Chapter 11
Exploring the Change in Nature and Efficacy of Learners' Questions Through Progressive Interaction with the Stanford Mobile Inquiry-based Learning Environment (SMILE)

Kenneth Y. T. Lim, Bing Heng Song, and Matthew Xiang Kho

Abstract Through the use of the Stanford Mobile Inquiry-based Learning Environment (SMILE), students are provided with a digital platform to generate questions, with the purpose of clarifying conceptual doubts, as well as to challenge and learn from each other. This paper seeks to find out whether SMILE has any effect on the nature and efficacy of learners' questions in Singapore and assess whether SMILE is an effective and reliable tool in helping students achieve better conceptual understanding and accuracy. It also demonstrates how the use of SMILE can be translated as well as sustained in schools, in alignment with the ecological framework which is the thesis of the present book. SMILE lessons were conducted at a secondary school during Physics lessons, with students being encouraged to generate questions related to the subject. Survey data was collected from both teachers and students, and the questions generated by students from three classes were analysed according to content relevance, conceptual accuracy as well as question type, the latter of which is categorised by Bloom's Taxonomy. There do not seem to be significant changes with regard to the percentage of accurate questions generated, nor the proportion of higher-order thinking questions per student. Nevertheless, both teachers and students are fairly optimistic about the use of SMILE in engaging students in critical thinking. This finding correlates with data indicating an increase in variation of question type over time.

K. Y. T. Lim (✉) · B. H. Song · M. X. Kho
National Institute of Education, Nanyang Technological University, Singapore, Singapore
e-mail: kenneth.lim@nie.edu.sg

D. Hung et al. (eds.), *Innovations in Educational Change*, Education Innovation Series, https://doi.org/10.1007/978-981-13-6330-6_11

11.1 Introduction

11.1.1 Rationale

Acknowledging the paradigmatic effect of the then-nascent Internet and its transformative potential in teaching and learning, Information and Communication Technologies (ICT) were formally introduced in 1997 with the launch of the first masterplan for ICT in education (Koh & Lee, 2008). Since then, three follow-on masterplans have been implemented, with the latest being in early 2015. While each plan reinforced the previous ones and prioritised the factors that predominated its "success", they were also able to adapt strategies to the shifting contexts of the Singaporean education system. This seamless adaptability is a crucial factor of the strength of ICT in the implementation of education masterplans in local schools.

With the implementation of these masterplans, the overall ICT infrastructure in schools has improved to the current state which allows for high-speed broadband and 4G access island-wide (Koh & Lee, 2008). At the same time, by 2011, ownership of mobile devices has held steady at about 150% of the population (Infocomm Media Development Authority Singapore, 2017). With the current generation of technologically savvy students who are capable of handling mobile devices and associated applications with ease, it would be comparably more effective to make use of mobile technologies to support teaching and learning.

In addition, there has been continual professional development of teachers, including ICT skills trainings and the peer-supported, collaborative and self-directed nature of ICT pedagogical developments. Hence, having been equipped with the appropriate sets of skills, teachers are not only familiar and comfortable with utilising ICT for teaching and learning but have also developed the mindset of a reflective practitioner in exploring different avenues regarding ICT pedagogical approaches. On top of these, the strategies adopted for the professional development of school leaders have contributed significantly to a conducive environment for the use of ICT for teaching and learning. Thus, the education system has the cultural disposition, infrastructure and expertise to engage in mobile-based learning.

The core design principle for this project was to experiment and develop an ICT programme that increases learner participation, understanding, engagement and motivation through an inquiry-based, learner-centred pedagogical approach. An existing tool, the Stanford Mobile Inquiry-based Learning Environment (SMILE), was identified for this programme, as it was found to be suitable for translation to local classroom contexts. This ICT programme, in which SMILE is used as an ICT tool to enhance teaching and learning, was designed to be in alignment with the masterplan for ICT in education, as well as to serve the mandate of the school in which it was piloted, part of the FutureSchools programme, under which it receives additional funding in order to pilot and spread innovative technology-mediated practices.

11.1.2 Overview of SMILE

SMILE is a simple assessment/inquiry maker which allows students to generate questions related to what was taught to them in class. After connecting to the SMILE server, students are provided with a stimulus, in the form of a video, related to a Physics topic (refer to Fig. 11.1).

After which, students are to generate questions based on the stimulus. They can also choose to attach a photograph of a diagram or any other object from their textbooks or any phenomena discovered in the laboratory and create a homework item (refer to Fig. 11.2). The questions created by students are instantly collected and subsequently shared with the entire class.

Questions created by students will be rated by their classmates based on how relevant or useful the questions are to their own learning (refer to Fig. 11.3). The teachers provided a scaffold for the peer evaluation process, with the criteria being (1) whether there were any misconceptions; (2) whether the answer given was right or wrong; and (3) the level of the question according to Bloom's Taxonomy. Teachers or facilitators can also review the questions and remove those which are irrelevant or not as useful.

A summary of each student's results is also accessible by them individually, as well as by the teacher or facilitator. The summary contains details such as which questions the student answered correctly/incorrectly, how many questions they answered, their percentage of questions answered correctly, their average rating and

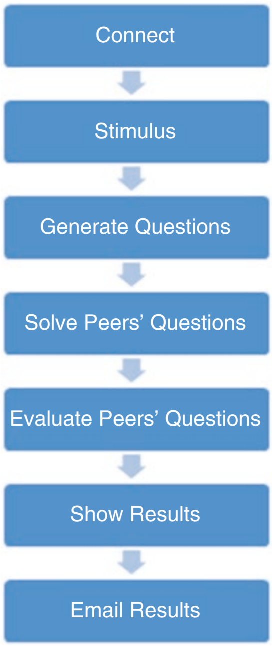

Fig. 11.1 Activity flowchart for a SMILE lesson

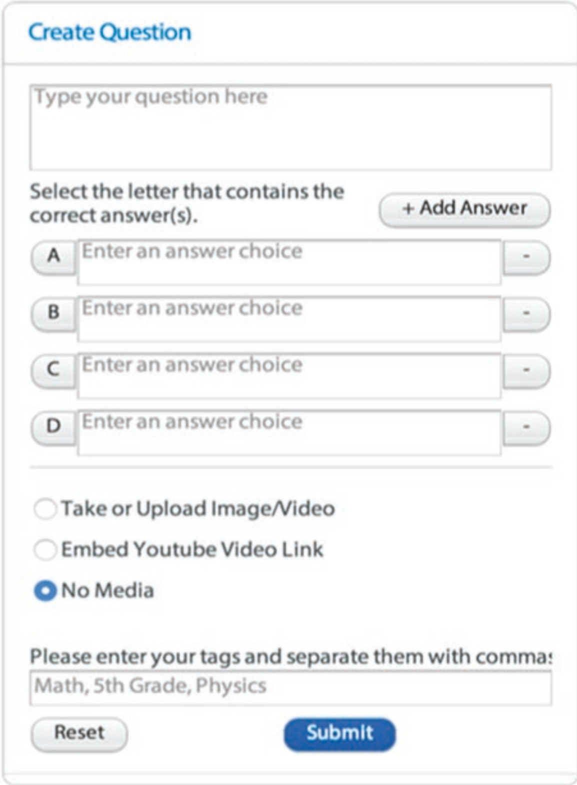

Fig. 11.2 Question-generating page on a SMILE device

their average time taken to answer. The session summary provides an overarching review of the session, including details such as who answered the most questions, who has the highest score, who answered the fastest and who posted the most questions.

The current prototype of this application supports the generation of students' questions for group sizes of around 40 learners. Larger learning communities such as at the village/school level or community/school district level will be supported soon. The former prototype, which comes in the form of a micro-cloud computer, takes place inside the classroom, while the latter application takes place outside the classroom. The current prototype can be accessed via a mobile device, which, in our study, was accessed via tablets using the SMILE website (https://smile2.stanford.edu/), thus enabling students or teachers to have access to the SMILE server regardless of time and place. In short, all homework items created by students are uploaded to and saved on the SMILE server, which is shared with the class. This in-out school network system offers continuous learning to students, enables them to pay attention to their own learning and assists them in acquiring a better understanding of what they have learned inside and outside the classroom.

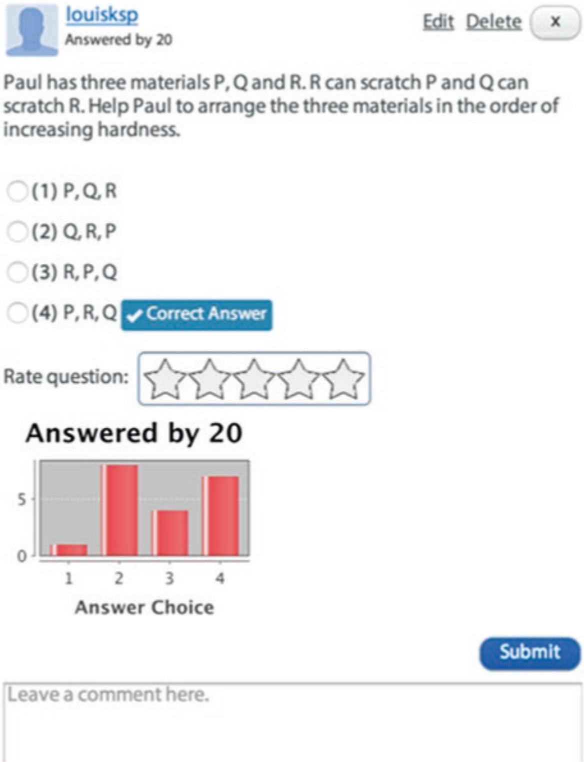

Fig. 11.3 Question-evaluating page on a SMILE device

The SMILE environment leverages on existing mobile technology used by students to increase student engagement and inquiries. It offers a pedagogical shift in moving away from the traditional pedagogical approaches which rely on teachers to come up with questions while students simply memorise and recall the right answers. The activities are designed to develop inquiry making, critical thinking and analytical skills. They help to transform conventional teacher-led classrooms into active learning environments where students construct their own learning. The learning is self-directed and peer-to-peer, which relates relevant content to a learner's practical experiences. This helps teachers identify and address learning gaps in order to improve student learning.

The programme is not content-based and hence is not domain or subject specific. Thus, it offers the flexibility to be used in a variety of formal or nonformal education and training scenarios where promoting higher-order learning (i.e. versus rote memorisation) and generating instant learning analytics are of importance. The combination of mobile and micro-cloud technology has the potential to be used in unique education settings such as on field trips and in rural areas.

11.2 Aims and Objectives

The study sought to find out if progressive interaction with SMILE affects the nature and efficacy of learners' questions and, in so doing, find out the extent to which SMILE, as a platform, is efficient in helping students achieve better conceptual understanding and accuracy.

Considering that many systemic problems faced in a traditional classroom setting can be ameliorated with the use of technology, our project sought to find out the extent to which such technology is able to mediate these limitations.

The school in which the intervention described in this chapter was implemented is a state-funded school in Singapore. In the course of recent years, it has enjoyed access to additional funds under the FutureSchools@Singapore programme of the Ministry of Education. Under this programme, the National Institute of Education works in partnership with the Ministry to manage the National Research Foundation's R&D programme on Interactive and Digital Media (IDM) in Education.

The FutureSchools@Singapore programme operates under a unified structure (known as eduLab) that couples the endeavours of schools, an Institute of Higher Learning (IHL) and industry, to focus on IDM in Education projects. EduLab has been effective in developing Singapore as a "living" lab for IDM in Education products. It reinforces the capabilities developed in schools, industry and IHLs to drive the following objectives:

1. Prototype educational models and IDM tools with a view to effectively scaling up their adoption in the school system.
2. Strengthen the collaborative partnerships between schools, IHL researchers and industry.
3. Develop new knowledge and local manpower capability, including education models and IDM tools that have potential for commercialisation.

The leadership team in this school are strong supporters of innovative and effective use of ICT for teaching and learning. Over the past few years, such support has given rise to many ground-up initiatives from teachers. Besides providing support for bottom-up initiatives, the school leaders are also actively involved in leading curriculum innovations and research to promote higher-order thinking and collaborative learning amongst students.

In terms of teacher readiness, more than 85% of teachers in the school have been trained in Teaching for Understanding with Technology (Wiggins & McTighe, 2011), and of these, 30% of teachers attained the status of Microsoft Office Specialist. The teachers have common pedagogical language and expertise that allows for active engagement and participation in the development of innovative curriculum. The school nurtures professional learning communities amongst teachers to enable them to meet and collaborate on curriculum improvement and innovation.

The school campus is wireless and has subscribed to a dedicated data transfer capacity of 20 Mbps to back up teaching and learning. With respect to the student profile, a research survey conducted by the school on 830 students in 2011 demonstrated that students are regular and proficient users of Web 2.0 technologies, and all students have access to an e-learning portal as well as Web 2.0 tools.

As seen in the following conversation which took place during a Physics lesson (without the use of SMILE technology) on 16 October 2013, a student was unable to clarify his thoughts with the teacher due to his inability to articulate his doubts:

> Teacher: Next question. If there is a change in the freezing process of a substance, what can we say about the substance? Hmmm.…you?
> Student: […]
> Teacher: What can we say?
> Student: {silence}

Through the use of SMILE, students were provided with a digital platform to raise questions, either to clarify certain doubts or to test and compete with each other. We hope to add to existing knowledge on the use of SMILE by studying whether it had any effect in helping students in Singapore learn how to generate better questions.

Some of the assumptions we made were that:

- Each class has been given the same verbal instructions by the teacher conducting the lesson..
- Each class has been given the same amount of time to interact with SMILE.

We acknowledge that these assumptions might not necessarily hold true. The investigation was conducted with 15- and 16-year-old students over the span of a few months (May to August for one class and June to September for two classes) in 2015. SMILE lessons were primarily carried out during Physics lessons, although towards the end of the study, teachers from other subjects had begun to use SMILE in their lessons as well. Such lessons included a Humanities field trip and an English language lesson on vocabulary.

The research question which drove our inquiry was: How does the nature and efficacy of learners' questions change over time through progressive interaction with SMILE?

11.3 Literature Review

The research described in this report is framed through Kaptelinin and Nardi's (2006) activity theory. For the purposes of the present analysis, Vygotsky's (1978) original focus on mediated action from the perspective of the individual would be most applicable.

Vygotsky argued that there is never a direct relationship between a human subject and an object; this relationship must be sought through other means in culture and society, as opposed to the individual mind unto itself (as cited in Engeström, 2001). In an attempt to explain the development of human consciousness, Vygotsky

(1978) proposed that consciousness emerges from human activity mediated by artefacts (tools) and sign, for example, physical artefacts such as hammers or machines, cultural artefacts such as language and theoretical artefacts such as algebra.

Wells (2007) represents this concept of semiotic mediation within Vygotsky's triangular model which features the triad of Subject, Object and Mediating Artefact. In mediated action, the Subject, Object and Artefact stand in a dialectical relationship, whereby each affects the other while also affecting the activity as a whole.

In the intervention described in this chapter, Subject would refer to the student, the Mediating Artefact would refer to the use of SMILE, Object would refer to the questions generated, and Outcome would refer to the greater conceptual understanding of the topic. Understood this way, some of the theories which form the context of this study are the pedagogical approaches of:

1. Inquiry-based learning, in which learners generate questions to develop their knowledge, is also defined as "an activity of a teacher and a pupil that is focused on the development of the knowledge, skills and attitudes based on the active and relatively individual cognition of the reality by the pupil who learns on his/her own how to explore and explores" (Dostál, 2015). This is a constructivist method of teaching, whereby learners actively construct knowledge from their experiences, which is crucial to the education of scientific subjects (Cole, 2009).
2. Socratic questioning, where learners are probed to think deeper through structured and systematic questioning. Socratic questions include:
   - Questions for clarification—Why do you say that?
   - Questions that probe assumptions—How can you verify or disprove that assumption?
   - Questions that probe reasons and evidence—What do you think causes…to happen? Why?
   - Questions about viewpoints and perspectives—What is another way to look at it?
   - Questions that probe implications and consequences—How does...affect...?
   - Questions about the question itself—What was the point of this question?
3. Bloom's Taxonomy, which provides a hierarchy and framework for categorising different types of questions.

A study done by Healey (2005) emphasises the benefits of inquiry-based learning, in terms of depth of students' learning and understanding. Kubieck (2005) found that when students generate questions, they are often required to revisit and expand upon prior curricular material. Chin and Brown (2002) also argue that questions can reveal students' thought processes as well as their gaps in knowledge or understanding, allowing teachers to surface misconceptions.

However, studies show that only a small percent of questions asked in class are student-generated. Dillon (1988) wrote that students generated very little questions, and of those, most were regarding instructional clarifications, rather than content-related inquiries. Kolb (2008) suggests that one of the many reasons why students were hesitant in asking questions was because they were afraid of negative reactions from both classmates and teachers, which may have stemmed from structural concerns and the extent of the teacher's authority and control.

Technology, as a mediator, may be able to encourage students to generate more questions at their own pace and without facing negative reactions from their class. Indeed, mobile phones are being increasingly recognised as engaging tools that schools can take advantage of (Dillon, 1988). Kubieck (2005) similarly suggests the use of technology as a platform to employ inquiry-based learning in Science subjects but cautions that it must be used appropriately to be pedagogically effective.

Recent research on SMILE (Seol, Sharp, & Kim, 2011) has categorised the students' questions according to types drawn from Bloom's Taxonomy. Data gathered from 26 students revealed that the remembering-type were the most common, followed by understanding-type, with analysing-type questions being the least common (Seol et al., 2011). Another study by Buckner and Kim (2014) comments that students primarily generated remembering-type questions because they lacked the experience in asking questions and/or were used to memorising facts in their traditional classroom setting. It was also found that the facilitator played a key role in setting early guidelines for stimulation and learning evaluation, which helped improve the quality of questions asked over time (Buckner & Kim, 2014).

11.4 Methodology and Materials

The SMILE application enables homework generation, completion and competition during class. It encourages students to review what has been taught, tests their conceptual understanding and clarifies any misconceptions. Students can immediately review their results once they have submitted their answers and, in doing so, can quickly identify and clarify their mistakes or compensate their lack of learning with peers' questions. The instant activity prevents students' learning of the day from fading away easily and helps them to strengthen their conceptual knowledge as they can immediately apply what was taught. After the activity, a teacher can also choose to provide additional information and detailed explanations to the class.

Teachers can serve as facilitators by controlling and monitoring the activity flow so that students will not get distracted easily. They are also in charge of addressing and rectifying any mistakes made by the students during the question-generating stage. The teachers are also tasked with providing the stimulus and scaffolding the question-generating process by using the models of Bloom's Taxonomy and Socratic questioning. They can also choose to select and show good examples of higher-order thinking questions.

SMILE lessons have been carried out by the teachers at the school. Types of data include the questions generated by the students, survey responses gathered from students and teachers and audio recordings of the SMILE lessons.

These lessons are primarily conducted during Physics lessons in an integrated co-teaching classroom, where students are allowed to utilise tablets for the purpose of accessing SMILE (refer to Fig. 11.4). The teacher first explains the models of

Fig. 11.4 SMILE lesson in progress. (Copyright [2018] by K. Y. T. Lim. Reprinted with permission)

Table 11.1 Dates and topics of SMILE lessons per class

Class	Date	Topics covered
3R8 (Class C)	30 Jun 2015 (holiday assignment)	Kinematics, Forces
	28 May 2015	
	11 Aug 2015	Thermal Physics
4R6 (Class A)	1 Jul 2015	Kinematics, Forces, Dynamics, Sound
	30 Sep 2015 (e-learning)	
4R7 (Class B)	2 Jul 2015	Kinematics, Forces, Dynamics, Sound
	30 Sep 2015 (e-learning)	

Socratic questioning and Bloom's Taxonomy to the students. A Physics-related video is played, and students are to generate their own questions after that. The teacher then goes through the questions one by one and clarifies any conceptual inaccuracies with the students.

We report the data collected from three classes in Table 11.1. There were two 10th grade classes of 17 students each; these are referred to in this chapter as Classes A and B. Additionally, there was a 9th grade class of 29 students; this class is referred to in this chapter as Class C. Classes A and B were relatively smaller in size compared to Class C because of the subject combinations offered. Students from all three classes were of similar academic abilities as inferred from their performance in nationwide 6th grade examinations. SMILE lessons were conducted by the same teacher from May to July 2015, with an e-learning lesson conducted for two classes in September 2015.

11.5 Results and Discussion

11.5.1 Survey Data

The survey data conducted for teachers was analysed and categorised according to themes. Three questions were asked in the survey:

- Describe how you can make use of SMILE in your lesson.
- Does the use of SMILE make students more curious about the subject you teach?
- How do you think SMILE can benefit our students? Do you think it will make them change the way they ask questions?

As the third question is most pertinent to our research question, the analyses of the survey data are as follows: Teachers felt that the technology of SMILE "will provide students with the confidence to ask questions, without fearing judgement from their peers", and is also able to overcome practical barriers such as absence from class. Conversely, students may continue to be afraid of asking questions given that the questions are visible to the entire class. Teachers also believed that students "will be motivated to read up their content first in order to generate tougher questions and answer their peers' questions as well". Students may feel more inclined to read and understand the content before the lessons as the element of friendly competition encourages students to pose more challenging questions.

Teachers felt that students will "have a deeper understanding of the topic as they may want to ask higher order questions". In this way, SMILE can help students to think critically and try to find the answers themselves before asking questions, thus building on their conceptual understanding of the topic at hand. Students will also be able to understand the process behind crafting good questions, as stated by one of the teachers that they "will then realise that every part of the question is important and figure out what details they need to answer the question", thus learning to identify key points when answering questions.

Some teachers felt that "this activity is suited to students who are strong conceptually so the list of questions to correct would not have been extensive". However, some teachers believed that it can also benefit weaker students through process writing and encouraging them to be inquisitive and critical thinkers. Additionally, students will benefit from each other due to exposure to multiple perspectives and questions. Quite a number of teachers wanted to "use SMILE to conduct a post-lesson evaluation of the chapter with students" as it would be easier for students to test their own understanding of the concepts and clarify any misconceptions or doubts. Nevertheless, some teachers were sceptical towards SMILE's ability in benefiting how students learn and the efficiency in students' learning, as they felt that teachers "need to think how they can effectively employ it… so that it does not become a mere exercise".

The survey data conducted for students included the following open-ended questions:

- How does SMILE make you think more critically?
- Has using SMILE helped you in any way to have a better idea about how physicists look at the world?
- Does the use of SMILE make you more curious about Physics?
- Has SMILE changed the way you ask questions? How?
- What do you think are some questions that are important in physics?
- In general, how has SMILE benefited you?
- What are the challenges you face when doing a SMILE activity?

Some of our findings are as follows: SMILE makes students think about the subject they are learning as a few mentioned that “some questions posted by my friends require me to think harder”. SMILE encourages students to ask questions and helps them to think deeper when trying to create a question. The majority of the students feel that SMILE has helped them to “relate physics concepts to real world problems” and have a better understanding of how physicists look at the world, as students have to think like physicists when creating Physics questions. There is, however, a minority of students who do not feel that SMILE has helped them in understanding how physicists look at the world. Nevertheless, students generally feel that the use of SMILE will make them more curious about Physics. A student commented that “when my classmates submit their questions, there are a few that I have not seen before and sometimes it is interesting”.

Our observations suggest that quiet students tend to voice out their questions more often when using SMILE as compared to lessons conducted normally in class. Students will think critically and try to find the answers themselves before asking questions, building on their conceptual understanding of the topic. Most students “can’t ask too easy questions because it will be too simple, so they have to think of questions that can activate their ability to think”.

Students feel that the important questions are those that concern their “daily lives and practical use” so that they can relate to them and apply better conceptual understanding. Many students think that SMILE has benefited them by creating a more engaging learning environment because students are able to interact with one another. Most importantly, students feel that they “learn better” and “learn more stuff” from each other as they answer different types of questions created by their peers. Some students find that questions created by other students are difficult to understand as there were “some confusing questions and hard ones” and hence are unable to answer the questions. Students also find it hard to create what is deemed as a “good” or “suitable” question.

In addition to these questions, students were asked to rate several statements with regard to the usefulness of the SMILE activity as well as their interest towards it, from 1 being the least true to 7 being the most true. Figures 11.5 and 11.6 reveal that students are fairly optimistic towards SMILE’s usefulness, although a considerable percentage of students are undecided. Nevertheless, the majority of students feel that the activity was enjoyable, and being actively engaged and interested is beneficial to the students’ learning.

Fig. 11.5 Results of survey data concerning SMILE's perceived ability to improve learners' questions

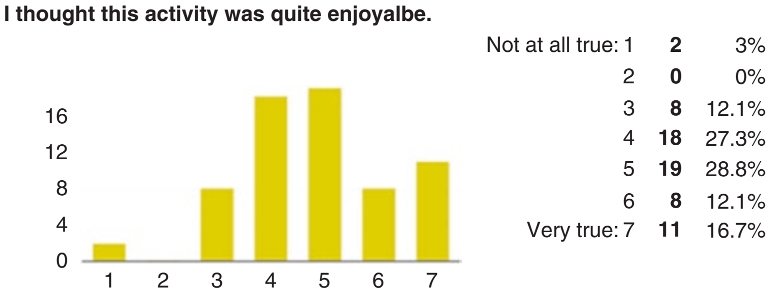

Fig. 11.6 Results of survey data concerning students' interest towards SMILE

11.5.2 Student-Generated Questions: Conceptual Accuracy

Apart from the survey data collected, questions generated by students from three classes were also collected and analysed. These questions were categorised according to various parameters, such as content relevance and conceptual accuracy. It was found that all but one question were relevant to the topic or subject, which in this case was Physics. This could imply either that the students are mature enough to use SMILE solely for educational purposes or that the presence of a teacher or facilitator is important in keeping the students focused.

Conceptual accuracy was dependent on both the question asked and the option students chose as correct. Examples of accurate questions generated by the students [(correct) indicates the option the student has chosen to be correct for the question] are:

1. According to kinetic molecular model, in gases
   a. The particles are closely packed together, and they occupy minimum space.
   b. The particles occur in clusters with molecules slightly further apart.
   c. The molecules are very far apart and occupy all the space made available to them. (correct)

   d. The particles vibrate about fixed positions and are held together by the strong intermolecular bonds.

2. Convection is transfer of thermal energy due to
   a. Vibration of the particles
   b. Expansion of fluid
   c. Movement of particles from one place to another (correct)
   d. Radiation of waves

3. Why do people standing on a bus tend to be at risk of falling when the bus suddenly comes to a stop?
   a. They did not grab hold of a pole.
   b. They were too heavy.
   c. They did not feel inclined to move.
   d. Due to inertia, the reluctance for a body to change its state of motion. (correct)

Examples of inaccurate questions generated by the students [(correct) indicates the option the student has chosen to be correct for the question] are:

1. A good thermometer generally
   a. Is able to measure a huge range of temperatures
   b. Responsive to some temperature changes only
   c. Is safe to use (correct)
   d. All of the above

The answer depends on what the thermometer is going to measure. The student did not state what the thermometer is measuring; hence, there could be more than one correct answer.

2. Which of the following increases when the volume of a fluid is reduced?
   a. Frequency of collision (correct)
   b. Speed
   c. Kinetic energy
   d. Pressure

There is more than one correct answer; both frequency of collision and pressure increases.

3. What happens to the mass and weight of a satellite as it is launched from earth into space?
   a. Mass decreases, weight increases
   b. Mass increases, weight decreases
   c. Mass stays the same, weight stays the same
   d. Mass increases, weight stays the same
   e. Mass stays the same, weight increases (correct)

The correct answer is none of the above; when a satellite is launched from earth into space, its mass stays the same and weight decreases.

Amongst the three classes combined, it was found that there was an increase in the percentage of inaccurate questions over time (from 2.41% to 8.90%). A two-sample *t*-test between proportions was performed to determine whether there was a significant difference between the first and second lessons with respect to the percentage of inaccurate questions. The *t*-statistic was not significant at the 0.05 critical alpha level, t (228) = 1.919, p = 0.0562 (1st lesson N = 83, 2nd lesson N = 146). Therefore, we fail to reject the null hypothesis and conclude that the increase in inaccurate questions between the first and second lessons was not significant.

11.5.3 Student-Generated Questions: Thinking Skills

Using the questions generated by the students, we analysed and categorised each question by using Bloom's Taxonomy to identify whether a student's question was indicative of higher-order thinking.

These are examples of the student-generated questions and how we have classified them according to Bloom's Taxonomy:

1. Remembering:
    a. What is the best way for a thermocouple to work?
    b. According to kinetic theory, what does temperature measure?
    c. What makes gases compressible?
    d. Convection is transfer of thermal energy due to ___________?
    e. What is a property of both liquids and gases?
2. Understanding:
    a. The diagram shows a container with three spouts. The container is filled with water. Jets of water pour out of the spouts. Why does the jet of water from the bottom spout travel the furthest out from the container?
    b. When a barometer is taken up a balloon, the mercury level ____________?
    c. Why is the base area of a lamp heavy?
    d. Is there a resultant force acting on an object moving with constant speed? If yes/no, why?
    e. When does an object float in water?
3. Applying:
    a. The surface of water in a domestic tank is 6 m above a cold water tap. The density of water is 1000 kg m^3. What is the pressure of water as it leaves the tap?
    b. Person has 40 kg mass on earth. When Person is on the moon, what is the mass?

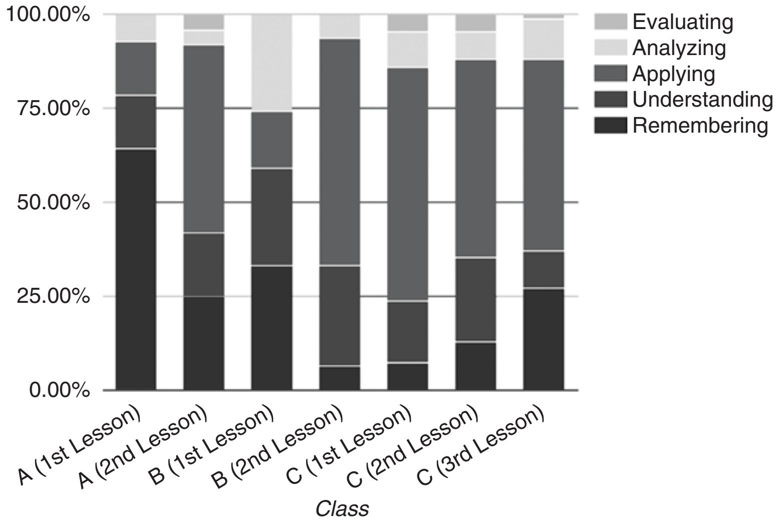

Fig. 11.7 Percentage of types of questions generated by students per lesson

c. A ball has a mass of 500 g. It travels towards a boy at 20 m/s. The boy kicks the ball with a velocity of 150,000 cm/min. What is the force exerted on the ball during contact?
d. If an object of mass 9 kg starts from rest and attains a velocity of 24 m/s after 6 s, then the force acting on it is?
e. What is the net force on a 200 g ball when it hits a wall with acceleration of $10 m/s^2$?

4. Analysing:

a. Which of the following has the highest pressure?
b. Which of it explains what happens after the air is heated?
c. Which shows the greatest external pressure?
d. There are three states of water. Which of the following is the densest?
e. Which is the centre of gravity (CG) that will make the man be stable?

5. Evaluating:

a. What happens to the coloured water level in a round bottom flask with a coloured water droplet in a tube is held by warm hands?
b. A truck is travelling at constant speed along a road and discovers that a thin sheet of ice has formed on the road. Fearing for his safety, the driver applies the brakes to stop the truck. Compared to braking on a dry road, what may happen?
c. What does one person do when being chased by an elephant? And why?
d. The diagram below shows an oval disc free pivoted at point A. The bottom of the disc is pulled to the left by a thread at point D as shown. Which of the point is the centre of mass of the disc?
e. What would be the reasonable estimate for the volume of a metre rule?

Table 11.2 Change in proportion of remembering-type questions per student in Classes A and B

Remembering-type questions		N	Mean	Std dev.		
	1st lesson	17	0.515	0.419		
	2nd lesson	17	0.147	0.343		
		Sum of squares	df	Mean square	F	Sig.
	Treatment (between groups)	1.149	1	1.149	12.2	0.003
	Error	1.507	16	0.094		
	Ss/Bl	3.184	16			
	Total	5.840	33			
	η^2	0.197				

From Fig. 11.7, we can see that the percentage of remembering-type questions decreases over time with the use of SMILE, with the exception of Class C. There is also an increase in the percentage of applying-type questions in the second lesson for Classes A and B. However, majority of the questions fall under the applying-type as these are commonplace in Physics questions, and students may have been familiar with such questions before. Another probability is that students may not be generating the questions themselves and may have copied questions off other sources.

Tables 11.2, 11.3, 11.4 and 11.5 present a one-way analysis of variance (ANOVA) analysing the changes in proportion of question types against the first and second lessons for Classes A and B, as they were given the same instructions and topics. To paraphrase Field (2005) and Lund, Liu, and Shao (2016) (amongst others), ANOVA was used to determine whether there were any statistically significant differences between the means of three or more [question types]. The decrease in proportion of remembering-type questions and the increase in proportion of applying-type questions were both found to be significant ($p = 0.003$, $p = 0.011$, respectively), with the effect size being considered small according to Cohen's effect size criteria ($\eta^2 = 0.197$, $\eta^2 = 0.212$, respectively). This shows a small but significant improvement as students generate lesser remembering-type questions which belong to the lowest level of Bloom's Taxonomy and instead generate more applying-type questions.

However, as seen in Table 11.5, the change in analysing-type questions, which is considered a higher-order thinking question, is insignificant ($p = 0.332$). This may be due to the limited number of lessons the classes were exposed to.

Tables 11.6, 11.7, 11.8, 11.9 and 11.10 present a one-way analysis of variance analysing the changes in proportion of question types against the first, second and third lesson for Class C. Contrary to what was found earlier for Class A and B, the proportion of remembering-type questions for Class C increased steadily from the

Table 11.3 Change in proportion of understanding-type questions per student in Classes A and B

Understanding-type questions		N	Mean	Std dev.		
	1st lesson	17	0.191	0.300		
	2nd lesson	17	0.265	0.400		
		Sum of squares	df	Mean square	F	Sig.
	Treatment (between groups)	0.046	1	0.046	0.4	0.536
	Error	1.860	16	0.116		
	Ss/Bl	2.140	16			
	Total	4.046	33			
	η^2	0.011				

Table 11.4 Change in proportion of applying-type questions per student in Classes A and B

Applying-type questions		N	Mean	Std dev.		
	1st lesson	17	0.147	0.294		
	2nd lesson	17	0.529	0.450		
		Sum of squares	df	Mean square	F	Sig.
	Treatment (between groups)	1.243	1	1.247	8.35	0.011
	Error	2.382	16	0.149		
	Ss/Bl	2.235	16			
	Total	5.860	33			
	η^2	0.212				

Table 11.5 Change in proportion of analysing-type questions per student in Classes A and B

Analysing-type questions		N	Mean	Std dev.		
	1st lesson	17	0.147	0.294		
	2nd lesson	17	0.059	0.166		
		Sum of squares	df	Mean square	F	Sig.
	Treatment (between groups)	0.066	1	0.066	1	0.332
	Error	1.059	16	0.066		
	Ss/Bl	0.765	16			
	Total	1.890	33			
	η^2	0.035				

Table 11.6 Change in proportion of remembering-type questions per student in Class C

Remembering-type questions		N	Mean	Std dev.		
	1st lesson	29	0.059	0.206		
	2nd lesson	29	0.126	0.187		
	3rd lesson	29	0.241	0.280		
		Sum of squares	df	Mean square	F	Sig.
	Treatment (between groups)	0.495	2	0.248	4.53	0.015
	Error	3.065	56	0.055		
	Ss/Bl	1.306	28			
	Total	4.865	86			
	η^2	0.102				

Table 11.7 Change in proportion of understanding-type questions per student in Class C

Understanding-type questions		N	Mean	Std dev.		
	1st lesson	29	0.111	0.278		
	2nd lesson	29	0.218	0.271		
	3rd lesson	29	0.098	0.170		
		Sum of squares	df	Mean square	F	Sig.
	Treatment (between groups)	0.253	2	0.127	2.01	0.143
	Error	3.535	56	0.063		
	Ss/Bl	1.493	28			
	Total	5.282	86			
	η^2	0.048				

Table 11.8 Change in proportion of applying-type questions per student in Class C

Applying-type questions		N	Mean	Std dev.		
	1st lesson	29	0.698	0.419		
	2nd lesson	29	0.517	0.229		
	3rd lesson	29	0.546	0.364		
		Sum of squares	df	Mean square	F	Sig.
	Treatment (between groups)	0.545	2	0.273	2.52	0.090
	Error	6.061	56	0.108		
	Ss/Bl	4.023	28			
	Total	10.630	86			
	η^2	0.051				

Table 11.9 Change in proportion of analysing-type questions per student in Class C

Analysing-type questions		N	Mean	Std dev.		
	1st lesson	29	0.086	0.270		
	2nd lesson	29	0.092	0.152		
	3rd lesson	29	0.103	0.242		
		Sum of squares	df	Mean square	F	Sig.
	Treatment (between groups)	0.004	2	0.002	0.04	0.961
	Error	2.940	56	0.053		
	Ss/Bl	1.372	28			
	Total	4.317	86			
	η^2	0.001				

Table 11.10 Change in proportion of evaluating-type questions per student in Class C

Evaluating-type questions		N	Mean	Std dev.		
	1st lesson	29	0.046	0.194		
	2nd lesson	29	0.057	0.128		
	3rd lesson	29	0.011	0.062		
		Sum of squares	df	Mean square	F	Sig.
	Treatment (between groups)	0.033	2	0.017	0.81	0.450
	Error	1.152	56	0.021		
	Ss/Bl	0.465	28			
	Total	1.650	86			
	η^2	0.001				

first lesson to the third lesson, and this was found to be significant ($p = 0.015$). The effect size is likewise considered to be small ($\eta^2 = 0.102$). One of the reasons why the results for Class C may differ from the above results may be attributed to the different types of lessons that took place. Classes A and B had an e-learning lesson as their second lesson, whereas class C had their first lesson as a holiday assignment. Perhaps when students are given more time outside of class to generate their own questions, they will be more likely to generate questions that are of a higher level, resulting in a lower proportion of remembering-type questions.

Similar to Classes A and B, there was minimal change found in Class C in the mean proportion of understanding-type questions. This change was not found to be significant.

In line with results from Table 11.6, it was found that the mean proportion of applying-type questions decreased from the first lesson to the second lesson, but increased again from the second lesson to the third lesson, albeit still being lower than the first lesson. This change, however, was not significant.

Table 11.11 Change in question type per student amongst three classes

Class	Total no. of students who attended the first two lessons	No. of students who adopted a different question type	No. of students who adopted a different question type (which was of a higher order)
A	8	6	5
B	9	7	3
C	29	26	10

With regard to higher-order thinking questions (analysing-type questions and evaluating-type questions), it was found that the change in proportion did not differ significantly, which was similar to what was found for Classes A and B, despite the additional lesson held for Class C.

In order to track an individual student's progress over time, we took the most frequently used question type from all the questions generated by the student to be indicative of the student's level of thinking at that point in time. A considerable minority of students (38.3%) showed improvement in the second lesson with regard to the type of questions they generated (refer to Table 11.11), and a large majority of students (85.1%) adopted a different question type in the second lesson, which might be indicative of the students' ability to generate different types of questions after exposure to SMILE, despite not generating more higher-order questions.

Figure 11.8 shows that out of the students who did not adopt a different question type in the second/third lesson, most of them adhered to the applying-type questions. Despite the fact that the complexity of their questions may have increased, such as questions which indicated an appreciation of the multi-factorial nature of many problems in the sciences, the form of the questions were similar to each other. This could imply that these students may have been over-familiarised with such questions and thus became unable to think outside of the box. This rigidity in thinking, however, is a challenge that cannot be solved with SMILE alone and may require other forms of intervention or instruction.

Using these results to revisit our theoretical framework, it would seem that the use of SMILE (as a Mediating Artefact) may help the students (the Subjects in the diagrammatic representation) generate more questions of different types, but not necessarily more accurate questions or questions of a higher order (the Object), and thus may not build towards higher conceptual accuracy (the Outcome).

11.6 Considerations for Implementation, Diffusion and Sustainability

Through in-depth interviews with teachers and school leaders (of the schools involved in this study), several areas that can support the diffusion and sustainability of the SMILE platform were identified. In terms of Bronfenbrenner's (1995) ecological paradigm which this book has appropriated as a meta-structure, the

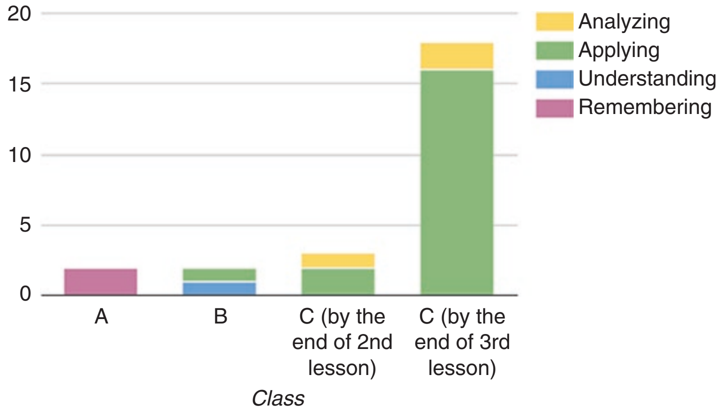

Fig. 11.8 Distribution of question type amongst students who did not adopt a different question type

dimensions pertinent to the present study can be analysed at the micro (classroom)-, meso (school)-, macro (policy)- and exo (partners)-levels.

At the level of micro-level analysis, the school leadership and teachers should have a positive attitude about the implementation. While top-down innovations are sometimes required, such adoptions can often be mechanical, superficial and fleeting. To create systems that support and educate students, the attitudes, assumptions and expectations from teachers and school leadership are important. This was stressed by teachers: "I think the first and foremost criteria [for a teacher to want to adopt SMILE, or try it out in their own context] is the teacher himself must have an open mind, and be willing to try, you know? Must see the potential". At the school involved in this study, SMILE benefited greatly from the hard work of the Science teachers who planned and implemented the platform. According to the school leadership:

> (Teacher A)...because of his ICT expertise, he is our in-house edu-tech consultant. So he goes around and helps different departments when edu-tech is concerned. He has been working with different groups of teachers: for example apps, and teachers who are interested in using SMILE… Even going to the classroom. He is not just giving technological support, but he works with the teacher before class to craft how the tool can best support the lesson objective. I think this really helps the adoption. That's our advantage. We have somebody who can go into the different classrooms (with the teacher). Looking at the wider picture, in terms of scaling to different schools, this can be a little challenging. You can take the tool, but do you have the person who can work with the teacher before the lesson, and maybe even going in during class to give you the support…

At a meso-level analysis, school-site leadership is responsible for planning and implementation. They must ensure that the implementation satisfies local needs, aligns with the school's academic mission and generates practice knowledge and data to inform improvements in the school community through sharing and practical advice.

In terms of a macro-level analysis, supportive policy and practices which encourage the diffusion of innovation across departments and schools is important. SMILE as a platform "is not subject-specific. It is a tool that you can use in (different) classrooms. And I think it is versatile enough that it can be used in most subjects". The school was very open to introducing new platforms to the teachers from various departments and allowing them to experiment:

> One issue is that whether the teacher is comfortable enough to use it. And (this) we can overcome. (Teacher A) and (Teacher B) are very happy to go into the classroom with the teacher and look at how that can be done, if there are any technical difficulties and so on. So, scaling within (School) is definitely possible. So as (Teacher A) and (Teacher B) suggested, one way is that, minimally, every department can try it out at least once. And then if they find it useful, they can obviously use it.

It was also observed that the school held regular sharing sessions amongst teachers within the school to facilitate the spread of innovations.

Finally, in terms of exo-level analysis, the importance of stable infrastructure support was commented on by the teachers who did the ground work for implementing SMILE: "Really, that we need a very stable infrastructure, especially the bandwidth. And also we need students to have ready devices to be able to, you know, better engage with this intervention".

11.7 Conclusion

This study set out to find out the extent to which SMILE might be an effective and reliable tool in enabling learners to achieve better conceptual understanding and accuracy, through the enabler of a tool which facilitates the student generation of questions. The research question that has driven our inquiry is how the nature and efficacy of learners' questions change over time, through progressive interaction with SMILE. Our analysis suggests that it is largely evident that SMILE, as an inquiry-based platform, is able to encourage and compel students to ask different types of questions over time. However, the accuracy of questions and the proportion of higher-order thinking questions do not seem to show any significant change.

We acknowledge the following limitations inherent in the study:

1. The sample size may be insufficient as we were limited to conducting the SMILE lessons in only one school, which may affect the validity of the results obtained.
2. The amount of time learners spend interacting with SMILE may be varied, due to technical errors that may disrupt lesson time.
3. The change in the nature and efficacy of learners' questions cannot be completely attributed to their progressive interaction with SMILE, as the timespan is over a few months, and other factors may come into play, such as exposure to inquiry-based methods in other subjects.

4. SMILE lessons cannot be carried out on a regular basis as it would disrupt the curriculum schedule.
5. Questions may not be entirely generated by students, as they could easily copy questions from other sources.

Nevertheless, there still remains a place for SMILE in the formal curriculum. For example, in a Physics lesson conducted without the use of SMILE which was carried out on 16 October 2013, conversation was mostly unidirectional, with the teacher driving the conversation and students being passive receivers. A probable reason as to why there was a lack of student response could be because there was insufficient time for students to generate questions on the spot, as seen in the following quote:

> *Teacher:* Are we clear? Any questions? We have already learned this theory, kinetic theory from chapter seven. And you'll be tested on Monday. Don't forget.

In comparison, the use of SMILE made it easier for the teacher to surface students' doubts, as seen in the following quotes, which were taken on 30 August 2014 during a Physics lesson with the use of SMILE:

> *Teacher:* Who wrote this question? Because I want to… I wanna [sic] know what it means. … Does it answer your question? Is what I interpreted the same as what you were going to ask?
>
> *Teacher:* There's a lot of questions on Newton's 3rd Law… maybe the concept wasn't drilled in last year.

Beyond the immediate context of use reported in this chapter, SMILE has been used at the same school by a Physics teacher who used it during a feedback session on her lesson and a Chemistry/Biology teacher who used it during a Science practical lesson. SMILE was also used during the semester break for grade 9 Physics students—each student was tasked to craft three questions of low-, intermediate- and high-order thinking questions in the topics of Kinematics and Forces, and they would subsequently have to answer each other's questions as a form of revision and also provide feedback to their peers. For a grade 7 Science class from a relatively academically weaker cohort, SMILE was used as a summative assessment tool—each student was tasked to answer and rate the difficulty of the questions. During Science Week in the school, SMILE was used as a platform to gather students' impressions about the different stations and sites they had visited as part of the activities.

The use of SMILE has been applied in both the Sciences as well as in the Humanities and language learning. However, the latter has been less researched in our local context. For example, SMILE was used during a Humanities Learning Journey field trip, and it was also introduced to a grade seven class for the learning of vocabulary. In this lesson, each student was given a list of vocabulary words and tasked to craft questions to demonstrate their understanding of the word in use.

There has also been external research demonstrating the implementation of SMILE in Mathematics classroom and in the healthcare sector (Seol et al., 2011; Kim & An, 2016). The benefits of SMILE flexibility regarding different content are clear. Students who are already using SMILE in one subject can continue to use it for other subjects, both in and out of school. Very often, students feel less pressure to answer perfectly the first time they try the questions in the SMILE environment. The platform can be extended for students' use at home, where they can revise in informal study groups as often as they want.

Schools and school networks are invaluable structures in sharing and scaling up any ICT innovation. Often, teachers and educators need to invest time in familiarising themselves with the technology, and it is important that there are supporting qualitative or quantitative evidence that the new practice is beneficial and of relevance to their work. In the case of SMILE, the skill level needed is low, and the programme can be fitted into a vitality of different subjects. For the initiative to not be short-lived or isolated, sustainability consideration should be built into the programme, either through sharing, publication or documentation. Various factor such as school and organisational culture, size of organisational networks, personal experience, level of executive support, etc. will affect how the project becomes more widely adopted and sustainable over time. There are some factors that can encourage the spread of any innovation: giving staff time away from normal duties to consider new changes and innovations, facilitating and supporting sharing amongst teachers and personal and professional development, providing evidence that new innovations help attainment certain learning targets and more.

Future research on SMILE could also consider its effect on the learning of other languages; however, this is contingent on whether SMILE allows for various language inputs. These, and other supporting structures such as a stable wireless network of sufficient bandwidth, and support for/assistance with the creation of student accounts, were raised by teachers on the programme.

SMILE lessons should also be conducted on a wider scale, in other schools and other levels, in order to broaden the sample size of the data, as well as to research its effect in differing contexts.

In a broader sense, the use of SMILE can potentially contribute significantly to the aims of the 3rd ICT masterplan, in particular the development of self-directed (SDL) and collaborative learning (CoL) skills in students. Key attributes of SDL, for instance, require that the student extend his/her learning. With a relatively simple tuning of pedagogical practices, the development and subsequent discussions of the questions generated by the students can be meaningfully employed to bring out an extension of student learning. More importantly, the students would have a good platform to "practise" such skills. At the same time, the collaborative aspects of SMILE can be made explicit for the students so as to enhance their understanding and "practice" of group processes. Given such possibilities, future iterations of SMILE can incorporate these aspects to not only bring about deeper learning of the subject matter but also important twenty-first-century skills. This implies that teacher professional development will need further tweaking to accommodate such pedagogical practices.

It is useful to note that inquiry-based learning is a key pedagogical approach advocated within the Singapore Science curriculum. To this end, SMILE is well-positioned to provide a strong illustration of what can be achieved when inquiry-based pedagogies are effectively practised. This is useful for the purposes of spreading such practices within the system, as teachers are likely to be more receptive to SMILE given the emphasis of the curriculum.

From a teaching and learning perspective, perhaps the most important impact of SMILE is the nudge it provides towards shifting the role of the teachers towards being facilitators of learning rather than primary sources of knowledge. By getting the students to develop questions, teachers can facilitate the development of deeper understanding of the content through leading the students in the construction of the questions. This translates into professional development content for teachers with a focus on pedagogies of question constructions.

On the whole, the extension possibilities offered by SMILE can be potentially impactful in pushing students' learning towards greater depths, as well as providing a simple platform to rebalance the role of teachers with a stronger emphasis on the facilitation of learning.

References

Bronfenbrenner, U. (1995). Developmental ecology through space and time: a future perspective. In P. Mien, G. H. Elder, Jr. & K. Luscher (Eds.), *Examining lives in context: Perspectives on the ecology of human development* (pp. 619–647). Washington, DC: American Psychological Association.

Buckner, E., & Kim, P. (2014). Integrating technology and pedagogy for inquiry-based learning: The Stanford Mobile Inquiry-based Learning Environment (SMILE). *Prospects, 44*(1), 99–118.

Chin, C., & Brown, D. E. (2002). Student-generated questions: A meaningful aspect of learning in science. *International Journal of Science Education, 24*(5), 521–549.

Cole, M. (2009). Using Wiki technology to support student engagement: Lessons from the trenches. *Computers & Education, 52*(1), 141–146.

Dillon, J. T. (1988). The remedial status of student questioning. *Journal of Curriculum Studies, 20*(3), 197–210.

Dostál, J. (2015). The definition of the term "Inquiry-based instruction". *International Journal of Instruction, 8*(2), 69–82.

Engeström, Y. (2001). Expansive learning at work: Toward an activity theoretical reconceptualization. *Journal of Education and Work, 14*(1), 133–156.

Field, A. (2005). *Discovering statistics using SPSS*. London: Sage.

Healey, M. (2005). Linking research and teaching exploring disciplinary spaces and the role of inquiry-based learning. In R. Barnett (Ed.), *Reshaping the University: New relationships between research, scholarship and teaching* (pp. 67–78). Maidenhead, England: McGraw Hill.

Infocomm Media Development Authority Singapore. (2017). *Telecommunications statistical charts*. Retrieved from https://www.imda.gov.sg/industry-development/facts-and-figures/telecommunications

Kaptelinin, V., & Nardi, B. A. (2006). *Acting with technology: Activity theory and interaction design*. Cambridge, MA: MIT Press.

Kim, P., & An, J. Y. (2016). New evaluation vector through the Stanford Mobile Inquiry-Based Learning Environment (SMILE) for participatory action research. *Healthcare Informatics Research, 22*(3), 164–171.

Koh, T. S., & Lee, S. C. (Eds.). (2008). *Information communication technology in education: Singapore's ICT masterplans 1997-2008*. Singapore: World Scientific.

Kolb, L. (2008). *Toys to tools: Connecting student cell phones to education*. Washington, DC: International Society for Technology in Education.

Kubieck, J. P. (2005). Inquiry-based learning, the nature of science, and computer technology: New possibilities in science education. *Canadian Journal of Learning and Technology, 31*(1).

Lund, R., Liu, G., & Shao, Q. (2016). A new approach to ANOVA methods for autocorrelated data. *The American Statistician, 70*(1), 55–62.

Seol, S., Sharp, A., & Kim, P. (2011). *Stanford Mobile Inquiry-based Learning Environment (SMILE): Using mobile phones to promote student inquires in the elementary classroom*. In: Proceedings of the 2011 International conference on frontiers in education: Computer science & computer engineering, pp. 270–276.

The Six Types of Socratic Questions. (n.d.). Retrieved from http://www.umich.edu/~elements/5e/probsolv/strategy/cthinking.htm

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Wells, G. (2007). Semiotic mediation, dialogue and the construction of knowledge. *Human Development, 50*(5), 244–274.

Wiggins, G., & McTighe, J. (2011). *The understanding by design guide to creating high-quality units*. Alexandria, VA: ASCD.

Kenneth Y. T. Lim is Research Scientist at the Office of Education Research, National Institute of Education. He operates at the intersection of Cultural Anthropology, the Learning Sciences and Cognitive Psychology. Kenneth is one of about a dozen people worldwide to have been invited by UNESCO as a member of the organisation's Symposia on the Future of Education for Sustainable Development, 2016–2017. He conceptualised the Six Learnings framework of curriculum design for fictive worlds and virtual environments. Kenneth edited a book titled *Landscapes of Participatory Making, Modding and Hacking: Maker Culture and Makerspaces* which was published in 2017. Kenneth's work on the Six Learnings framework and Maker Motes helped him posit a theory of learning around the notion of Disciplinary Intuitions; the latter is elaborated upon in a book published by Springer in 2015.

Bing Heng Song is an aspiring young man who enjoys learning and acquiring new knowledge. Throughout his Nanyang Research Programme journey, Bing Heng has developed inquiry skills that led him to perceive the world in different perspectives. He has also sharpened his time management skills and gained much insight to research paper writing. Bing Heng enjoys reading and volunteering during his free time. Bing Heng is currently serving his national service after completing his tertiary education in Innova Junior College.

Matthew Xiang Kho graduated from Raffles Junior College in 2016, having taken subjects such as Physics and Literature. He is interested in both the Sciences and Humanities and aspires to continue studying both in future. He is also piqued by the idea of using technology and video games for educational purposes, having played and learnt a lot from various video games. His other hobbies consist of finding good food and playing the guitar.