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C^{2}FIP: A Design Framework for Streamlining ICT-Enhanced Seamless Science Learning for Wider Diffusion in Primary Schools

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Abstract: Seamless learning refers to a continuous, holistic learning process across learning contexts. In the past decade, most researchers and practitioners believe that seamless learning should be implemented with 1:1 (one-mobile-device-per-learner), 24x7 setting. One of the key research efforts of seamless learning was the WE Learn project in Singapore. With the aim of transforming the formal Primary 3-4 science curriculum into a seamless learning experience, the learning model has been diffused to ten schools after the successful proof-of-concept in the seed school. Nevertheless, we see the challenge of further spreading the model with the 1:1, 24x7 setting as most primary schools are not ready to implement Bring Your Own Device in 5-10 years. Thus, we propose an alternative techno-pedagogical framework that relies less on 1:1 and instead combines social media and multiple ICT tools – individual students may switch between these tools at their convenience to have access to a common social media space for seamless learning. In addition, we streamline the design principles in order not to overwhelm the teachers and yet preserve the essence of seamless learning.

Keywords: Conceptual paper, seamless learning, science learning, mobile learning, social media, curriculum design principles

1. Introduction

Seamless learning refers to a continuous, holistic learning process across learning contexts, such as formal and informal learning settings, individual and collaborative learning, and learning in physical and digital realms. In the past, the research and practice in seamless learning has mostly been adhering to what is recommended by the seminal paper Chan et al. (2006), that is, with the mandatory requirement of the 1:1 (one-mobile-device-per-learner), 24x7 setting. The rationale is that the personal smartphones that individual learners are bringing along anytime, anywhere would become a learning hub with (1) a suite of affordances to support a wide range of learning activities and (2) the learner's learning history (including stored resources and self-created artifacts) which (s)he may refer to and build on in her/his subsequent learning activities (Zhang et al., 2010).

One of the key research efforts of seamless learning was the WE Learn project (2008-2015) (Looi et al., 2010) in Singapore. With the aim of redesigning and transforming the formal curriculum of Primary 3-4 science into a seamless and inquiry learning experience, the learning model has been diffused to ten schools after the successful proof-of-concept in the seed school. Nevertheless, we see the challenge of further spreading such a seamless science curriculum as we argue that Singapore primary schools are not ready to implement Bring Your Own Device (BYOD) at least in the next 5-10 years. The reasons are that many students do not own personal devices; while most parents tend to limit their children's usage of devices. Most of the schools in emerging economies which are inspired to implement 1:1 may also encounter similar challenges.

To fill the gap before a greater penetration rate of personal devices among younger children, we see the need to adapt the seamless science pedagogy for less reliance on 1:1. In doing so, we re-conceptualize seamless learning as a learning approach at its own right, rather than a special form of mobile learning which must be materialized with 1:1 setting. Thus, we propose an alternative model that combines social media and multiple ICT (InfoComm Technology) tools (school and home computers, schools' or family members' handheld devices or cameras, etc.) – individual students may switch between these devices at their convenience to have access to a common social media space for seamless learning activities. In addition, we strive for simplifying the design principles in order not to overwhelm the teachers (who will shoulder the seamless learning design tasks when the researchers have completed their studies and left the schools) and yet preserve the essence of seamless learning.

2. Literature Review

Seamless learning has been identified as one of the advanced learning approaches that can address the needs of 21st century learners (Sharples et al., 2012). With the salient characteristic of bridging multifaceted learning efforts across a variety of learning settings, the intention is to nurture a disposition in students to continually carry out the trajectories of learning-application-reflection through recontextualizations of previously constructed knowledge (Wong, Milrad, & Specht, 2015).

Seamless learning was first proposed in the field of higher education (American College Personnel Association, 1994; Kuh, 1996) with an emphasis on policy-level reform to foster a culture of seamless learning (bridging in-class and out-of-class, curricular and co-curricular experiences) within colleges while the potential facilitating role of the technology is not explicitly explicated. The notion was then incepted into the context of mobile learning by Chan et al. (2006) which advocated the use of mobile technology in 1:1, 24x7 setting to facilitate individual students' ongoing, cross-contextual seamless learning. This seminal paper launched the line of research in mobile-assisted seamless learning which has later been spread to more than 40 countries in the past decade, with science being the most popular domain that seamless learning has been applied to (Wong, 2015). Over the years, there has been a gradual shift of researchers' perceptions on mobile-assisted seamless learning from a technology-enabling perspective (e.g., Hwang, Tsai, & Yang, 2008) to a curriculum design perspective (e.g., Looi & Wong, 2013) to the fostering of a learning culture (e.g., Milrad et al., 2013). This reflects a swing of the foci of the community of seamless learning from developing innovative technologies for seamless learning to the unpacking of the nature of seamless learning and making pragmatic impacts in the schools. The perception of having 1:1, 24x7 as a mandatory condition for seamless learning has been challenged. Rather than taking it as a special form of mobile learning, more recent literature argues that seamless learning is a learning notion at 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" (i.e., using different digital or even non-digital tools available at various locations) model (Wong, 2012; Wong & Looi, 2011) and the use of social media (Charitonos, Blake, Scanlon, & Jones, 2012).

In particular, social media are increasingly used for supporting students' communicative and creative endeavors (Greenhow, Robelia, & Hughes, 2009). Social media supports process-oriented learning by promoting interactions amongst students and between students and teachers. Posted thoughts and ''information pieces" make it possible for users to participate with others in their thinking (Ebner, Lienhardt, Rohs, & Meyer, 2010). More importantly, social media affords situating of learning in multiple contexts through the same social network. For science learning, teachers may create topical social media items to solicit student responses in and out of classroom, or encourage the students to generate social media on specific curricular themes, or on any real-life encounter that triggers curiosity. Such student-generated social media will then be opened to negotiation and retelling through peer replies, as contending meanings come into play, as different experiences are shared, and as new ideas come to light (Lewis, Pea, & Rosen, 2010). In the perspective of seamless learning, designing seamless learning processes around social media would free the students from relying on 24x7 access to personal devices, as social media spaces are accessible by multiple platforms or devices (i.e., "division of labor"). In short, the age of social media offers unprecedented opportunities for educators to create learning environments for pervasive trajectory of authentic, cross-contextual and socialized learning.

3. Our Prior Work – the “WE Learn” Project

Since the inception of seamless learning in Singapore science classrooms in 2009, we have established a proof-of-concept for the learning model. Beginning with a pilot study in a Primary 3 class in the seed school during 2009-2010 (1st cycle of intervention), the model was later refined and scaled up to the entire Primary 3 level in 2012 (2nd cycle of intervention). The model has now become the anchoring pedagogical model in the regular Primary 3-4 science classes in the seed school, with the support of 1:1, 24x7 setting. Furthermore, the school has taken over the agency to diffuse the model to nine other schools since 2014, with further model localization (3rd cycle of intervention). Rich data were collected and analyzed across these cycles, with the evidences of the model’s efficacy in transforming science learning being reported in Zhang et al. (2010) and Looi et al. (2014). In particular, we found the students developed inquiry skills, reflective thinking skills and reasoning skills with participation in more inquiry activities, collaborative activities and completion of mobile learning tasks using different learning tools (Looi et al., 2014; Song, Wong, & Looi, 2012).

4. A New Seamless Science Learning Design Framework – C^2FIP

4.1. C^2FIP

Despite of the success of the WE Learn project, we see the need to address the issue of relatively limited access to mobile devices for most of the young students at present stage before we can further diffuse our seamless learning model to more schools. Whereas the mainstream educational technology research tends to push the boundary of technology and assume that students can benefit from the most advanced (but typically costly and not necessarily sustainable) technical solutions in an ideal world, it is equally important for practice-driven researchers to explore lower-cost means to accomplish similar learning outcomes – for those educational settings which cannot afford relatively expensive technologies. Another key consideration and motivation for us to translate the design framework is that we would like to streamline various sets of design principles that we developed in different cycles of the WE Learn project in order not to overwhelm the teachers in developing the design capacity for seamless learning.

Throughout the course of the WE Learn project, we had developed three sets of design principles as reported in Zhang et al. (2010), Wong (2013b) and Looi and Wong (2013) respectively, with 6-8 principles being laid out in each set. Now, with the aim of reducing the design complexity, we streamlined these principle sets into five principles, namely, **C^2FIP** (**C**onnectivity of learning spaces, (socio-)**C**onstructivist inquiry learning; **F**ormative assessments with student artifacts; leveraging resources in **I**nformal settings; **P**ersonalized and self-directed learning). We hope the streamlining will make the model easier for more teachers to comprehend and adopt for implementation, while retaining the essence of seamless learning. By making each lesson plan (typically for delivering one scientific topic) as a unit of design, a teacher may apply the principles to transform the learning process into a seamless learning experience. The five principles are elaborated below,

- **C**onnectivity of learning activities: Make the learning process cross-contextual, not just encompassing formal and informal settings but also learning in both individual and social settings, and in both physical and digital environments, that is, to “do the right thing with the right tool at the right time/place” (Sha, 2015) (e.g., engagement and preliminary learning in class, application and observation in daily life, and further research and peer discussions on the web, etc.), and to bridge these learning efforts. In addition, facilitate outdoor learning trails (in or out of campus) that require the applications of knowledge of not just one single science topic but across multiple topics (i.e., help students to connect old and new knowledge).
- socio-**C**onstructivist inquiry learning: Facilitate an interplay of individual and collaborative inquiry learning. Encourage diverse ideas from the students during various learning activities, and help the students in connecting ideas or pieces of knowledge (e.g., between concrete and abstract knowledge, between prior and new knowledge) through various means such as concept

mapping. Make students' diverse thinking visible and therefore shareable, and later synthesize the knowledge.

- **F**ormative assessment: Different forms of student artifacts created at various learning activities can be used for formative assessment purpose. The teacher may foster the students' peer and self-evaluation skills across several lesson plans – this not only about "learning how to learn" and the nurturing of critical thinking, but also for mitigating teachers' load in reviewing student works.
- leveraging resources in **I**nformal settings: The students' out-of-class, day-to-day living spaces may offer authentic learning resources to make their learning more relevant and meaningful. Examples include students' self-searching of appropriate online resources, mini-activities with family involvement, out-of-school learning trails at suitable sites such as the science center, the zoo or farms.
- **P**ersonalized learning: Incorporate different learning modalities (e.g., video & photo taking, experiments, KWL, concept mapping, etc.)/ to suit students of different learning preferences and yet elevate multi-intelligence, and allow flexible learning pathways for individual students. The learning experience should be student-centered, and perhaps encourage interest-driven learning out of class (i.e., individual students to pick up hobbies related to science learning) and group students with similar interests together to stimulate informal peer learning.

Among the five streamlined principles of C^2FIP, it is the first principle "C", namely, connectivity of learning contexts that weaves all of them together to form a holistic learning journey. With the last four principles being implemented "at the right time, in the right place, with the right contextual tools", the students may draw the best out of each learning context. Thus, student learning would be continuously recontextualized and therefore deeper learning could be achieved.

4.2. Weaving the Activities Together: The Facilitated Seamless Learning (FSL) Framework

The C^2FIP framework provides rationales for the incorporation of individual learning activity types. To weave the activities together, we will use a process framework (see Figure 1; adapted from the Facilitated Seamless Learning (FSL) design framework proposed by Wong (2013)).

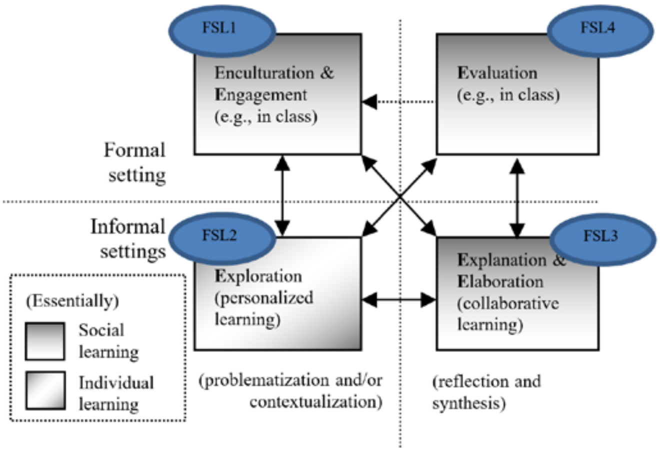

Figure 1. The adapted Facilitated Seamless Learning (FSL) framework.

As seen in Figure 1, the four-activity FSL process aims to reinforce the connectivity of learning contexts in individual learning processes. Though we recommend the basic sequence of FSL1 → FSL2 → FSL3 → FSL4, the actual combination and sequence of the activities are customizable from lesson to lesson, as indicated by the bidirectional arrows. Apart from denoting the possible activity sequences, these arrows may also represent the spill-over effect of knowledge, skills and learning resources as the flow from one activity to another, i.e., knowledge of skill learnt, learning resources adopted or student artifacts generated during one activity may come into use in another activity.

5. Discussion and Conclusion

This paper articulates C^2FIP, a design framework for seamless science learning adapted for primary schools where most of their students do not have regular 1:1, 24x7 access to mobile devices. We believe that the lower penetration rate of advanced technological tools (due to cost or other concerns) should not hinder further diffusion of a technology-enhanced learning notion which has proven its effectiveness through research. We are inspired to explore alternative strategies which leverages technologies that are readily available in specific school contexts while striving for preserving the critical success factors of the learning notion through constructing a streamlined set of lesson design principles.

Teachers will play a key role in facilitating and affectively supporting their students' seamless science learning journeys. To ensure successful translation and diffusion of the C^2FIP model, we recommend the enactment of comprehensive teachers' professional development (PD) activities to develop the teachers' capacity in accomplishing the pedagogical goals. We envisage that through co-designing (with the researchers) and enacting lesson plans guided by the C^2FIP and FSL frameworks, the teachers will experience the facilitation of, and observe their students' engagement in socio-constructivist, authentic, personalized activities and the generation of a variety of student artifacts which are formatively, critically assessed by their peers; and more importantly, these activities are weaved together to form a cross-temporal, cross-spatial trajectory of learn-apply-reflect. If such seamless learning journeys are indeed properly designed and enacted, the teachers will witness the positive learning outcomes from the students, thus levelling up their understanding and confidence in the model. We foresee that such PD activities will become an agent to transform the teacher learning and student learning cultures into a participatory, constructivist nature.

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