ambiguity in meaning and hence might compromise the quality of answers returned to students [2].

The recent development in Generative Artificial Intelligence (GAI) and recent large language models (LLM) such as Amazon's Titan, Goggle's Bard (LaMBDA) and OpenAI's ChatGPT has changed the way many educators are designing their learning activities and assessments. made a strong impact on learning and assessments. Some notable example of large language model (LLM) chatbot in the education domain include Duoling's chatbot, which assists language learners in practicing their conversational skills. Another example is Khanmigo, Khan Academy's AI-powered guide that leverages AI to bring one-on-one tutoring for students. Khanmigo mimics a coach that gives prompts and suggestions to students.

It is important to note that at the time this study was conducted (July – Sept 2021) such LLMs, though existent, were not commonly used yet, and as such we do not compare our approach to those methods.

III. METHODOLOGY

Current literature suggests that instructor immediacy may have a positive impact on student online learning experience. To improve completion rate and increase students' engagement level with CQ, a virtual conversational teaching assistant (QA tutor) was designed and developed to support students who are enrolled in CQ [1]. The QA tutor was designed not to provide direct answers to practice questions in CQ. The QA tutor is envisioned to handle clarification questions that may be posed by students when reviewing learning materials or while attempting the practice questions on CQ. This is analogous to a student asking questions to a lecturer during the process of revising lecture materials or a student seeking clarification from an instructor after tutorial questions have been discussed in class.

The research study addresses two main research questions:

***RQ1**: Do online students who experience instructor-immediacy or QA-immediacy through synchronous communication have improved learning outcomes compared to a control group?*

***RQ2**: Will QA-immediacy explain significant variance in student affective learning, cognitive learning, and motivation in online classes?*

The hypotheses are as follows:

H1: We expect that students who experience instructor-immediacy through synchronous communication via the AI-chat will have improved learning outcomes than students who did not.

H2: We expect QA-immediacy result in significant variance in student affective learning, cognitive learning, and motivation in online classes.

A. Chatbot Implementation

The chatbot was developed as a Software-as-a-Service (SaaS) solution. More details about the system architecture and chatbot engine are described in a separate work [1]. **Error! Reference source not found.** shows sample screenshots of the QA tutor at the time of the study. The look and feel, and dialogue flow of the QA tutor has since undergone several iterations and improvements.

B. Data

The target population of this study consists of matriculated pre-freshmen male and female students in four different programmes:

- Pharmaceutical Engineering,
- Food Technology,
- Chemical Engineering A, and
- Chemical Engineering B

A total of 218 students from the four different programmes were invited to complete CQ prior to the start of their first trimester. Students came from varying backgrounds including Diploma in Food Science and Technology, Diploma in Biomedical Engineering, and even Mechanical Engineering. All students were given access to the QA tutor. Out of the 218 students, 20 students officially enrolled in the research study.

The research study period ran between 5 July 2021 and 31 July 2021. Participants who enrolled in the research study research had to abide to the following instructions:

- Participant had to complete CQ within one month
- Participant had to interact with tutor when going through the various topics in CQ
- Participant had to record two audio clips detailing their experience interacting with the QA tutor by answering a set of questions
- Participant had to attend a 60-minutes interview sharing their experience interacting with the CQ tutor

Out of 218 students that were invited to CQ, 136 students completed CQ but did not participate in the study. Out of those 136 non-research participants, 10 of them interacted with the QA tutor.

Before embarking on their CQ journey, the students' current level of chemistry knowledge was assessed through a pre-test. At the end of their CQ learning journey, students are reassessed through a post-test containing the same questions as the pre-test for a fair comparison. No answers nor feedback were given to the students for both pre-test and post-test questions. Information such as the pre-test, post-test and final CQ scores was recorded. Students were also invited to complete a survey conducted after the post-test. The complete survey question can be found in Table I.

Data collected were analyzed, these include: (1) CQ performance data from both non-research and research participants were analyzed, (2) CQ survey result, and (3) interview transcripts from research participants.

A total of 34 students responded to the survey after completing CQ. Out of 34 survey respondents, 14 of them interacted with the tutor. Those who interacted with the tutor were presented with additional survey questions. Semi-structured interviews were also conducted with study participants in the form of semi-structured interviews and cultural probes. The interviews and cultural probes are analyzed and discussed in a separate work [2].

C. Measurement

To answer RQ1 and gain insight on whether there is a difference in terms of learning outcomes achieved by students who interact with the QA tutor versus non-QA tutor users, data analysis is performed on pre-test, post-test, and final CQ score. The test scores were analyzed and compared using paired Student's t-test, which is a statistical parametric test on the means of quantitative data with normality assumption.

Various measurements are used to address RQ2 including motivation, verbal immediacy, affective and cognitive learning. Data for these measurements were collected through student survey responses. The survey questions were strategically categorized into distinct sections, allowing for effective measurements of the different factors.

State motivation refers to "students' attitude toward a particular course". Trait motivation, on the other hand, deals with students' general tendency toward the learning process [31]. While students' trait motivation is typically constant during a whole course, their state motivation is open to drastic changes. As mentioned by Hiver and Al-Hoorie [32], student state motivation can be dramatically influenced by their viewpoints and attitudes toward their instructors, course content, and learning environment. The measure consists of 10 bipolar adjectives [33]. The scale has a 7-point range with bipolar adjectives at either end of the scale (ex. 1=motivated, 7 = unmotivated, 1=excited, 7=not excited, 1=interested, 7=not interested etc.), with five numbered choices between the two opposites. Data for student motivation were based on student responses to questions in Section A (Motivation) of the survey.

To measure *verbal immediacy*, the Gorham Verbal Immediacy Scale is used. A 13-item Likert-type scale is used to measure student perceptions of instructor immediacy. The scale has been used to study verbal immediacy in online learning environments [13] [19]. Qualitative interviews are used to prove significant areas of agreement or disagreement found within the data. Verbal immediacy data were based on student responses in survey Section B (Immediacy).

Perceived *cognitive learning* is measured via the Learning Loss Scale [34]. The scale comprises two questions crafted to generate a quantification of learning loss. This refers to the disparity between what a student perceives they learned in the course and the maximum amount the same student could learn in that course under an ideal instructor. The Learning Loss Scale has been used in numerous studies related to instructor immediacy and almost exclusively in instructional communication research to measure cognitive learning [35]. Measurement of the Learning Loss Scale was based on student responses in survey Section C – Cognitive Learning.

The six-scale measure of *affective learning* first created by McCroskey et al. [36] is used to measure affective learning. The scale, which was later modified by Gorham [8] to delineate between the *affective* and *behavioral* learning components, was modified to include four statements regarding attitudes towards the course content, the instructor, and behaviors recommended in the course. There are seven selections between each continuum, and a composite affective learning score will be computed by assigning a score of 1 through 7 to each of the bi-polar scales and summing the items to produce a single affective learning score. Affective learning data were collected through responses in survey Section D- Affective Learning.

Behavioral intention in terms of likelihood of attempting to engage in the behaviour recommended in the course, and likelihood of taking another course with the same teacher if choice and schedule were similarly measured by four seven-step bi-polar scales: likely/unlikely, impossible/possible, probably/improbable and would/would not. Survey section E – Behavioral learning contained questions measuring student behavioral intention.

Student engagement is assessed using self-reported measures in Survey Questionnaire Section F, focusing on questionnaire item F2 asking ''How many hours per week did you devote to this course? "

IV. Results and Analysis

To understand and answer our 2 research questions, we analyzed quantitative data collected from survey responses. The data were analyzed and summarized to understand the impact of the QA tutor on the various measurements previously identified and described in Section III.

A. *RQ1: Do online students who experience instructor-immediacy or QA-immediacy through synchronous communication have improved learning outcomes compared to a control group?*

This research question is answered by analyzing the completion data and score in CQ. Table II shows comparison results of average final CQ score, average post-test score, and overall average score improvement of QA tutor users to non-QA tutor users. An independent t-test showed no significant difference between the scores of the two groups. Nevertheless, the results do highlight three points:

1. Students who interacted with QA tutor had a higher overall mean final CQ score than those who did not interact with the QA tutor
2. Students who interacted with QA tutor scored higher in their post-test results compared to those that did not use the QA tutor
3. Students who interacted with QA tutor had better improvements in score when comparing pre-test scores and post-test scores than those that did not use QA tutor

B. *RQ2: How does student engagement with QA tutor relate to three criterion variables in an online learning environment: motivation, cognitive learning, and affective learning*

To answer research question RQ2, analysis was performed by comparing average scores of QA tutor users to non-QA tutor users to the relevant student survey questions.

1) Analyzing student state motivation

Looking at student survey responses in Section A, when comparing the average state motivation between QA tutor users and non-QA tutor users, it is observed that the QA tutor users overall have a more positive attitude towards CQ. Fig. 3 shows the comparison of average state motivation between QA tutor and non-QA tutor users. Looking at survey responses A1, QA tutor users were more motivated toward CQ (3.53) compared to non-QA tutor users (2.85) on a scale of 1-7 where 1 is motivated and 7 is unmotivated. Similarly, QA tutor users were more interested (A2 - 2.62 vs 3.41), more involved (A3 - 2.54), more inspired (A6 - 2.92 vs 3.88), and more excited (A10 – 2.77 vs 4.41). Analyzing results for question A4, QA tutor users also felt more stimulated (5.38) compared to non-QA tutor users (4.41) where scale 1 is not stimulated and 7 is stimulated. Using similar scale, QA tutor users responded more positively in wanting to study (A5 – 5.54 vs 4.24), QA tutor users also felt more challenged (A7 – 5.77 vs 5.65), more invigorated (A8 – 5.08 vs 4.82), and more enthusiastic towards CQ (A9 – 5.23 vs 4.24).

2) Analyzing Immediacy

Students that interacted with the QA tutor were posed questions to measure immediacy in survey Section B (Refer to Table I). To measure *verbal immediacy*, the Gorham Verbal Immediacy Scale (GVIS) [8] is used. A 13-item Likert-type scale is used to measure student perceptions of instructor immediacy with a scale of 0 (never) to 4 (very often). The GVIS is essentially a tool used to measure the degree to which a speaker, in this case the QA tutor, uses language that creates a sense of closeness or immediacy with their audience (in this case the students). A high GVIS can be interpreted as the QA tutor has managed to create a sense of closeness with the students, while a low score indicates a more formal or distant communication style.

Fig. 4 showcases the average QA tutor user responses for survey questions in Section B that measures verbal immediacy. Looking at the average score for question B6, users of the QA tutor responded most positively to the fact that the QA tutor was available and provided immediate feedback within 24 hours (average score of 2.92 out of 4). Similar sentiment could be observed in question B7 on prompt feedback on assignments (average score 2.0). QA tutor users also felt that the QA tutor was taking the time to provide thoughtful responses to their queries as can be seen in the results to question B12 (average score of 2) and B13 (average score of 1.92).

It can be observed from the results that users of the QA tutor noticed that the QA tutor lacked in expressiveness and social friendliness as can be seen from the low scores to questions B3 (0.23), B4 (0.69), B2 (0.77), and B1 (0.85).

3) Analyzing Cognitive Learning

The perceived *cognitive learning* is measured via the Learning Loss Scale [34]. The scale consists of two questions designed to produce a measure of learning loss. The questions were posed in survey Section C (Refer to Table I). The first question C1 asks "How much do you think you could have learned in the class if you had the ideal tutor?". while the second question C2 questions "how much did you learn in CQ (0 means you learned nothing and 9 means you learned more than in any other class you've ever had?). The learning loss measure is calculated as the difference between what a student believes that she or he learned in the course and how much the same student could learn in the same course with the ideal instructor [34]. Learning loss was calculated by subtracting the response on the second scale (C2) from the response on the first scale, where learning loss = C1 – C2. A low learning loss indicates that students do not perceive a big difference between their current learning experience and their perceived learning experience with an ideal tutor.

Results in Fig. 5 show that QA tutor users had a lower learning loss scale compared to non-QA tutor users (1.23 vs 2). The average responses in question C2 show that QA tutor users responded more positively and felt that they learned more (6.6) compared to non-QA tutor users (5.41).

4) Analyzing Affective Learning

Affective learning focuses on learning that relates to the learner's interests, attitudes, and motivations. Knowledge of students' affective characteristics leads to more targeted instruction and successful learning experiences for students. Whereas cognitive assessments measure what students can do, affective assessments measure what students will do in the future. Affective learning measurements were evaluated by analyzing the four survey questions regarding students' attitude towards the course content, the instructor, and behaviors recommended in the course. Fig. 6,7,8 and 9 show the average score to student survey responses for question D1, D2, D3 and D4 respectively. Overall, the results show that QA tutor users have a more positive impression of the content of the CQ course, the delivery of the CQ course and the recommended behavior in the course. QA tutor users also had positive impression of the QA tutor.

The results in Fig.6 show that QA tutor users have a more positive impression of the CQ course compared to non-QA tutor users (2.38 vs 3.27) and QA tutor users also had an overall good impression of the CQ course (1.54 vs 2.87). QA tutor users viewed the course as more valuable compared to non-QA tutor users (6.08 vs 5.13). Both QA tutor users and non-QA tutor users gave similar score in terms of the fairness of the course (3.31 vs 3.27).

In terms of delivery of the CQ content, overall QA tutor users have a more positive impression of the delivery of the CQ content (2.54 vs 3.20) as shown in Fig. 7. Similarly, QA tutor users had a good impression of the delivery of the course content (2 vs 3.53), felt that the delivery was valuable (5.77 vs 4.67) and fair (2.54 vs 3.33).

5) Analyzing behavior learning

Upon analyzing student's behavior learning, Fig.10 reveals that users of the QA tutor exhibit a higher likelihood of engaging in the behaviors recommended in the course (2.23 vs 3.13, where 1 is likely and 7 is unlikely). Similar results can also be seen in other related questions, where QA tutor users indicated that they would attempt to engage in the recommended behaviors (2.31 vs 3.13), more probably (2.62 vs 3.13) and more possibly (5.85 vs 4.87). Fig. 11 also shows that QA tutor users are more likely to take another course with a similar QA tutor system.

Based on the results, it is possible that the QA tutor system provided additional support and motivation to students, which increased their confidence in their ability to engage in the recommended behaviors.

V. Discussion

The analysis of the quantitative data collected from the student survey responses aimed to address two research questions. Firstly, RQ1 investigated whether online students who experienced instructor-immediacy or QA-immediacy through synchronous communication demonstrated improved learning outcomes compared to a control group. The quantitative results showed that there was no significant difference in the average final CQ score or post-test score between users who interacted with the QA tutor and those who did not. However, there was better improvement in scores for students who engaged with QA tutor. The findings suggest that the QA tutor may have had a positive impact on learning outcomes.

Next, RQ2 aimed to explore the relationship between student engagement with the QA tutor and three criterion variables in an online learning environment: motivation, cognitive learning, and affective learning. The analysis focused on survey responses and compared the average scores of QA tutor users to non-QA tutor users. Regarding student state motivation, the results indicated that QA tutor users exhibited a more positive attitude towards CQ, with higher levels of motivation, interest, involvement, inspiration, and excitement compared to non-QA tutor users. Additionally, the analysis of immediacy revealed that QA tutor users perceived the tutor as being available, providing immediate feedback within 24 hours, and offering thoughtful responses to their queries. However, users felt that the QA tutor lacked expressiveness and social friendliness. Moreover, in terms of cognitive learning, QA tutor users reported lower learning loss and a higher perception of learning compared to non-QA tutor users. Lastly, the analysis of affective learning demonstrated that QA tutor users had a more positive impression of the CQ course, its delivery, and the recommended behaviors, indicating that the QA tutor system potentially provided additional support and motivation to students.

Overall, the analysis of the survey data shed light on the impact of the QA tutor on various measurements and addressed the research questions. The findings indicate the potential benefits of implementing a QA tutor system in online learning environments, which may enhance student engagement, motivation, and overall learning experiences.

A. *Limitations*

Our QA system is targeted at factoid questions, while learners' questions are usually long and open-ended [37]. A majority of QA systems also expect perfectly formulated questions [38], and hence are ill-suited to handle real student questions, which are often loosely formulated and peppered with grammatical and spelling errors.

New circumstances of living, post COVID-19, may influence the motivation of students or their desired style of communication. The COVID-19 pandemic has made remote learning prevalent which may affect the motivation and learning styles of students. Students may be more isolated and have less access to resources, which could affect their engagement with the course and their interactions with the chatbot. Students may prefer different channels in terms of educational tools.

The COVID-19 pandemic has highlighted inequalities in access to technology and internet connectivity, which could affect the ability of some students to engage with the course and the QA tutor. Students who lack access to reliable internet connections or who do not have the necessary devices may be at a disadvantage when it comes to using the QA tutor effectively.

B. *Future Research*

Following development of the supplementary QA tutor to Chem Quest, there has been new development on generative AI as the new model for creating tutoring system. The integration of generative AI techniques with chatbot frameworks has shown significant potential in the realm of AI chatbots for education. These systems enable personalized and interactive learning experiences by leveraging generative AI algorithms to simulate human-like conversations and provide tailored feedback. While there are currently a few notable development such as DuoLingo, IBM Watson Tutor and Khanmigo, further research is required to address limitations such as handling complex queries and improving response accuracy. Nevertheless, the advancements in generative AI offer promising avenues for the development of intelligent tutoring systems that can revolutionize education by providing personalized, accessible, and effective learning experiences.

VI. Conclusion

Chatbots are gaining popularity in education. This study investigates the use of QA tutor to supplement an adaptive online chemistry course. The research study explores the impact of QA tutor on students' learning experience when engaging with the online *CQ* course by looking at various factors including affective learning, cognitive learning, and motivation. Various measurements were analyzed including completion rate, student performance and survey results.

Overall, QA tutor in an online course may be a useful strategy for increasing students' likelihood to engage in recommended behaviors.

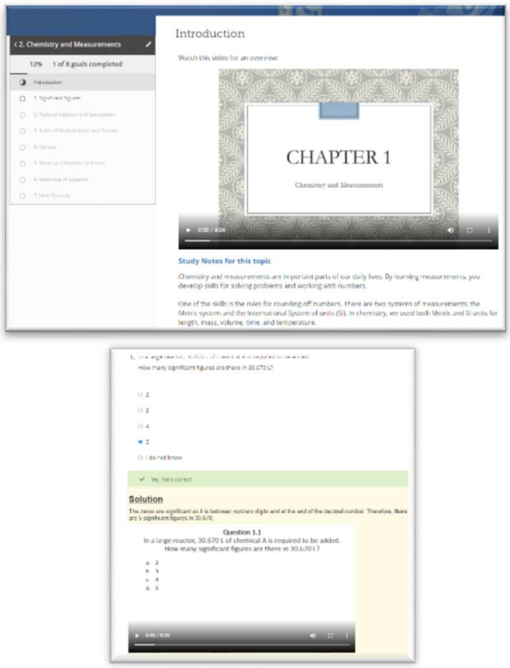

Fig. 1 Screenshot of sample Chem Quest question (top) and sample relevant video resource provided for the question (bottom).

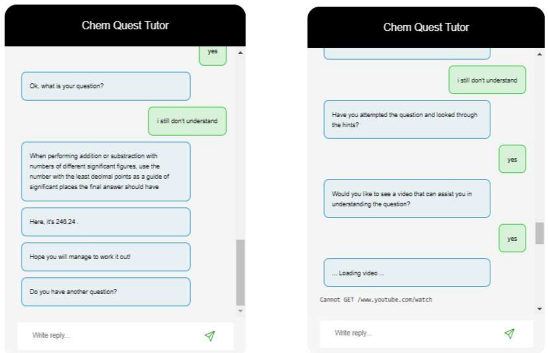

Fig. 2 Screenshot of the QA tutor designed to supplement the Chem Quest. Note that these screenshots show the QA tutor ver.1 as deployed at the time of the study (July – Sept 2021). The interface and dialogue flow of the QA tutor has since undergone several iterations.

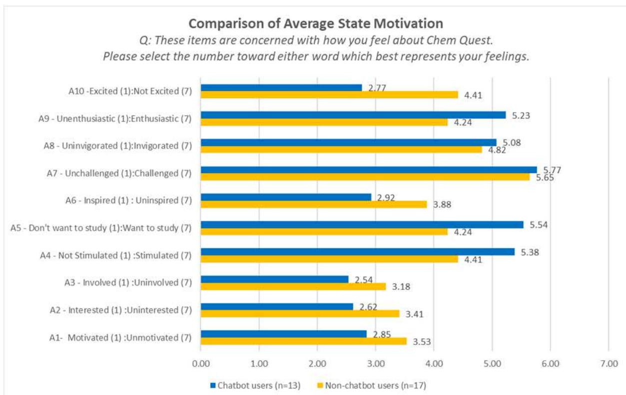

Fig. 3 Analyzing student state motivation based on survey responses in Section A – State Motivation.

TABLE I. COMPLETE SURVEY QUESTIONS

1	Did you interact with the Chem Quest tutor?
Section A. Motivation - State Motivation Scale	
	These items are concerned with how you feel about Chem Quest. Please select the number toward either word which best represents your feelings. Note that in some cases the most positive score is "1" while in other cases it is "7". A1: Motivated: Unmotivated; A2: Interested: Uninterested; A3: Involved: Uninvolved; A4: Not stimulated: Stimulated; A5: Do not want to study: Want to study; A6: Inspired: Uninspired; A7: Unchallenged: Challenged; A8: Uninvigorated: invigorated; A9: Unenthusiastic: Enthusiastic; A10: Excited: Not excited
Section B. Immediacy - Gorham's Verbal Immediacy Scale	
	Below are descriptors of things some tutors have been observed doing or saying in some classes. Please respond to each in terms of your interactions with the Chem Quest Tutor. For each item, select the number 0 - 4 which indicates the behaviour of a tutor in that class. Scale: 0 = Never | 1 = Rarely | 2 = Occasionally | 3 = Often | 4 = Very Often
B1	My tutor uses social verbs (e.g. "wave" or "high five") to translate a physical action when communicating.
B2	My tutor uses words typed in all capital letters or italics (e.g. "Good" or "not") to indicate emotion when communicating.
B3	My tutor uses acronyms (e.g. "LOL" for "laughing out loud) when communicating.
B4	My tutor uses punctuation (e.g. "!!!") to indicate expressiveness when communicating.
B5	My tutor uses emoticons (e.g. 😊 or :P) when communicating.
B6	My tutor gives prompt feedback on questions, often answering questions within 24 hours.
B7	My tutor gives prompt feedback on assignments, allowing students ample time to use feedback on future assignments.
B8	My tutor clearly communicates important course topics.
B9	My tutor clearly communicates important course goals.
B10	My tutor provides clear instructions on how to participate in course learning activities.
B11	On class discussion boards, my tutor responds to most every comment contributed by students.
B12	My tutor takes the time to provide me with thoughtful responses to my posted comments/questions.
B13	My tutor takes the time to provide me with thoughtful responses on my assignments.
Section C. Cognitive learning	
C1	How much do you think you could have learned in the class if you had the ideal tutor?
C2	On a scale of 0 - 9, how much did you learn in Chem Quest (0 means you learned nothing and 9 means you learned more than in any other class you've ever had)?"
Section D. Affective Learning	
D1	My impression of the content of the course - Good:Bad; Worthless:Valuable; Fair:Unfair Positive:Negative
D2	My impression of the delivery of the Chem Quest content - Good:Bad; Worthless:Valuable; Fair:Unfair Positive:Negative
D3	My impression of the behaviours recommended (online, individual, self-paced learning) in Chem Quest - Good:Bad; Worthless:Valuable; Fair:Unfair Positive:Negative
D4	My impression of the tutor of this course - Good:Bad; Worthless:Valuable; Fair:Unfair Positive:Negative
Section E. Behavioral Learning	
E1	My likelihood of actually attempting to engage in the behaviors recommended (online, individual, self-paced learning)
	Likely:Unlikely; Impossible:Possible; Probable:Improbable; Would:Would not
E2	The likelihood of my taking another course with the tutor of this course, if I have a choice, is
	Likely:Unlikely; Impossible:Possible; Probable:Improbable; Would:Would not
Section F. Chem Quest Survey	
F1	How would you rate your overall learning experience in Chem Quest? 1-Extremely dissatisfied – 5 Extremely satisfied Please elaborate on your response
F2	On average how much time per week did you spend on Chem Quest?
F3	How did you spend your time between going through Learning Resousrces and attempting the exercises
F4	How useful did you find the following features in Chem Quest? Study Notes; Hint in exercise; Workedout solution videos; External learning resources; Proficiency check and confidence check quizzes for self-assessment; Chem Quest Tutor
F5	Has Chem Quest helped to enhance your learning and understanding of concepts and skills in chemistry?
F6	Has Chem Quest helped to improve your performance in chemistry topics offered in the course?
F7	On a scale of 0 to 10, how would you rate your chemistry competency BEFORE taking Chem Quest? (
F8	On a scale of 0 to 10, how would you rate your chemistry competency AFTER taking Chem Quest? (
F9	Has Chem Quest motivated or encouraged you to do more independent learning?
F10	How satisfied are you with the Chem Quest course site in terms of accessibility and navigation?
F11	What can be improved in Chem Quest?

Table II. COMPARING THE LEARNING PERFORMANCE OF CHATBOT VS NON-QA TUTOR USERS

	Chatbot user (n=27)		**Non-chatbot user (n=109)**			
	Mean	**Variance**	**Mean**	**Variance**	**df**	**p**
Average final Chem Quest score	130.19	436.46	123.72	490.41	42.00	0.16
Average post-test score	5.89	2.14	5.64	2.47	42.00	0.44
Average improvement in post-test score	2.19	4.21	1.98	3.10	36.00	0.63
Average improvement in post-test score (%)	108.70	43772.38	74.05	8442.86	29.00	0.41

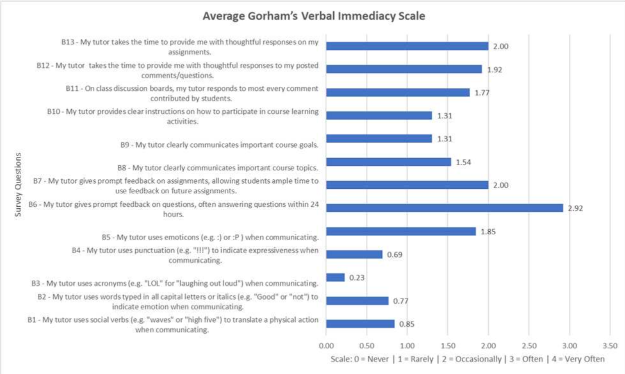

Fig. 4 Analyzing immediacy based on survey responses in Section B – Immediacy

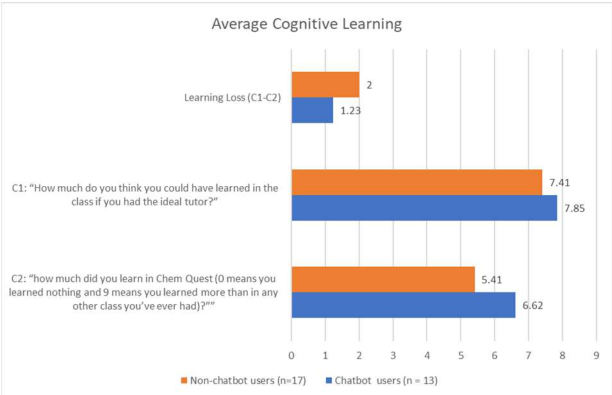

Fig. 5 Analyzing cognitive learning based on survey responses in Section C – Cognitive Learning

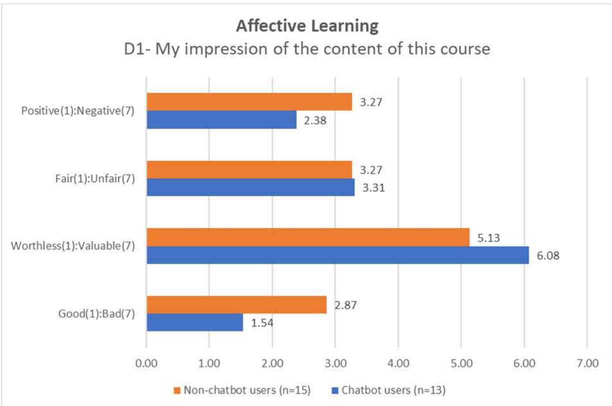

Fig. 6 Analyzing affective learning based on survey responses in Section D1

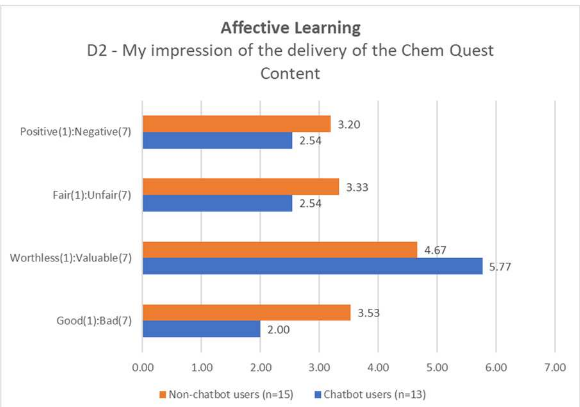

Fig. 7 Analyzing affective learning based on survey responses in Section D2

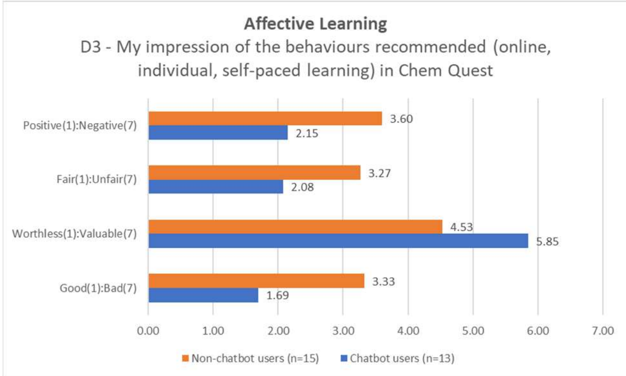

Fig. 8 Analyzing affective learning based on survey responses in Section D3

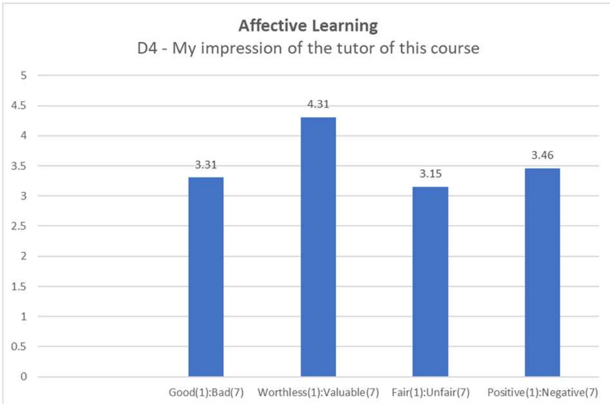

Fig. 9 Analyzing affective learning based on survey responses in Section D4

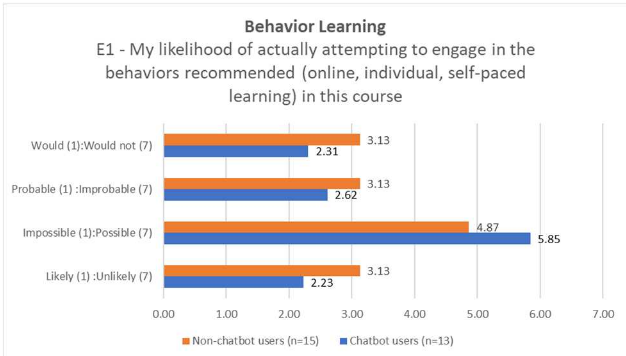

Fig. 10 Analyzing students behavioral learning based on survey responses in Section E1

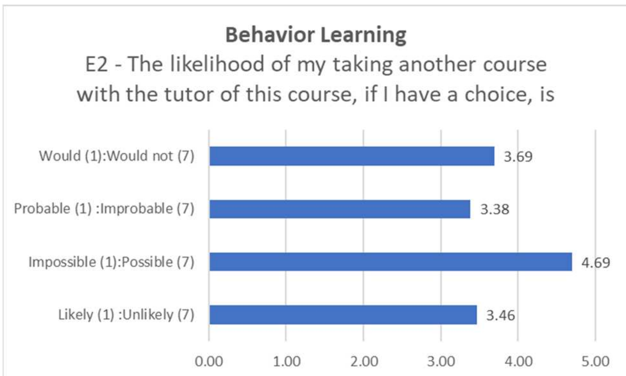

Fig. 11 Analyzing students behavioral learning based on survey responses in Section E2

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