ABSTRACT
This paper traces Singapore’s decade-long trajectory of implementation research in seamless learning. The emphasis in the earlier years was on leveraging on 1:1 mobile technology support, and the emphasis in the latter years was shifted to social media mediation. Seamless learning was introduced to Singapore schools around 2007. Starting with a pilot study on the feasibility of developing a national curriculum-aligned pedagogy, a series of translation and diffusion efforts were carried out in the next decade, making Singapore the leading country in deep penetration of seamless learning into the formal curricula – in contrast with research elsewhere where the relevant research efforts have either remained at the experimental or clinical trial stages, or have been enacted as relatively short-term researcher-driven practices. Underpinned by the notions of implementation research and translational research, we will trace the evolutions of seamless learning practices in Singapore. We will discuss the rationales of developing various translated seamless pedagogical models during different periods of time, as a vivid example of a trajectory of design-based research and design-based implementation research that impacts school practices.

Author Keywords
Seamless learning; Mobile learning; Social media for learning; Implementation research; Curriculum integration

INTRODUCTION
Seamless learning refers to a person experiencing a continuity of learning across a combination of locations, times, technologies or social settings, and intentionally connecting such multifaceted and multimodal learning efforts to achieve deeper learning (Sharples et al., 2012; Wong, 2015). From the perspective of existing school establishment, the expected key changes in integrating seamless learning to the current school practice are:- (1) to bridge the formal curriculum facilitated by authentic and social learning opportunities outside the classroom; (2) to expansively deploy mobile and cloud technologies throughout their students’ cross-contextual learning journeys. These requirements would result in tensions and challenges for seamless learning to be settled in the school system.

Seamless learning was introduced to Singapore schools around 2007, hot on the heel of the publication of the seminal paper on seamless learning mediated by 1:1 (one-mobile-device-per-student) settings (Chan et al., 2006). After a pilot study on the feasibility of developing a school-based, national curriculum-aligned pedagogy, a series of translation and diffusion efforts were carried out in the next decade, making Singapore the leading country in deep penetration of seamless learning into formal curricula – compared to the rest of the world where almost all of the relevant research efforts have either remained at clinical stage, or have been enacting relatively short-term, perhaps ad-hoc researcher-driven practices (Wong, 2015). Underpinned by the notions of implementation research and translational research, we will trace the evolutions of seamless learning practices amongst participating schools in Singapore. We will discuss the rationales of developing various translated seamless pedagogical models during different periods of time, as a vivid example of a trajectory of design-based research and design-based implementation research that impacts school practices.

UNDERPINNING FRAMEWORKS
Seamless Learning
Despite owing its conceptual origin to the non-technology-related research theme of the same name in the field of higher education studies (American College Personnel Association, 1994; Kuh, 1996), seamless learning was introduced to the learning technology field with the aim of promoting research on and practice of learning in 1:1 settings (Chan et al., 2006; Wong & Looi, 2011). Further unpacking of seamless learning results in the foregrounding of two striking features, namely, “bridging” and “recontextualization”. Seamless learning is lying in a learner’s continual “recontextualization” of previously constructed knowledge to facilitate rise-above and elevate sophistication of the knowledge. This should be accomplished through the “bridging” of learning-application-reflection activities that are situated in various contexts appropriate for specific activities respectively (Wong, Chai, Aw, & King, 2015).

Nevertheless, the early perception of seamless learning as a special form of mobile learning has been challenged in recent literature (Wong, 2015; Wong & Looi, 2019). Seamless learning is now seen as a learning notion on its own right. What is advocated in recent literature is human-centric, instead of technology-driven forms of seamless learning. While mobile
technology may significantly enhance the fluidity of learning across contexts, a new challenge has been placed on more recent practice-driven seamless learning projects that our team has been working on. The question is: if most young learners do not own mobile devices, can we re-design seamless learning to rely less on 1:1 and mobile technology but leverage more on other digital (e.g., social media) or even non-digital tools to bridge the learning efforts across different contexts?

Implementation Research and Translational Research

The diffusion of techno-pedagogical innovations is often subject to “replica cap”, which refers to cloning everywhere that worked in the seed school without taking into account of individual sites’ variations in needs, assets, capacities, and commitments (Dede, Honan, & Peters, 2005; Wiske & Perkins, 2005). The effectiveness of diffused innovations is often diluted by variations in implementation contexts (Clarke, Dede, Ketelhut, & Nelson, 2006). Such failures call for the rejection of the “one-size-fits-all” approach and the empowerment of flexibility of the innovation to foster robust adoption across a wide range of contexts (Looi, Xie, & Chen, 2015).

Thus, the approach of “implementation research” (e.g., Barab & Luehmann, 2003; Farrar, De Sanctis, & Cohen, 1980) comes to the picture, which refers to the processes to promote the uptakes of research findings, that is, to address the challenges that are faced when generalizing research “in the real world”. In the context of the Learning Sciences, implementation research overlaps with the notion of translational research. Translational research in medicine is defined as “effective translation of the new knowledge, mechanisms, and techniques generated by advances in basic science research into new approaches for prevention, diagnosis, and treatment of disease which is essential for improving health” (Fontanarosa & DeAngelis, 2002, p. 1728). Woolf (2008) developed the ontology of Type-1 and Type-2 translational research, which was later mapped onto the Learning Sciences by Pea (2010). According to him, Type-1 Translation (or design-based research) is about translating principles from basic learning research to school-based interventions; while Type-2 Translation (or implementation research) involves translating interventions developed in one or more settings into interventions that are scalable to many settings.

THE JOURNEY OF IMPLEMENTATION/TRANSLATIONAL RESEARCH IN SEAMLESS LEARNING IN SINGAPORE

The journey for diffusing a new learning innovation typically begins with Type-1 Translation or proof-of-concept, with an implementation-oriented techno-pedagogical model being developed and validated. Such a model would become a “gold standard” of the innovation which could be robustly implemented in other settings. Nevertheless, as discussed in the previous section, it is a false assumption that all the adopting contexts are similar. Henceforth, Hung, Lee, and Wu (2015) called for the identification of a “sufficing standard” (or, in our words, the “critical success factors”) to enable the spreading of innovation and culture throughout different levels of the education system. According to them, teachers need to be able to take innovations to their own respective classrooms (or equivalent) and implement the core ideas of that innovation. Beyond these “mandatory” core ideas, teachers are given freehand to adapt the lesson activities and/or the use of ICT tools in their lesson designs and enactments, perhaps with the researchers’ guidance at the early stage. Such endeavours belong to Type-2 Translation. At this stage, the researchers may change their roles from innovators and intervention drivers to supporters of and consultants on the teacher-led interventions. To the researchers, the new experience and insight gained, or even unexpected outcomes during the translated interventions might also prompt them to revise either the gold standard or the sufficing standard, or both.

Indeed, our decade-long journey of translational research on seamless learning in Singapore schools has resulted in multiple versions of seamless learning models being developed. These were the outcomes of translations of the early model to different school levels (of the same subject), subjects, and specifications of techno-pedagogy (including the variations of core learning activities and the ICT infrastructures). Often, a subject translation and a techno-pedagogical translation come hand-in-hand. This is because it is almost impossible to apply the seamless learning approach to a different subject while holding the core learning activity designs constant, due to the varied epistemological natures and teaching objectives between the subjects.

The descriptions of various Type 1 and Type 2 translation projects that we have carried out in the last decade are given below. They are not presented in chronological order. Instead, projects with the same subjects are clustered together as that better reflect how the subject matter-specific learning theories were privileged in guiding the translational efforts.

Various early exploratory studies (2007-2008) (Type-1 translation)

Our seamless learning research program commenced with the mutual interest of our research team and Nan Chiau Primary School in making the latter as the seed school for developing a 1:1 ecology. Seamless learning was adopted as the underpinning techno-pedagogical framework so that the subsequent 1:1 curriculum transformation will not fall into the “trap” of making 1:1 learning activities predominantly classroom-bound. Thus, a series of exploratory seamless learning studies were carried out to help us in gaining experience in designing, facilitating and managing such mobile learning trajectories with intensive use of ICT. These studies made use of the school’s earlier inventory of Pocket PCs, Personal Digital Assistants (PDAs) or Ultra Mobile Personal Computers (UMPCs) with 3G broadband subscriptions which were loaned out to the students for episodic seamless learning activities. In the following paragraphs, we will give an account on two of the mini-studies that was more influential and inspiring to our later translational efforts.

In 2007, a UMPC-supported Chinatown heritage trail (So, Seow, & Looi, 2009) was facilitated. With the aim of ensuing deeper understanding through location-based learning, we incorporated Google Maps and the marking of locations on the
map. For each marking, notes, pictures, and hyperlinks can be added, providing a platform for the students to compose their location-specific reflections and experiences. The maps can be shared with peers for supporting collaboration by co-editing the content within the location markers. Finally, post-trail peer discussions and knowledge co-constructed continued on the Google Maps for another two weeks. The originally discrete informal and formal learning experiences, and individual and social learning efforts were then connected via mobile and Web 2.0 technologies. The study constituted the basis for our future translation model of “in-situ knowledge building” for integrated humanities, and provided the conceptual framing for the seamless Chinese learning models of “Move, Idioms!” and MyCLOUD.

Another study was anchored on a two-hour lesson plan on English prepositions for Primary 2 (2nd grade) students in 2008 (Looi et al., 2009). During the lesson, students were introduced six prepositions. The students then worked in groups to go out of the class, identify authentic contexts or enact scenarios, and take photos with PocketPCs (1:1) to illustrate the prepositions. Back to the class, the groups shared their photos and the associated prepositions for peer learning and peer critique. The techno-pedagogical implications drawn from the design and the students’ learning outcomes were, (1) multiple entry points and learning pathways; (2) multi-modality; (3) in-situ student improvisation; and (4) the creation and sharing of student artifacts on the move. In addition, the first attempt of teacher empowerment in (co-)designing the lesson plan and spearheading the implementation reaffirmed the importance of teachers’ professional development. The experience gained through this study had laid the foundation for the SEAMLESS project, where the aforementioned implications had informed the curriculum re-design. The core activity design of “taking photo to apply what is learnt” had also conceptually inspired the “Move, Idioms!” project.

Science - SEAMLESS Project (2009-2010): Primary 3-4 science (Type-1 translation)

Armed with the new insights from the aforementioned exploratory studies, we embarked on our first longitudinal seamless learning project in Nan Chiau Primary School. In particular, we worked with two teachers to revise the national curriculum for Primary 3 and 4 Science by considering the opportunities afforded by students’ personal mobile devices. In 2009, a Primary 3 class piloted the seamless curriculum; yet it followed the same class schedule and assessment schemes as the rest of the classes. In 2010, we continued engaging the same pilot class who had by then moved up to Primary 4, and spread the intervention to another Primary 4 class. Activities were designed to extend learning activities beyond the classroom. The students were each assigned a smartphone with 24x7 access in order to mediate a variety of learning activities such as in-class small-group activities, field trips, data collection in the neighborhood, home-based observations or experiments involving parents, online information search and peer discussions, and digital artifact creation. GoKnow, a commercial tool with a suite of apps to support young students in mobile learning, were installed in all the smartphones. The apps consist of KWL (“I know; I wonder; I learned” – a scaffold for goal-oriented learning), Stop Watch, Sketchy (animation creator), and Picomap (concept mapping tool).

Changes occurred in the experimental class and the teacher involved with evidences from research analysis (Looi et al., 2011; Zhang et al., 2010) during the two years of intervention, and from interviews with the school leaders and teachers. With the seamless lessons, we observed students engaging in science learning, and they performed better than other classes as measured by traditional assessments in the science subject (Looi et al., 2011; Sha, Looi, Chen, Seow, & Wong, 2012). We also saw a shift in the teachers’ attitudes and behaviors towards science teaching, from a style that saw them pre-occupied with just covering the curriculum to one that allowed them to watch over and facilitate students’ work on the inquiry activities on their smartphones.

Science - WE Learn (2012-2015): Primary 3-4 science and English (Type-1-to-Type-2 translation)

Informed by the positive outcomes of the SEAMLESS Project, the school leaders decided that it was a worthwhile innovation and would like to scale it up. Thus, in 2012, researchers and teachers reflected the designed lessons, and spread the curriculum at the entire Primary 3 level, with about 350 students using smartphones daily for science lessons. Subject translations were also taken place, where seamless learning was implemented in English and Chinese lessons. Both the translated science and English curricula were lumped under the “WE Learn” project. The Chinese seamless curriculum was developed and studied under a separate project known as MyCLOUD (My Chinese Language ubiquitOUs learning Days) which will be elaborated in a later section. The three-subject translations were later spread to Primary 4 in 2013. In 2014, the seamless science curriculum was further diffused to ten more schools.

In terms of the techno-pedagogical translation, we strived for customizing the curriculum for a more generic mobile technology for sustainability. While initially the innovation used smartphones, the goal was to create curriculum, instructional strategies, and formative assessments that are mobile technology agnostic. Mobile technologies are changing very quickly. Thus, we did not want our learning resources to be tied to a specific commercial product. Instead, our team developed a new MyDesk platform with a stronger emphasis in blending mobile and cloud computing technologies. The new direction not only offered a feasible solution to the above-stated challenge of changing technologies, but also had the potential for developing new affordances to mediate a wider range of seamless learning activities. For example, digital badges were implemented in the new platform to motivate the students in self-directed learning (Boticki, Baksa, Seow, & Looi, 2015). Furthermore, while the apps on the GoKnow platform were essentially used for students’ individual artifact creation, MyDesk allows greater teacher-student interactions and peer sharing of artifacts.

On the other hand, in developing our seamless English lessons, we hybridized the two pedagogical strategies of P4C and Marzano’s 6-Steps to Better Vocabulary Instruction and extended the learning trajectory to informal settings (Koh, Loh, &
P4C (Philosophy for Children) (Lipman, 1976) draws on the Socratic method of learning pioneered initially in Plato’s dialogues and focuses on learning how to ask a question and how to respond when asked a question. Marzano’s 6-steps to Better Vocabulary Instruction (Marzano & Pickering, 2005) helps children understand words by building relationships and links amongst the words, by using words in their proper contexts (particularly in out-of-school contexts).

Science4C (2017-2019): Primary 3-5 science (Type-2 translation)
Despite the success of the WE Learn Project in diffusing the 1:1 seamless science learning model to 10 more schools, we saw the challenge of further spreading such a 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 possess personal devices; even for those luckier students who do have their own devices, the usage is usually restricted by their parents with the fear of mishandling, addiction or health hazard. Furthermore, throughout the SEAMLESS and WE Learn Projects, 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 and with the assumption of availability of 1:1, 24x7 settings. The motivation of the follow-up techno-pedagogical translation project, code-named Science4C, is to streamline the design principles and mitigate the reliance on 1:1 settings as well as not to overwhelm the teachers in developing the design capacity for seamless learning. The “4C” in Science4C refers to science learning in four types of learning spaces (Classroom, Cyberspace, Common daily life, and Community); and constituting four salient features of seamless learning (Connective, Contextualized, Constructivist, and Collaborative).

In the Science4C project, we guided three primary schools in piloting the translated seamless science model in selected Primary 3-5 lessons. We continued to apply the professional development (PD) approach of teacher-researcher co-design of lesson plans, informed by a streamlined design principle set, C²FIP, denoting Connectivity, socio-Constructivist inquiry learning, Formative assessment, learning in Informal spaces, and Personalised learning.

Furthermore, we adopted an alternative model that combines social media and multiple ICT 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. This model is known as “division of labor” (Wong, 2012) as the “1:1, 24x7” settings are no longer required. Additionally, to assist the teachers in developing their design capacity for seamless science learning, we construct a rubric informed by the C²FIP principles for them to formatively self-evaluate “how seamless” their own lesson plans are (Wong, Looi, & Voon, 2018). The rubric is undergoing a validation process at the time of writing; and we are envisaging generalization of the rubric to become subject- and level-independent.

Language - Move, Idioms! (2009-2010) (Primary 5 Chinese) (Type-1 translation)
The “Move, Idioms!” project was a conceptual spin-off of the earlier exploratory seamless English preposition lesson. The seamless Chinese learning model underwent a two-month pilot study in late 2009, followed by a full-fledged ten-month intervention in 2010. Whereas a set of Chinese idioms selected from the textbook were adopted as the explicit learning goals, what equally crucial was to develop the students’ Chinese communication skills through contextualized social media creation and peer interactions/reviews, as well as the disposition of self-directed seamless learning. In both rounds of study, our project team loaned out smartphones with 3G broadband subscriptions to the participating students in 1:1, 24x7 basis.

An iterative seamless activity process was derived and implemented, which was later generalized (becoming subject-independent) into the Facilitated Seamless Learning (FSL) design framework as reported in Wong (2013b). Each iteration of the process consists of four activities as summarised below,

Activity 1 – in-class idiom learning (designed in the form of lesson plans): The students learned a set of idioms by watching comical animations on their phones which depict the meanings and usage of individual idioms. They then worked in groups to brainstorm for suitable contexts and co-create social media (photos and captions that utilized the idioms) within campus.

Activity 2 – out-of-class independent social media creation: The students carried their phones 24x7 for proactive identification of authentic contexts or self-created contexts in their daily lives which could be associated with one or more idioms learnt, creation of social media which were then posted onto a class wiki space.

Activity 3 – online peer learning: The students performed peer reviews on the wiki space by commenting on, correcting or improving their peers’ social media write-ups.

Activity 4 – In-class consolidation: The teacher facilitated class-wide or small-group discussions on selected social media to improve both their artefact creation and peer review skills.

During the full-fledged study, the students contributed a total of 920 social media items. We found the students’ social media creation and commentary activities were relatively “informal”, authentic and yet strongly linking to the formal instructions. We performed content analysis on the student artifacts and observed a similar pattern of the students’ language improvement and their euger interactions with the physical environment in their daily lives (Wong, 2013a).

Language - MyCLOUD (2012-2015): Primary 3-4 Chinese (Type-2 translation)
Despite the encouraging outcomes from the “Move, Idioms!” project, there were challenges in its scalability and sustainability. The learning design was an add-on in relation to the formal Chinese Language curriculum. Thus, it was
Three classes of Primary 3-4 students were involved in the MyCLOUD project. Each student was equipped with a tablet computer with 3G broadband access, co-paid by the school and the parents. The four-activity Facilitated Seamless Learning framework was again deployed for the longer-term learning design, with the major tweaks of (1) tying each FSL cycle with a textbook passage; (2) the target vocabulary to learn and apply in each cycle is no longer restricted to idioms but all types of word forms; (3) a stronger emphasis in social network-like interactions (as compared to “Move, Idioms!” where students were mostly performing peer linguistic reviews) with the aim of nurturing a niche environment where they may use Chinese to communicate at ease – i.e., to blend the use of Chinese into their daily lives.

We co-designed and developed the MyCLOUD platform with teachers (Wong, Chai, Zhang, & King, 2015). The new platform consists of three main components, namely, (1) Mictionary (Mobile dictionary): This is a vocabulary learning e-portfolio where students record vocabulary that they encounter in and out of class, and subsequently build most of the content on their own, such as adding meanings, pooling relevant online resources or creating social media utilizing the words; (2) My e-Textbook: The digitalized textbook passages are associated with the read-aloud function; students may highlight unfamiliar words and those will be automatically added to Mictionary; (3) MyCLOUDNet: This is a social network for students to post social media and respond to others’ posts; the students may either directly post their social media here, or the social media that they created in Mictionary will be duplicated to here. In essence, My e-Textbook belongs to the formal learning space while MyCLOUDNet is an informal space. Mictionary provides the means of bridging the two spaces by linking to both My e-Textbook and MyCLOUDNet. The connection between Mictionary and MyCLOUDNet facilitates the bridging of individual and social learning.

The intervention resulted in significant increases of several indicators of the students’ linguistic competencies, self-directedness in learning, and activity level and sophistication of online interactions (Wong, Chai, Aw, et al., 2015; Wong, King, Chai, & Liu, 2016). However, such positive changes typically only prevailed after the first few months of enactment. Indeed, as Nation (2001) argued, language learning from contexts is a cumulative process which results in small but positive gains in each encounter – this is also true for promoting seamless learning which requires longer-term enculturation for the students. The MyCLOUD model was later diffused to four more schools since 2014.

Language - LI-nterChange: Secondary 1-2 Chinese (Type-2 translation)
LI-nterChange marked our team’s first attempt to spread seamless Chinese learning to the secondary school level. The “L” and “I” in LI-nterChange refer to “language” and “ideas” (or “interactions”) respectively; and “LI-nterChange” refers to the construction of a social network-based environment for “interchange” (exchange) of linguistic artifacts and ideas/meanings. The intention is to design for the bridging of informal discourses (social media creation and online interactions) and formal (teacher-assigned) writing as the socio-pedagogical means to develop students’ competencies in meaning making and communication in Chinese. To guide the interventional design, we proposed the SMILLA (Social Medial as Language Learning Artifacts) framework, a novel approach involving multiple learning paths within the context of seamless language learning (Wong, Chai, & Aw, 2017). To enact this framework, we developed a 3-stage Chinese learning process to foster secondary school students’ communicative abilities in four interactional types: narrative, descriptive, expository and argumentative. Stage 1: enculturating students to the new social media space in Chinese; Stage 2: scaffolding students in improving and enriching their social media by retelling in the four interactional types; Stage 3: connect the social media activities with formal classroom compositions where students are allowed to co-develop materials based on their relevant authentic experiences and personal voices before writing compositions.

Nevertheless, while we believe that the SMILLA framework is academically well-rooted and has been proven worked well at primary schools, we faced inevitable challenges in implementing the approach at secondary schools. Due to external factors and our miscalculation on secondary school teachers’ and students’ bandwidths in carrying out such longer-term interventions, the interventions were unable to be advanced to Stage 3 and therefore did not yield the expected outcomes. In terms of teachers’ and students’ bandwidths, in particular, the overall curriculum content across all subjects is double of that of primary schools, yet the class time of the Chinese subjects is reduced by half; and there are a lot more Co-Curricular Activities and school events as compared to primary schools. That resulted in frequent postponement of seamless lessons and disrupted the intervention timeline being planned months in advance.

Another challenge in the participating teachers is known as cognitive dissonance. Teachers are supposed to play the roles of agents and designers, who are making pedagogy relevant and meaningful to their students and themselves. Indeed, the PD sessions that we conducted at both schools aimed to transform their beliefs in Chinese learning and teaching, and equip them with the knowledge and skills needed to enact LI-nterChange. However, as Seamless Language Learning (SLL) (Wong, Chai, & Aw, 2015) is a socio-cultural, constructivist language learning model that defies most teachers’ behaviorist belief about language instructions, we noticed that the pilot teachers in both schools had been experiencing cognitive dissonance (Festinger, 1957; Frykholm, 2004) – a person performing an action that contradicts personal beliefs, ideals and values. That rendered unintentional distortion of lesson enactment which jeopardized the critical success factors of seamless learning. Similar situations occurred in the early stage of the MyCLOUD project in Nan Chiau Primary School. However, due to the more intensive lesson activities and PD sessions, we were able to dialogue with the pilot teachers in an ongoing
basis. Thus, we had gradually influenced the teachers to reflect upon and change their teaching styles and resolved their cognitive dissonance.

We drew important practical implications from the study as follows. If the intention is to nurture the students’ in seamless and self-directed learning dispositions, long-term interventions are required and should commence at primary schools where students’ mindsets are more malleable, and where both the teachers and students have greater bandwidths to sustain their active involvements in such pedagogy. On the contrary, if the intention is to foster other 21st century competencies through seamless learning pedagogy, then the intervention design can be episodic (e.g., project-based seamless learning) – such seamless learning pedagogy can be applied to secondary/tertiary students without prior seamless learning experience.

**Language - e-SDCL (2018-2019): Primary 3 Chinese (Type-2 translation)**

Similar to the Science4C project, the e-SDCL (e-Self-Directed Chinese Learning) model was our team’s another follow-up attempt to translate the MyCLOUD model to suit typical primary neighbourhood schools without 1:1 settings. Another key motivation is to “update” the MyCLOUD model to suit the 2015 national Chinese curriculum where the development of oral and written skills in authentic contexts are emphasized. Leveraging the existing technological infrastructure of the schools and the students’ home computers and devices, Primary 3 students from two schools ensue a year-long e-SDCL journey consisting of two interweaving, recursive components, (1) in-class meaningful, contextualized explicit instructions of words, sentences and paragraphs; (2) self-directed learning by doing in authentic settings (i.e., social media creation) adhering to the seamless learning approach. Furthermore, our reflection upon cognitive dissonance faced by the teachers involved in the LI-nerChange project has prompted us to adapt the teachers’ PD model for the new project. At the early stage, our team are developing the full teaching packages including the lesson plans so that the teachers may focus on lesson enactment (rather than being overwhelmed by doing both to start with); and we will assist the teachers to make sense of the essence of the learning model through teacher-researcher dialogue on the review of the lesson enactment. Afterward, we will gradually involve the teachers in co-designing the teaching packages so that they will pick up the relevant skills in a manageable pace and eventually take over the agency. The e-SDCL intervention is still ongoing at the point of writing.

**In-situ knowledge building (2010-2012): Secondary 2 integrated humanities (Type-1 translation)**

The “in-situ knowledge building” model (So, Tan, & Tay, 2012) was a conceptual extension of the Chinatown learning trail as reported in an earlier subsection. The model was studied in the School of Science and Technology where all staff and students are equipped with personal MacBooks for teaching and learning in all subjects. It brought together mobile-assisted outdoor learning trails and ongoing Knowledge Building (KB) with on Knowledge Forum (before, during and after the trails). In the mobile learning trail design, a majority of student ideas were arisen from the experiential learning activities in the real-world environment (i.e., Sentosa Island, WWII battles sites and Singapore River) for learning of integrated humanities (geography, history and biology). The environmental interaction with the physical and social element of the outdoor learning context at Sentosa fosters real-world application and acquisition of skills individually and collectively. These interactions included, for example, interviews with tourists, calculation of gradient of slopes (i.e., to practice geographic and mathematical skills), design thinking of the attractions, accessibility and amenities of the island. Indeed, KB includes the building of knowledge contexts; and such student-generated artifacts offer provisional contexts, which are triggers or bases of idea generation and rise-above (Bachmair & Pachler, 2015). According to the content analysis of students’ collaborative discourse in subsequent publications by the team (So & Tan, 2014; Tan & So, 2015, 2016, 2018), the overall learning experience was adhering to the 12 KB principles identified by Scardamalia (2002) and at the same time demonstrating the salient features of cross-contextual seamless learning and interdisciplinary thinking.

**IMPLICATIONS AND CONCLUSION**

While we have evolved the various designs and adaptations of seamless learning, they can be traced back to a set of design principles which has also evolved over time. The readers can recognize the assumed stable internal logic that tightly link one stage of cycle of innovation, adaptation or translation to another across levels and contexts, providing the seamlessness with which each translation moves across contexts. Each translation continues to seek to provide more balanced emphasis to the needs of the learners, the agency of teachers, the readiness of the school leaders, teachers, and students to embrace innovation, and the availability and support of the technological infrastructure. The sustained programme of research design and implementation embraces researchers working closely with practitioners to define the problems the latter would like to address in the diverse school settings. Our narrative of the various translations demonstrates the efficacy of the innovations and adaptations of seamless learning. This partially depends on a powerful set of design principles, a process of design-based research and implementation research, as well as on the agency, capacity, mindset and culture of the practitioners.

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