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A Descriptive Study on the Translation of the Seamless Science Learning Model for Wider Diffusion

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Abstract: A seamless learning environment connects private and public learning settings where learning occurs across various contexts. The notion of seamless learning was connected to mobile learning, in which the use of personal mobile devices for learning was recommended to facilitate students' cross-contextual learning. In seamless learning research, there are crucial technical and pedagogical considerations that may affect seamless mobile learning. The challenge is that most local primary school students did not possess personal devices for learning, thus, hindering the efficiency of scaling up to more schools. In addressing the problem, this paper reported a qualitative descriptive study on a practice-oriented project to implement seamless science learning in the formal curriculum. Three primary schools in Singapore participated in this two-year project. The participating teachers in the project designed and implemented selected seamless science lesson units at their classes. A significant contribution of the project is that it informs what it takes to switch from one-mobile-device-per-learner to the techno-pedagogical model of seamless science learning. The lesson enactment using the model increased students' engagement levels and resulted in significant learning gains in the second year of implementation. Another important implication of the project was teacher professional development. Several participating teachers reflected on how their involvement in seamless lesson design and implementation impacted their teaching methods, including the willingness to use ICT for lessons and making connections with parents. However, the challenge to the widespread adoption of seamless science learning was reported. In fact, a seamless curriculum is more than redesigning lessons and incorporating technology into the lessons, it should be perceived as a culture, and learners must be enculturated to change their current learning habits of mind.

Keywords: seamless learning; science inquiry learning; social media; translation of learning innovations

1. Introduction

Seamless learning is when a person experiences a continuity of learning, and consciously bridges the multifaceted learning efforts, across a combination of locations, times, technologies or social settings (Sharples et al., 2012; Wong, 2015), ideally with the support of one-mobile-device-per-learner (1:1) (Chan et al., 2006). Over the last decade, our team's ongoing research and practice of the techno-pedagogical model of seamless science learning has yielded remarkable results. The initial pilot in a primary school between 2010 and 2013 (Zhang et al., 2010) showed that the participating students exhibited improvement in higher-order thinking skills (Looi et al., 2014) and self-regulated learning (Sha, Looi, Chen, Seow, & Wong, 2012).

Notwithstanding, there were challenges in the earlier teaching toolkits that hindered direct and efficient scaling up to more schools. The teaching toolkits were originally developed with the condition of 1:1, 24x7 setting. The majority of local primary school students, however, did not possess personal devices for 1:1 learning. Henceforth, we embarked on a practice-oriented project to derive an alternative techno-pedagogical approach to tackle the problem. This paper reports on a qualitative descriptive study on the project which took place between 2017 and 2018. The positioning of this paper is *descriptive*, not *evaluative*. Specifically, the roles of social media in connecting students' cross-contextual learning efforts in seamless science lessons will be explicated.

2. Literature Review

Seamless learning is one of the contemporary learning notions that address the needs of 21st century learning (Looi et al., 2010). With the defining feature of bridging multifaceted learning efforts across a variety of learning contexts, the objective is to foster a disposition in students to continually perform iterations of learning-application-reflection through recontextualizations of previously constructed knowledge (Wong, Milrad, & Specht, 2015).

The notion of seamless learning was linked to mobile learning by Chan et al. (2006) which advocated the use of mobile devices in 1:1, 24x7 settings to facilitate students' cross-contextual learning endeavors. The aforementioned paper launched the research field on mobile-assisted seamless learning worldwide. Yet the earlier perception of having 1:1, 24x7 as a mandatory condition for seamless learning has been challenged in recent years. Rather than taking it as a special form of 1:1 mobile learning, more recent literature argues that seamless learning is a modern learning notion in its own right – as an aspiration (Sharples et al., 2012), a habit-of-mind (Wong & Looi, 2011) or as a set of metacognitive abilities (Sharples, 2015). Thus, alternative technological support models have been proposed, such as the "division of labor" (DoL; i.e., using different devices, computer sets or even non-digital tools available at different locations) model (Wong, 2012) and the use of social media (Charitonos, Blake, Scanlon, & Jones, 2012; Laru & Järvelä, 2015).

Social media are increasingly used for supporting students' communicative and creative endeavors (Greenhow, Robelia, & Hughes, 2009). Social media support student-student and teacher-student interactions across multiple contexts through the same social network. Teachers may create topical social media items to solicit student responses in and out of classroom or encourage students to create social media on day-to-day encounters that trigger their curiosity (i.e., personalized learning). Subsequently, tapping on the reply feature, social media can mediate subsequent cycles of collective reflection and (re-)production (Lewis, Pea, & Rosen, 2010) or social meaning making (Wong, Chin, Tan, & Liu, 2010) (i.e., collaborative learning). Furthermore, social media-mediated seamless learning would free the students from relying on 1:1, as social media spaces are accessible by multiple platforms or devices (i.e., the DoL model).

3. Method

We worked with three primary schools in Singapore for implementation during 2017 and 2018. Our intention was to handheld the participating teachers in piloting the revised seamless science learning model in selected lesson units. Four cross-school professional development (PD) sessions were also conducted for the participating teachers to share and compare their designs and enactment experiences.

At the beginning of each project year, the teachers selected their class levels and curricular units to design and enact seamless science lessons. Table 1 summarizes the key information of the enactments in the participating schools. The cohorts are differentiated by school, year and level, e.g., school S1's P4 students in year 2017 is considered one cohort. Every cohort involved two classes. One or two lesson unit(s) were selected to be designed as seamless science lesson(s). Each lesson may last for about 2-3 weeks with intertwining in-class and out-of-class, and physical and online activities.

Specifically, during the study, we guided the teachers to design their lessons based on a set of streamlined seamless science lesson design principles of **C²FIP** (Wong, Looi, & Goh, 2017),

- **C**onnectivity of learning activities: Make the learning process cross-contextual - bridging formal and informal, individual and social, physical and digital settings.
- socio-**C**onstructivist inquiry learning: Facilitate an interplay of individual and collaborative inquiry learning. Encourage diverse "ideas" (Wong et al., 2021) from the students, and help them connect ideas, and later synthesize the knowledge.
- cross-contextual **F**ormative assessment: Different forms of student artefacts created at various learning activities can be used for the purpose of formative assessment. Teachers may design for systematically fostering the students' peer and self-evaluation skills across several lessons.

- leveraging resources in **I**nformal settings: The students' out-of-class living spaces may offer authentic learning resources that make their learning more relevant and meaningful.
- **Personalized** learning: Incorporate different learning modalities to suit different learning styles, and allow flexible learning pathways for individual students. Encourage interest-driven learning and group students with similar interests together to stimulate informal peer learning.

Table 1. *Summary of enactments taken place in the participating schools (Sx = school IDs; P3xx-y/P4-yP5-y = class IDs, with xx denoting the year, y denoting the semester, and P3, P4, P5 denoting 3rd, 4th and 5th Grade respectively; and Tzz = teacher IDs)*

School & year	Classes & teachers	Number of students	Lesson topic (month of enactment)	Social media tools used
S1, 2017	S1P417-1 (T11) & S1P417-2 (T12)	56	- light & shadow (July)	Padlet, Google Classroom
S1, 2018	S1P518-1 (T11) & S1P518-2 (T12)	53	- cells (February) - human systems (April)	Padlet
S2, 2017	S2P417-1 (T21) & S2P417-2 (T22)	43	- light & shadow (May) - heat (September)	Padlet
S2, 2018	S2P418-1 (T21) & S2P418-2 (T23)	50	- light & shadow (April) - heat (July)	Nearpod
S3, 2017	S3P417-1 (T31) & S3P417-2 (T32)	59	- heat (July) - human digestive system (September)	MC Online†
S3, 2018	S3P318-1 (T32) & S3P318-2 (T33)	59	- materials (April)	MC Online
	S3P418-2 (T34) & S3P418-3 (T35)	69	- heat (July)	MC Online

†MC Online is a Singapore-based Learning Management System. The Social Learning Wall module with social media features of MC Online had been deployed by S3 teachers in implementing their seamless science lessons.

A qualitative descriptive study on the lesson enactments was carried out for us to yield in-depth understanding of whether and how the **C²FIP** principles could be materialized. The research question that guides the descriptive study is:

> RQ: "How might the implementation of seamless science lessons at the participating schools impact the students' learning experiences and the teachers' instructional practices in the aspects related to the seamless science lesson design principles of **C²FIP**?"

To address the research question, the following set of qualitative data were collected for analysis, (1) Pre- and post-interviews with all participating teachers and selected students; (2) Video and audio recordings of in-class lessons; (3) Student artefacts posted online and peer discussions.

4. Findings

We uncovered important and somewhat consistent patterns across all three schools in students' practices of seamless science learning. This was done through applying (qualitative) constant comparative method (Strauss & Corbin, 1990) of students' online posts and peer comments, one-to-one interviews and class recordings. With a simple coding scheme that comprises the codes corresponding with the five design principles of **C²FIP**, we categorized the patterns/findings around these principles to see how the application of individual principles in the seamless science lessons have (or have not) transformed the ways the students learned. Some of the evidence span across multiple themes. We categorised the evidence in this way to make a better sense of the impact of the five design principles.

4.1 Connectivity of learning activities across contexts

All teachers but T34 viewed this most salient concept of seamless learning positively. Some of them perceived the learning approach as a vehicle to overcome the limited class time.

“Seamless learning is something that the students get to experience and understand the concept based on what they have discovered outside the classroom, with the help of technology.”

(T32, pre-interview)

“For seamless learning … we are really trying to think of the way to make learning happen in the informal situation whereby something that is not intentionally build upon in class … we really try to engage our learners in different contexts, different environments, I think it will bring out learning more, rather than to say that every time we run into time constraint in school whereby everything is so rush. That is what I am hoping to achieve by seamless learning.”

(T21, post-interview)

In the actual practice, the teachers designed their lessons which largely adhere to the cycle of “preparation at home” → “in-class learning engagement ” → “out-of-class observations/ applications” → “online peer comments and knowledge co-construction”. Such learning flows had effectively guided the students through the process of “recontextualization” in their learning journey.

Teachers T11, T12, T21, T32 indicated during the pre-interviews that they had experiences in implementing flipped learning (Flipped Learning Network, 2014) in the past. Thus, they incorporated such activities into their seamless science lesson plans, which had also influenced other participating teachers in their subsequent lesson designs. For example, a lesson may begin in students being instructed to view a relevant YouTube video or research online on a given topic at home prior to the first in-class lesson.

For example, in class S3P418-2, after being exposed to the basic concept of heat in the classroom, the students were tasked to take a picture at home or download a photo from the web that captured an example to show how heat was transferred, created graphical representations of the underlying mechanism or explaining it in their words, and shared them on the Social Learning Wall of MC Online to stimulate further discussions. The two examples in Figure 1 demonstrate how the students created multimedia artefacts to demonstrate their understanding in the concept in focus.

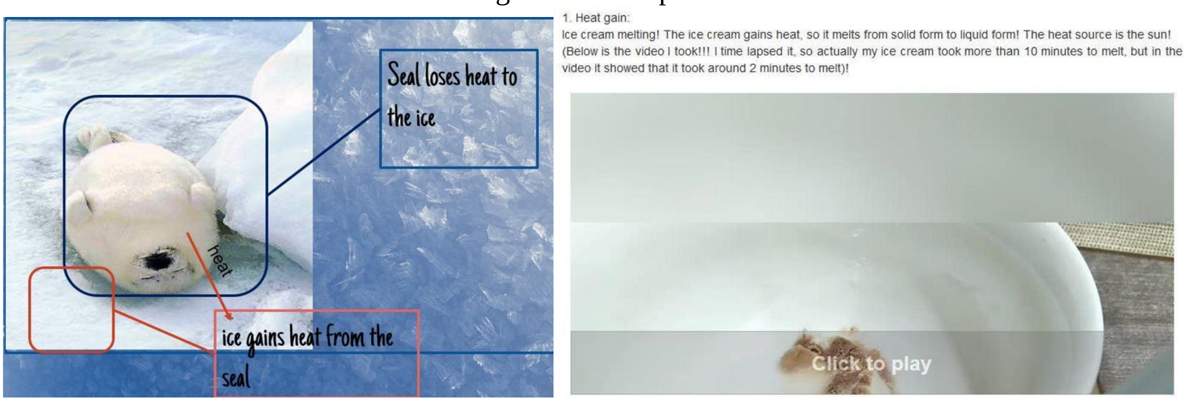

Figure 1: (left) a graphical representation on heat transfer with a web image; (right) a self-made video with caption to elaborate heat transfer (from class S3P418-2)

Such learning flows had resulted in the students’ greater engagement in learning as they defied the “patterns” of regular science classes. As one teacher described,

“The engagement level was higher when I did seamless learning. It wasn’t only because in and out of class, but during the lesson itself. … They anticipated, what are we doing today, why are we doing this. … I thought through different activities, we got the students to be very engaged, they felt very excited on what is coming up next. I asked some of them to give me feedback. They enjoyed the activity and would rather have this activity rather than teacher just telling them what to do.”

(Teacher T11, post-interview)

4.2 Socio-Constructivist inquiry learning

The students were actively learning in the informal setting through online portals. They co-constructed knowledge by posting social media and commenting on their peers’ works. That is, they made their ideas sharable for comparison and scrutiny, which led to negotiation of meaning. The benefit of bringing such activities online was articulated by a student as below,

> "The online portals enabled me to get the answer faster as I did not need to wait for classroom discussion. It was also interesting to read my friends' comments."
>
> (A student from class S1-P417-1, post-interview)

Examples of idea sharing, and peer comments are given in Figure 2. They are taken from the "heat" lesson at the class S1P417-1 where the students were asked to identify examples of heat sources.

Figure 2: Students' idea sharing and peer comments in the "heat" lesson at S1P417-1

Indeed, the key concept of this design principle is an integration of "social", "constructivist" and "inquiry" learning. In the participating teachers' lesson designs, inquiry learning usually takes place at in-class small-group experiments with well-defined procedures. Yet socio-constructivist learning is a broader term that covers not only such experiments but also other activities that require students to individually collect and interpret data in authentic settings or on the web, which constitute rich resources for subsequent knowledge co-construction. Such individual-to-social trajectory can be regarded as a trajectory of cross-contextual formative assessment (the next design principle). A participating teacher's comment reflects her understanding of this design principle,

> "With seamless learning, they *(students)* are able to do research; otherwise, they will have to go back to books and encyclopedia. Seamless learning helps to facilitate discussion. Deeper learning is not sufficient if just reading but do not provide comments."
>
> (T23, post-interview)

4.3 Cross-contextual Formative assessment

Various types of student-centered activities that required students to develop and share ideas, opinions or artefacts in the class-wide social space (either posting them online or presenting them in the classroom) have effectively served as the means for formative assessments. This is because the peers were then being encouraged to evaluate their views, compare alternative views from classmates, or provide feedback to improve their works. As the students deemed online social learning spaces as being semi-formal and low stakes, they were more willing to tinker and express diversified opinions.

> "They get to go online to discuss. To them it's like chit chatting with their friends, less scared to make mistakes because it's in an informal setting."
>
> (Teacher T24, post- interview)

Figure 3 presents two screen captures that illustrate such observations.

In a related note, a teacher explained why online discussion activities were valuable even if not all the students participated in out-of-school online discussion,

> "… I did get maybe 30-40% responses. From what they responded, I could screenshot and use it for classroom discussion. To me, it didn't matter how many people responded, just needed to capture important points and share with the class. I could use it as a teaching point. It was very clear to some of the students … I thought that one was actually a form of assessment because they checked on their own understanding."
>
> (T11, post-interview)

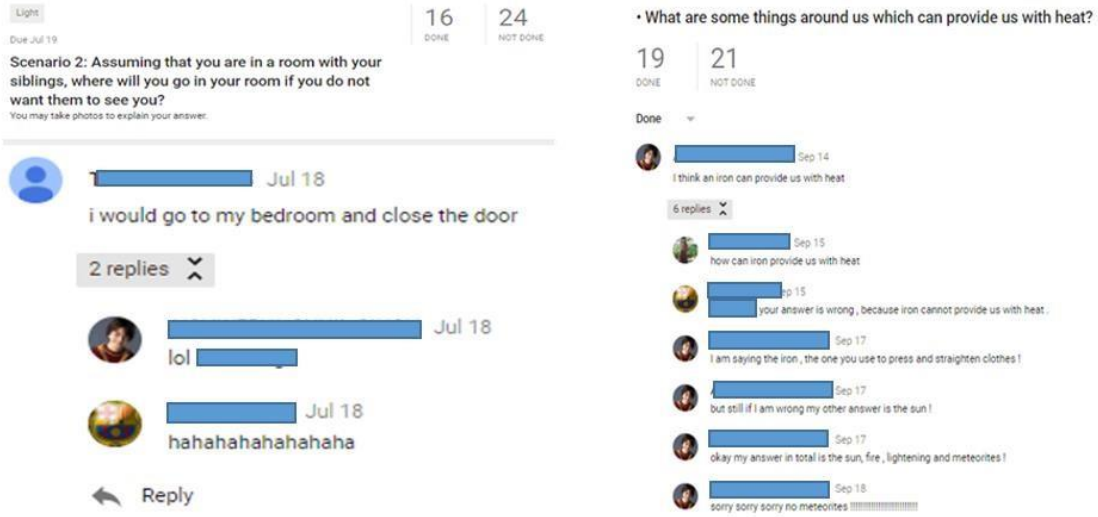

Figure 3: Students' easy-going and yet potentially constructivist peer interactions online (from class S1P417-2)

*4.4 leveraging resources in **I**nformal settings*

Teacher T21 shared his reflection on the value of leveraging resources in informal settings to advance students' learning. This is a means to foster their "eyes of science" in their daily lives. When being asked to compare inquiry learning and seamless learning, he posited,

> "I don't think I can compare. They are different things. Inquiry to me is I am giving the children the chance to talk, I am giving the children the opportunity to explore … *(For example,)* today I am going to teach about heat traveling from a hotter region to a colder region; so the children can think (*imagine*) that heat will always travel from a hotter to a colder region. But I think inquiry is getting them to explore. Did they observe that heat really travel from hotter to colder region? What was the observation that they made? What kind of measurement can they make to prove that what they have said is true? … In terms of seamless, I am just extending it to some other contexts whereby even be as simple as I may not need to conduct the lesson in my class. I would ask them to observe things that they have seen in their daily lives, and they can really connect with. So I think it is sort of like complementing one another."
>
> (T21, post-interview)

Indeed, most seamless science lesson designs required the students to collect data out-of-class which constituted rich resources for their subsequent deeper learning. Even if some of the student-generated materials were flawed, these would become the basis for peer review and knowledge co-construction (Wong et al., 2010). The examples in Figure 1 are two types of such data collected in informal settings. Another task under the same lesson required the students to conduct interviews with two family members or neighbors by asking them to compare the temperatures of the plastic handle and the metal blade of a pair of scissors, and to explain why the temperatures are different (see Figure 4).

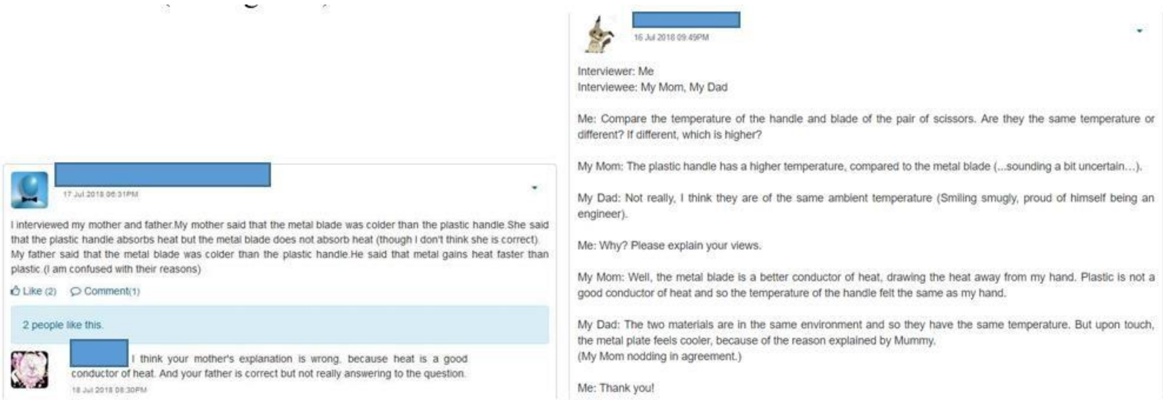

Figure 4: Students conducted interviews at home on the temperatures of handle and blade of a pair of scissors, and dissected their interviewees' views (from S3P418-2)

Other teachers have cautioned the enactment of such lessons. While the accessibility of ICT at home (despite a high percentage of students having that, there are always a few underprivileged ones around) has been a commonly known issue which teachers could find ways to work around, two teachers cited the parental support factor in enacting such learning journeys that privilege connectivity,

> "For those lessons we tried out, I really needed them to do the pre-lesson activities before the class sessions. It really depended on whether the parents were actively involved in such activities … some parents who cared enough would make sure their kids do, and feedback to me. For middle ability classes, the family is an important factor."
>
> (T11, post-interview)

> "… a lot of the students like to go to YouTube, and like to Google, because they are digital natives. But I feel that it could also struggle with their parents… I guess it was the parents who restricted the usage of the phones, because the parents have not seen the beauty, and say, 'I don't want to give you so long to surf.' … Maybe next year when we start again, it is useful to communicate to parents that, 'we are on this project where your child will...' If we have a meet-the-parents session at the right of the beginning, that could be a possibility."
>
> (T21, post-interview)

*4.5 **P**ersonalized learning*

We positioned this as an optional design principle in response to teachers' feedback, given the systemic priority of addressing the high-stakes examination syllabus and limited class time to facilitate interest-driven learning. Yet the teachers appreciated the rationale behind this principle and had been attempting to give students greater freedom in deciding what and how to learn whenever the circumstances allowed, which may constitute a small degree of self-directed learning (SDL). An excerpt of an in-class teacher-student dialogue demonstrates this (note: Student1 and Student2 belonged to the same group),

> T21: I would like you to write down what are you trying …
> Student1: To find out if the material takes the least time to melt the popsicle.
> T21: Okay, the material. So, you can write the aim of the experiment. Then, think about what are some of the materials you will need for making it?
> (Afterward, at group presentations)
> Student1: The aim is to choose a different type of bag is good for ice popsicles to not to melt for at least 15 minutes.
> T21: Okay. The aim is different. They have a time there. At least 15 minutes. So what are the instruments, what other additional instruments that you guys will need? (i.e., the teacher allowed the student group to set their own experiment goal and helped them to accomplish that) Student2: Instruments are thermometer, different type of bags, like metal, leather and foam. Ice popsicles, salt, Ziplock bag and plastic bottles.
> T21: Student2, what kind of instrument do they need? What are the variables that you have kept the same? Beside what they have said earlier? Student1: Room temperature
> T21: So that is environment, right?

Student1: Size of the bag. Volume of ice popsicle.
T21: Wait wait, they have one more, they have volume of popsicle. Okay we also need that to be the same. What else?
Student1: Temperature of ice popsicle. The environment. Amount of salt.
T21: Amount of salt. Why salt?
Student2: The salt can keep the ice don't melt so fast.
(The dialogue continued where T21's subsequent questioning made the students realise that salt was not needed in the experiment given the objective they had set.)

(The lesson on "heat" at S2P417-1, July 2017)

A teacher's observation may be an indication of an increased level of SDL among her students,

"To facilitate independent learning, let's say in online discussion, if their friends stated a wrong fact, they would research why the friend was wrong and gave a correct concept to them. In the past, they wouldn't do it, because they wouldn't come prepared before lessons to answer the questions."

(Teacher T12, post-interview)

Indeed, in general sense, SDL does not equal personalized learning. Nonetheless, the students' practice of SDL may promote personalized learning, particularly with the teacher's support to optimize an individual student's self-determined learning effort as such for the latter's learning need.

5. Discussion and Implications

A key contribution of the reported project is an improved understanding of what it takes to transform the school-facilitated seamless learning practice from 1:1 to the DoL model. The results of our study show both promises and challenges. In spite of an earlier doubt that the lack of learners' personal devices would undermine the expected effectiveness of seamless learning, our "division of labor" lesson plans were in general adhering to the five design principles of C^2FIP and managed to increase students' engagement level (because of the novelty in the learning activities and the use of ICT). The teachers have also acknowledged the value of seamless science lessons upon the end of the study, as they observed their students' positive changes in various aspects. Thus, the study provides evidence support that seamless learning based on the DoL model is a feasible and a good compromising technological model for 1:1 in seamless learning, given the current conditions in typical primary schools in Singapore and other countries.

Another key implication pertaining to teachers' growth lies in some participating teachers' reflections on how their involvement in seamless lesson design and enactment had impacted their own teaching styles which might potentially spill over to their routine teaching, such as "talking less, letting students talk more", inclination to use ICT for lessons, and engagement with parents. Their in-depth exposure to advanced pedagogical models which is novel to them may constitute opportunities for them to think out of box, to reflect upon and challenge their extant beliefs about their practices of teaching – in how they interact with their students, assess their students, be more sensitive to their students' needs, and be more adaptive in both their lesson designs and actual teaching, etc.

Implementation of the novel pedagogical model in the participating teachers' classes might also provide opportunities for students' talents or competencies, particularly relating to soft skills or ICT literacy, to be manifested in regular lessons and standard class assessments. The teachers would then rethink their previous assumptions on their students' abilities and therefore adapt their lesson design or enactment accordingly. Thus, regardless of whether they continue to implement the pedagogical model beyond the study, their involvement in the study is valuable to them.

A profound challenge for wider diffusion of seamless science learning is the schools' and teachers' willingness and readiness to implement longer term and more frequent seamless lessons. Indeed, seamless learning is more than redesigning lessons and putting technological resources in place. It should be regarded as a culture, and, as advocated by researchers in the field (Milrad et al., 2013), the learners need to be enculturated to transform their existing disposition in learning.

Specifically, students need to be fostered in the skills of SDL and collaborative learning to maximise the effect of seamless learning. Based on our lesson observations and teachers' feedback, the students had performed satisfactorily, if not thrived, in the aspect of collaborative learning (i.e., active online discussions with diversified opinions). Yet there is room for enhancement in their SDL – albeit isolated cases of students proactively sharing new artefacts or opinions in the online spaces beyond the seamless science lessons, which had not yet become a sustainable culture. High performing students might be more proactively Googling and sharing additional information (another form of SDL) to enrich the online discussions, while their counterparts were instead leveraging more on their existing prior knowledge (or misconceptions) in the discussions without carrying out additional research. If they were enrolled in a more intensive seamless curriculum instead, the "right" culture could be fostered. We argue that when both teachers and students become adept in seamless curriculum, more time would be saved, and the learning effects would be elevated.

6. Conclusion

This project addressed the adaptation of the seamless science learning model to fit the conditions of typical primary schools in which the constraint of the requirement of 1:1 was removed. It has illustrated that with the researchers' guidance, primary science teachers can be empowered to design good seamless science lessons that adhere to techno-pedagogical design principles. Research data analysis showed evidence of student learning as well as teacher growth in designing and enacting seamless science lessons (Voon, Wong, Chen, & Looi, 2019; Voon, Wong, Looi, & Chen, 2020). The project findings have led us to usable knowledge in terms of a deeper understanding of K-12 school-based seamless learning, and how to bridge such practices from the use of 1:1 technology to a DoL model.

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