

Student Questioning Tendencies and Learning Performances in a Classroom Inquiry Curriculum: An SEM Analysis

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Abstract: In this paper, we examine the use of the Stanford Mobile Inquiry-based Learning Environment (SMILE), a virtual learning environment and inquiry maker that allows students to be involved in their individual learning process. SMILE provides students a platform to generate their questions, leading to opportunities. Students undertake a process of creating and presenting their inquiries; analysing and responding to their peers' questions, through an interactive and engaging exchange. This empirical study, with an SEM analysis, connotes a positive causal relationship between student learning performances and questioning tendencies, upholds the value of fostering student to generate questions for their inquiries and learning.

Keywords: Inquiry-based learning, student-centred learning, technology-aided learning

1. Introduction

It is well documented that scientific inquiry in science classrooms is highly advocated [American Association for the Advancement of Science (AAAS), 1989, 1993; NRC, 1996]. From a teacher's perspective, Chin and Brown (2002) surmised that questions can reveal gaps in students' knowledge and understanding, allowing teachers to address their misconceptions. However, building a learning environment anchored on an attitude of questioning would not only help with knowledge gains, it can engage learners with a degree of understanding and cultivate a propensity towards further questioning (Scardamalia, 2002). Sustaining a disposition towards questioning would be an effective approach in learning as it encourages higher-order thinking (Papinczak et al., 2012; Bates et al., 2014). Armed with inquiry skills, learners could utilise what they had previously acquired in other aspects of learning and applying those skills beyond science (Bruner, 1960; von Secker & Lissitz, 1999). Additionally, the practice of inquiry could cultivate the development of cognitive skills such as critical thinking and problem-solving (DeBoer, 2004; Shulman & Tamir, 1973; Smith, Maclin, Houghton, & Hennessey, 2000). As a result, the cycle of inquiry stimulates the natural curiosity of learners and after being familiarised to such a learning culture, they become more confident with questioning, testing and redefining their ideas (National Research Council, 2000).

In Singapore, educators find it challenging to sustain student centred inquiry, especially student questioning. The Singapore education has been often regarded as a result-oriented system that features rampant rote learning, hence generating a learning culture of students who lack thinking skills and creativity (Tan & Gopinathan, 2000). In the early 2000s, the science curriculum was restructured to allow students to conduct their own investigations using an inquiry-based approach. Nonetheless, Poon and Lim's study (2014) found that the process of inquiry was not predominant in elementary classrooms, due to the pressures of preparing students for examinations and large class sizes. Students are likely to be passive learners in class and hardly contribute by asking questions (Chen & Looi, 2007). This seems to be a common concern, as educators elsewhere are uneasy about the absence of questions from students, even when they probe (Gall 1970; Nystrand 1997; Cazden 1988). Even though educators are keen for students to be more actively involved in the inquiry process, Dillon (1988) found that students were hesitant as they were anxious that there would be negative reactions from their peers and teachers, hence did not want to call attention to themselves (Good et. al, 1987).

To overcome these obstacles, this study intended to use technology to facilitate the process of inquiry, stressing on student questioning. A team consisting of researchers from the National Institute of Education (NIE) and primary school science teachers was formed. We used the Stanford Mobile Inquiry-based Learning Environment (SMILE) platform as a technological enabler and developed a series of lesson packages for primary four students, focusing around an inquiry-based framework. Each lesson commenced with an activity trigger, for instance, a specific phenomenon or a hands-on experiment. Students then generated and submitted questions using the SMILE platform, and responded to questions created by their peers, resulting in a collaborative learning environment that promotes student inquiry and reflection. Adopting an analysis approach of Structural Equation Model (SEM), this paper reports on student learning performance and tendencies

2. Overview of SMILE-enabled Lessons

SMILE is an inquiry maker, mobile learning management software designed to which allows students to generate questions related to what was taught in class (Figure 1). It was conceived to generate awareness of how mobile educational technology can cultivate student inquiry (Buckner & Kim, 2014). Students can generate questions in either an open-ended or multiple choice formats. Students will solve or respond to questions generated by their peers, and rate the questions on a scale of 1 to 5, based on what questions they would like answered. The entire process is controlled by a teacher using the platform’s activity management system interface. The interface collects corresponding data for meant for the teachers’ analysis and assessment, such as amount of inquiries generated, average ratings, and the percentage of correct responses for each question.

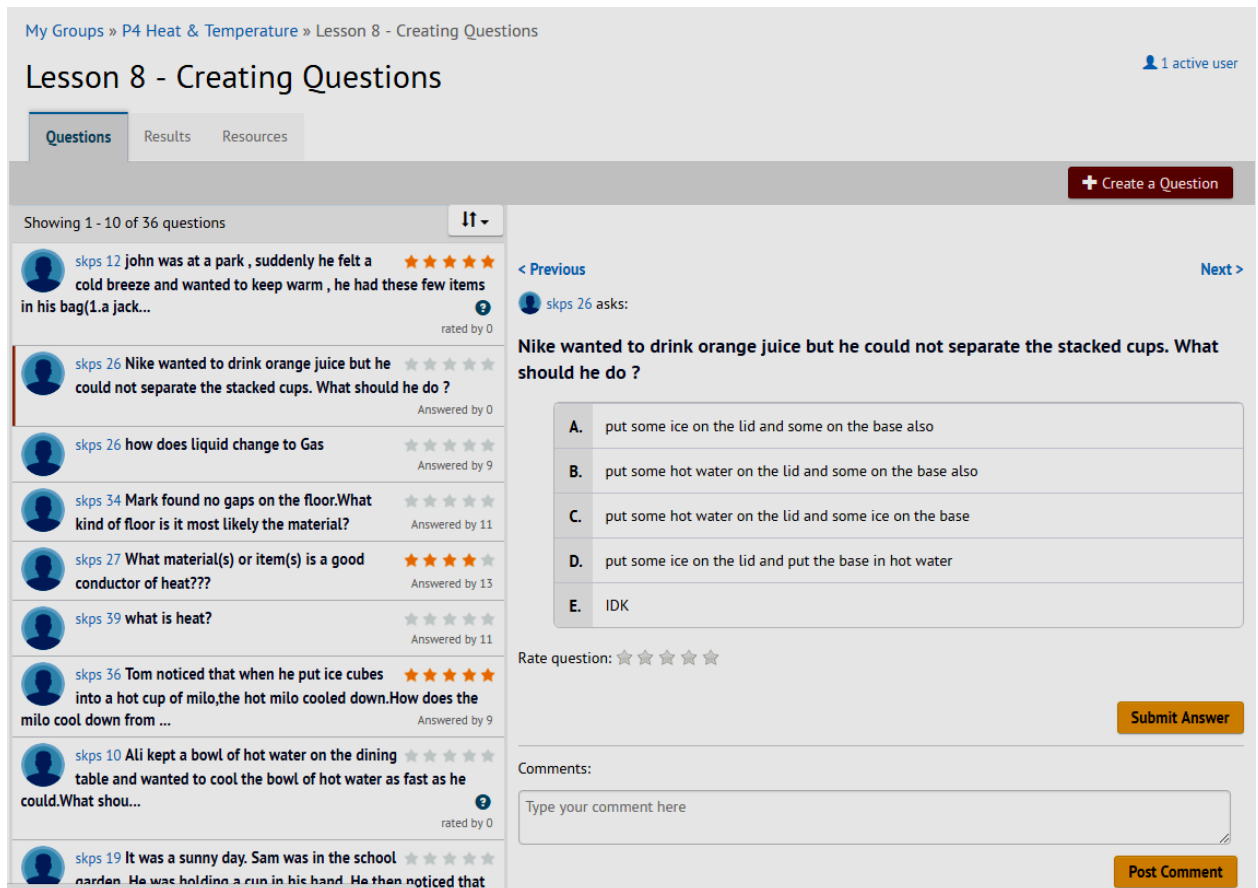


Figure 1. The SMILE interface

To begin each inquiry session, the teacher presented two inquiry-based models: an enhanced version of Harvard Project Zero’s Think–Puzzle–Explore (TPE) thinking routine, adapted to provide a section for student reflection (R) and Bloom’s Taxonomy (Project Zero 2007; Ritchhart 2002). The two models set the framework of the inquiry-based learning environment, supporting students to

take more initiative in their questioning-for-learning process with teacher guidance and facilitation. Using the subject of heat, the teacher masterfully weaved the concepts of heat through the story of Goldilocks and the three bears.

During each session, the teacher will set aside time for students to raise questions using SMILE. However, the questions that can be generated are specific only to the subject of heat. Students are guided in the process and the teacher suggested general areas in the subject of heat that they could inquire about. For example, if the topic they were studying that day was related to heat transfer, the teacher would propose that students ask corresponding questions. The teacher would also combine the process with teacher-scaffold questions, where she would ask questions and students would respond to them accordingly.

3. Methods

3.1 Participants

The participants consisted of 69 students from a primary four class school in Singapore of between 9 – 11 years of age. The school X in this study is a public primary school in a fairly new neighbourhood. For this study, the experimental class consisted of 37 students and the control class consisted of 32 students. The students from the experimental class are of mixed ability, while the students from the control class are of higher ability. For this study, the researchers worked closed with the teachers and students of the experimental class to develop and enact lesson packages on the several topics, such as heat and heat transfer, during duration of one semester (July 2017 to December 2017). We administered pre/post tests and pre/post surveys to the students and also conducted focus group discussions with students and teachers after the intervention had been completed.

3.2 Research Instrument and Structural Equation Model

There are different scholastic lenses of viewing the values and ways of student-generated questions. Humphries and Ness (2015) highlight that the 4th-grade standards require students to generate questions with sophisticated cognitive operations, including predicting, hypothesising, inferring, reconstructing, valuing, judging, defending, and justifying choices. To investigate the value of student-generated questions in the classroom inquiry curricula, we build on the constructs based on the work by Chin (2002), and Pittenger and Lounsbury (2011).

Testing of the measurement and research models was implemented by utilising partial least squares structural equation modelling (PLS-SEM) as it is a data analysis method that is suitable for analysing small sample sizes (Chin, 1998; Chin & Newsted, 1999). The software used was SPSS as well as SmartPLS version 3 (Ringle, Wende, & Will, 2018). Our Structural Equation Model (see Figure 2) consists of nine constructs: Value of Asking, Capacity to Ask, Means of Asking, Interest in Asking, Intentionality of Asking, Attitude towards Asking, Engagement in Asking, Attitude towards Asking, and Cognitive Assessment (via Pre-/Post-tests).

To evaluate the nine constructs of this study, the survey instrument of the study consisted of a questionnaire with 21 items as well as a cognitive assessment comprised of a pre-test and a post-test. All items relating to the questionnaire were measured on a 5-point Likert scale ranging from 1, strongly disagree to 5, strong agree. The cognitive assessment that was comprised of a pre-test (full marks was 11) and a post-test (full marks was also 11).

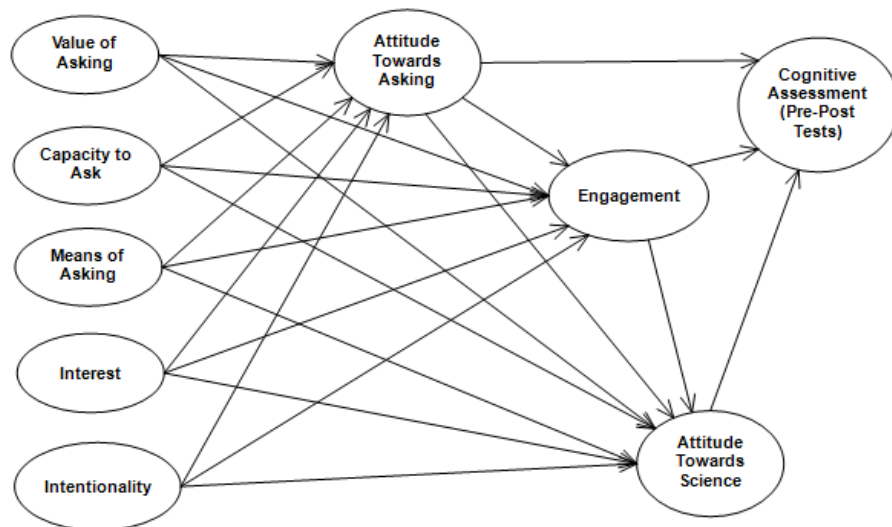


Figure 2: Exploratory hypotheses model of conceptual constructs (SMILE-Ask framework)

4. Results

4.1 Learning Performances

Both quantitative and qualitative data were gathered for the study. Pre/post- tests and surveys were distributed to students before and after the study ended. Additionally, FGDs and interviews were conducted with participating teachers and students. The students' results from their middle and end of term school-based formal science assessments – the SA1 and SA2 tests, were collated and analysed.

From the results, we observed that the experimental class demonstrated learning gains in MCQ ($t = 5.36^{***}$, $p < .001$), Open-ended ($t = 2.086^*$, $p < .05$) and Total ($t = 6.224^{***}$, $p < .001$). The control class demonstrated learning gains in MCQ ($t = 3.16^{**}$, $p < .01$) and Total ($t = 2.705^*$, $p < .05$). We did not perceive significant gains for Open-ended Questions ($t = .161$, $p > .05$). The experimental class showed more pronounced improvement in both MCQ and open-ended sections, as compared to the control class. These results indicate that the utilisation of SMILE-based lesson packages had a beneficial influence on the students' understanding of the subject matter.

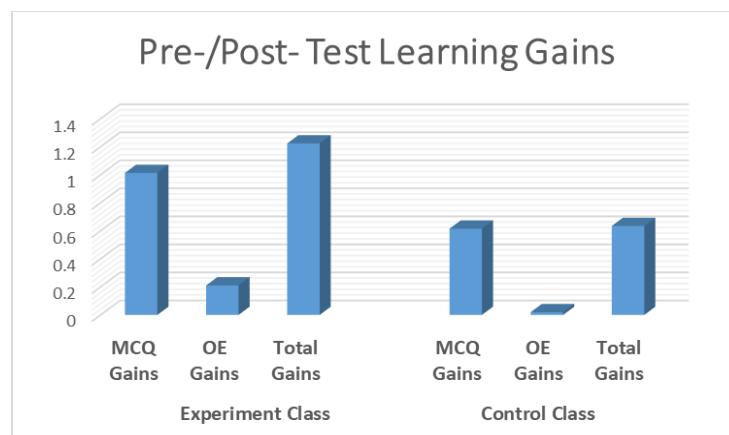


Figure 3: Pre-/Post- Comparisons

In terms of the school-based formal science assessments – the SA1 and SA2 tests results showed that the experimental class revealed gains in Total ($t = 2.315^*$, $p < .05$). No significant gains were observed in the control class for Total Gains ($t = .613$, $p > .05$). These results are in line with the pre-/post- test results, which further substantiates that the SMILE-based lesson packages had an effective impact on the students' learning in science.

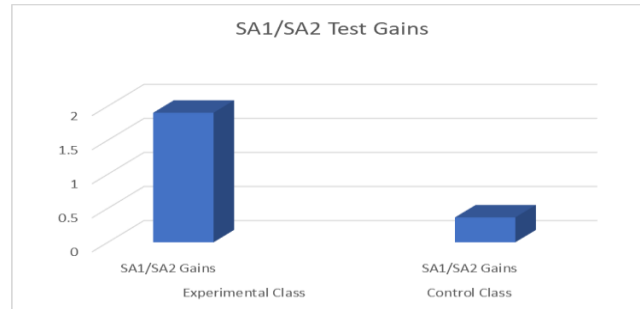


Figure 4: SA1/SA2 Test Gains

4.2 Measurement Model: Validity and Reliability

Prior to testing the hypotheses, the measurement model was assessed for the validity and reliability of the indicators. Reliability refers to the extent to which the variables of a construct are consistent and error-free. Validity refers to the extent to which a variable of a construct is different from a set of variables.

Assessment of the reliability of the construct items for both the experimental class and the control class was accomplished in terms of the item loadings. Almost all the items exceeded Chin's (1998) threshold of 0.7, with the exception of ATT_QUES_Q3 (0.688), ATT_QUES_Q7 (0.605), and MEANS_QUES_Q16 (0.533) for the experimental class, and ATT_QUES_Q3 (0.678), ATT_QUES_Q7 (0.632), MEANS_Q17 (0.686) for the control class, however, they were considered acceptable since they were greater than 0.5 (Chin 1998; Shepherd, Tesch & Hsu 2006).

Internal consistency reliability was assessed in terms of Cronbach's alpha as well as composite reliability, using Nunnally and Bernstein's (1994) recommended threshold of 0.7. Satisfactory values of composite reliability were achieved for all of the constructs (values ranging from 0.758 to 0.933) for the experimental class. Satisfactory values of composite reliability were also achieved for most of the constructs (values ranging from 0.793 to 0.920) for the control class, except for Capacity to Ask (0.589) for the control class.

In terms of Cronbach's alpha, the majority of the constructs exceeded 0.7 for both the experimental class, with the exception of Engagement (0.616) and Means of Asking (0.640) for the experimental class, and also with the exception of Means of Asking (0.524) for the control class.

The assessment of the validity involved the examination of two subtypes of validity: convergent validity, as well as discriminant validity. Convergent validity utilizes the values of Average Variance Extracted (AVE) used to check whether a set of construct items corresponds to the same construct. Fornell and Larcker (1981) proposed that the AVE value for each item should be greater than 0.5. In the current study, the convergent validity of the construct items of the experimental class as well as the control class were all greater than 0.5, which suggested that each latent variable was able to explain more than 50% variance of its indicators. Discriminant validity was checked using the Fornell and Larcker (1981) test. All the constructs satisfactorily passed this test and achieved discriminant validity.

4.3 Questioning Tendencies

The relations between constructs in the research model were assessed for statistical significance using SmartPLS. The t-values were examined using the two-tail test with statistical significant levels of $p < .05$.

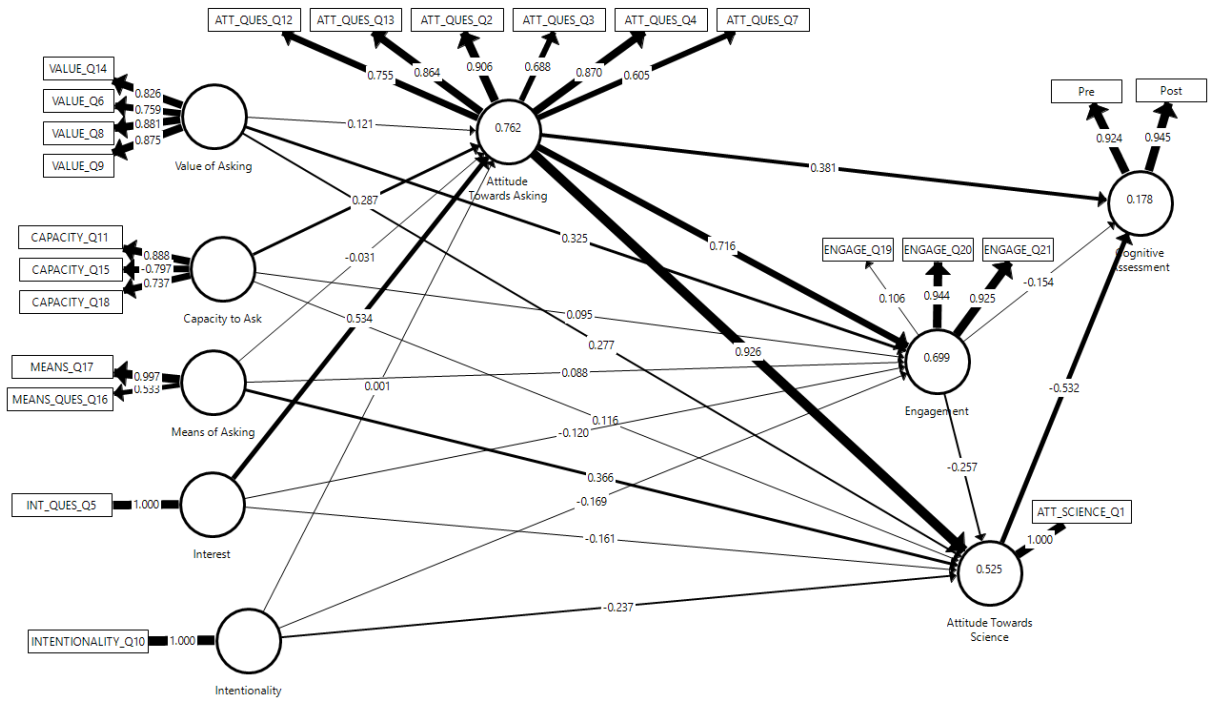


Figure 5. Structural Equation Model of the SMILE Experimental Class

The coefficient of determination R^2 for each endogenous variable was shown in Figure 5 for the experimental class and in Figure 6 for the control class to assess the predictive strength of each respective model. For the experimental class, the model was able to explain 76.2% of variance in Attitude Towards Asking, 69.9% of variance in Engagement, 52.5% of variance in Attitude Towards Science, however, only 17.8% of variance in the Cognitive Assessments (Pre- and Post-tests). For the control class, the model was able to explain 86.5% of variance in Attitude Towards Asking, 68.5% of variance in Engagement, 30.2% of variance in Attitude Towards Science, however, only 17.6% of variance in the Cognitive Assessments (Pre- and Post-tests). This might be due to the small sample size utilized in the current study.

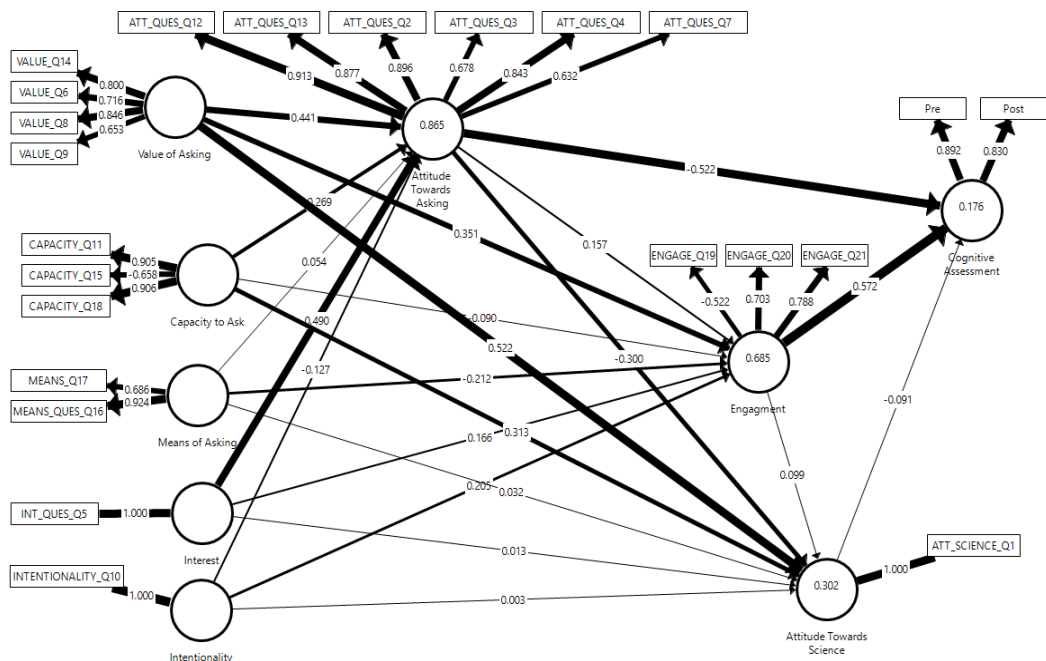


Figure 6. Structural Equation Model of the Control Class: without SMILE intervention

There was significant positive effect of *Interest* on *Attitude of Asking* for both the Experimental Class and the Control Class. This suggested that both groups were sufficiently motivated by the interest generated in their respective science classes. As an example, one student from the experimental class explained “Yes, you want to find out more, like why, like how does it go through the metal, what is inside the metal that makes it go through.” There was also significant positive effect of *Interest* on *Attitude of Asking* for both the Experimental Class and the Control Class. This suggested that both groups were sufficiently motivated by the interest generated in their respective science classes. As an example, one student from the experimental class explained “Yes, you want to find out more, like why, like how does it go through the metal, what is inside the metal that makes it go through.”

There was significant positive effect of *Value of Asking* on *Attitude towards Science* for both the Experimental Class and the Control Class. This suggested that the students could see the significance of asking questions in class. Interviews with the experimental class revealed that when other students asked questions that they too could not answer, it made them curious: “Yes because it’s interesting and you don’t actually know, it makes you want to ask more questions about it. You actually get really curious about it after that.” Students reasoned that they could learn from their peers’ questions, especially if they did not know the answer. A student explained: “Because other people will also ask questions, then when you see the questions, you might not know how to answer it. Then you want to find out as well. Then nobody knows it, so you really want to find out, how do you answer the question.”

More noticeably, there was significant positive effect of *Means of Asking* on *Attitude towards Science* for the Experimental Class, but there was no positive effect of *Means of Asking* on *Attitude towards Science* for the Control Class. This suggested that both groups had sufficient means of asking questions which led to positive attitudes to science. One student from the experimental class shared that SMILE provided a conducive platform for her to ask questions especially if she was “shy”: “Everybody is shy to ask teacher, so you can do it there, so you don’t have to go up to the teacher and ask, you can type it in and post it. They don’t know if it’s you are not, it is not an embarrassment if you ask not that good a question. Because they don’t know your register number. So when you say that, the teacher will reply, they help us how to find out.”

There was also significant positive effect of *Attitude towards Asking* on *Engagement* for the Experimental Class but not for the Control Class. There was significant positive effect of *Attitude towards Asking* on *Attitude towards Science* but for the Control Class. There was polarity in the results, which implied that there might be significant positive effect of the *Attitude towards Science* on *Attitude towards Asking*. For one student, he shared that he was excited with the new science knowledge that he learned and was eager to “also share with our friends and family, that little bit in science.”

For the Experimental Class, there was very slight significant positive effect of *Attitude towards Science* on *Engagement*. For the Control Class, there was **no** significant positive effect of *Engagement* on *Attitude towards Science*. This suggested that SMILE was instrumental in the intervention with the experimental class. One student from the experimental class mentioned using SMILE in science lessons: “You get a little bit of fun way to learn science.”

From the SEM analysis, a prominent insight is it reveals positive chain relationship as to interest, attitudes towards asking, attitudes towards science and cognitive assessment. It connotes a possible causal relationship between students questioning tendencies and their learning performances. As Biggs (1987) and Marton (1983) have explained, as students develop interest in their task, they gain a deeper understanding of the subject, as they are motivated to understand the material, in an attempt to link new ideas to previous knowledge, and theories to everyday occurrences. Then, the learner will personalise his/her knowledge, making it relatable and significant to one’s own experiences (Chin & Brown, 1999). Once the learner has developed a deep approach in learning, the interest in the subject would be sustained and the learner would be more persistence in their person pursuit of the subject matter (Chin & Brown, 1999).

5. Discussion and Conclusion

Dillon (1988) proposed that technology could assist as a mediator to engage students in the inquiry process. Likewise, Kubicek (2005) recommended technology and emphasised its interactivity in supporting students in the inquiry process. Similarly, Tapscott (1996) notes that interactive and collaborative functions of technology can mitigate the passivity of the traditional learning models, where students learn through the transmission of didactic knowledge. We examined how engage students to ask questions in classroom inquiry using technology-enhanced learning environment. Questions can reveal students' thought processes as well as their gaps in knowledge or understanding, allowing teachers to surface such misconceptions. This empirical study, with an SEM analysis, connotes a positive causal relationship between student learning performances and questioning tendencies, upholds the value of fostering student to generate questions for their inquiries and learning. More classroom studies are needed to understand and optimise the collaborative process considering individual questioning and learning tendencies.

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