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CREATING AND LEARNING THROUGH DESIGN: TEACHER PROFESSIONAL DEVELOPMENT FOR 21ST CENTURY LEARNING

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ABSTRACT

Twenty-first century learning is encapsulated in educational experiences that engage students to develop socio-cultural, cognitive, metacognitive, productivity, and technological competencies for the 21st century workplace. While the fostering of 21st century skills is fast becoming an educational imperative, empirical studies have found it to be absent in teachers' pedagogical practices. The learning models to support the integration of 21st century skills have yet to be pervasive in classroom teaching and learning practices. Coupled with the unique contexts of schools, classrooms and students, teachers face a significant design task when it comes to the creation of pedagogical practices to foster 21st century skills. Teacher professional development therefore needs to equip teachers with the necessary skills to design their pedagogical repertoire for engendering 21st century skills in students.

This study first describes the theoretical conception of a professional development framework that is designed to support the creation and learning of new professional practices. Drawing upon the conceptions of design thinking described by researchers such as Donald Schön and Nigel Cross, this process emphasizes opportunities for teacher engagement of reflection-in-action through continual opportunities for the iterative framing, developing, and reflection of design ideas. The process also exemplifies how target scaffolds, social scaffolds, and process scaffolds can be used to support this process.

The study then describes how this process was implemented with three teams of ten teachers at a Singapore primary school throughout a school year. Using a multiple case study approach, the pedagogical changes implemented by each team was analyzed according to the themes underlying 21st century skills and described. The professional knowledge generated by teachers as well as their perceptions of the usefulness of the professional development process were also examined from the teachers' reflections. Through these analyses, the study will surface the considerations for implementing design-driven teacher professional development. It will also discuss the implications for work-based professional development programmes that foster the innovation of professional practices.

21st CENTURY SKILLS AND 21st CENTURY LEARNING

As can be seen from the proliferation of frameworks for 21st century skills since the last decade (MetiriGroup & NCREL, 2003; OECD, 2005; PS21, 2009; Skills, 2011), the need for schools to produce workers with 21st century skills is not a new challenge that is confronting teachers. In their reviews, authors such as Voogt and Roblin (2012) found that frameworks for 21st century skills typically recommend the need for competencies in five areas. Firstly, social-cultural competencies are required for managing communication and collaboration within and beyond the social-cultural contexts that workers are familiar with. Secondly, cognitive competencies such as critical thinking and creative thinking are needed to support complex problem-solving. Not only do workers need cognitive competencies, they must also be equipped with metacognitive competences to think about their own thinking, to reflect, and to engage in self-improvement. These three kinds of competencies need to be engaged together with competencies for productive organization of work, as well as technological competencies to exploit appropriate information and communications technology (ICT) for efficient and effective work outcomes.

In order to nurture students' 21st century skills, teachers need to engage them in supporting learning practices. In a large-scale study spanning 28 countries, Kozma and Anderson (2002) characterized innovative pedagogical practices as those that go beyond passive learning; where ICT is being used to support the solving of authentic real-world problems, the facilitation of collaborative learning and the self-management of one's learning goals. It would appear that when students undergo such kinds of learning experiences, they should have enhanced opportunities to develop the social-cultural, cognitive, metacognitive, work-oriented, and technological competencies that are being emphasized as 21st century skills. In fact, Howland, Jonassen, and Marra (2012) proposed that meaningful learning with technology can be used to support student development of 21st century skills. This encompasses students using ICT as tools for supporting learning experiences that are active, constructive, intentional, authentic, and collaborative.

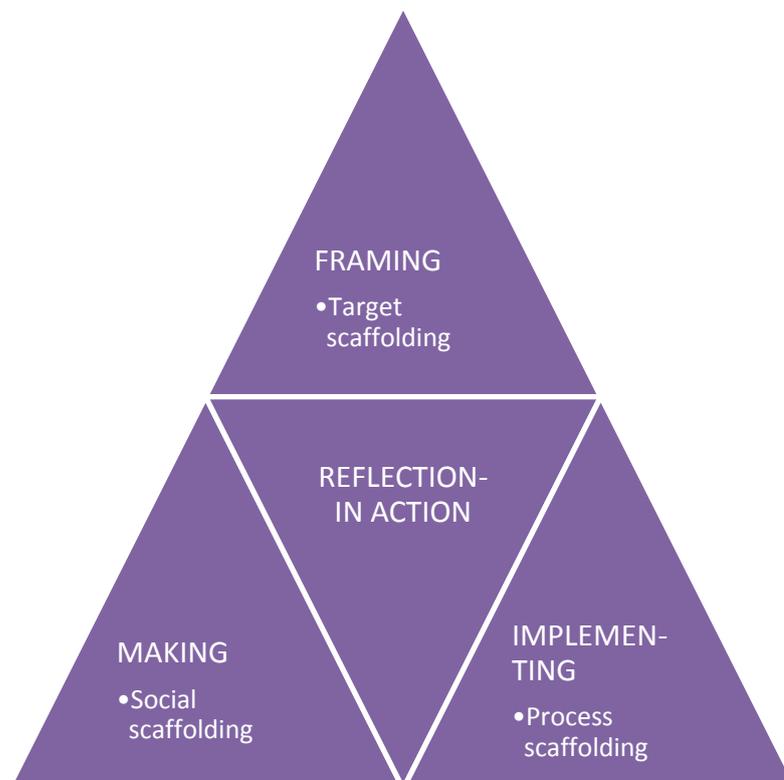
While the educational sector is not short of the pedagogical vision for fostering 21st century skills, the translation of this vision into practice remains challenging. Not only does it require teachers and students to change their conceptions of learning, it also involves the reconsideration of curriculum plans (Ertmer & Ottenbreit-Leftwich, 2013; Tubin, Mioduser, Nachmias, & Forkosh-Baruch, 2003). Coupled with the fast pace of technological changes, this implies that teachers can rarely integrate 21st century skills without some form of design and redesign of their existing lessons. Nevertheless, it appears that teachers have yet to develop the required design capacities as empirical studies show that such kinds of pedagogical practices are still not prevalent even among teachers who have integrated ICT into their lessons (e.g. Lim & Chai, 2008; Ward & Parr, 2010). Developing teachers' capacity for the design of lessons that engender 21st century skills in students is therefore an important agenda in teacher professional development. This paper explores the conceptions and outcomes of a teacher professional development programme targeted at doing so.

CREATING AND LEARNING PROFESSIONAL PRACTICES THROUGH DESIGN

Empirical studies show that new forms of pedagogical knowledge are created by teachers when they engage in design activities (Koehler, Mishra, & Yahya, 2007; Koh & Divaharan, 2013). These findings concur with studies of professionals such as architects and industrial designers which concluded that the knowledge for problem-solving and design are being generated as designers continually play with ideas, develop artefacts, test prototypes, and most importantly, engage in critical reflection with the design situation (Cross, 2011; Lawson, 1997). Termed as reflection-in-action, it is this concurrent doing and reflecting that helps the designer to generate new forms of understanding about the design problem as well as its required solutions (Schön, 1983). Designers' expertise therefore rests on their ability to engage in such forms of reasoning which is known as design thinking (Dorst, 2011).

Our professional development model is built upon the premise that teachers can best learn how to design new pedagogical practices by engaging in design experiences that scaffolds their design thinking (See Figure 1). For teachers to effectively create and learn the professional practices for developing pedagogical practices to bring out 21st century skills, we suggest that they need to be engaged in professional development processes that scaffold them in framing, making, implementing and reflection-in-action.

Figure 1: Framework for professional learning through design



Framing

Frames refer to designers' interpretation of design problems which often determines the kinds of solutions adopted (Dorst & Cross, 2001). In our framework, we help teachers to establish appropriate frames for integrating 21st century skills through a lesson evaluation rubric developed by Koh (2013). It articulates guidelines for classroom implementation of 21st century skills as per Howland et al.'s (2012) theoretical proposition of it having active, constructive, authentic, collaborative, and intentional dimensions. Take the authentic dimension for example. A lesson is rated as zero for this aspect if teachers do not relate subject matter to real-world phenomenon or problems, and rates a one if teachers merely presents the phenomenon or problems to students (e.g. showing youtube videos of the kinds of energy that are at work during a roller coaster ride). The rating increases when students are given opportunities to investigate and propose solutions (e.g. analyse effects of different kinds of energy on a simulation and design a roller coaster that has the highest possible loop). The maximum score that can be given for each dimension is four.

The rubric recognizes that teachers need to make pedagogical choices when considering 21st century skills and that not all skills can be covered within a lesson. Therefore, the rubric is used as a form of target scaffolding which supports teachers to visualize lesson possibilities and select focus areas that provide opportunities for students to be engaged in the practice of 21st century skills. This is important as the lack of clear pedagogical goals often prevent teachers from designing 21st century experiences successfully (Somekh, 2007).

Making

Once teachers have completed their goal-setting, they move on to the "making" of their design which typically involves ideas generation, ideas exploration as well as development of lesson artefacts. This is similar to intent to the ideation, sketching, and prototyping activities that designers undertake (Cross, 2011). We advocate a team-based approach because it has been found that teachers' professional growth can be fostered through such kinds of collaborative design opportunities as well as communities of practice (Clarke & Hollingsworth, 2002). Furthermore, teachers need to draw upon their technological, pedagogical, and content knowledge to design effective lessons (Mishra & Koehler, 2006). As it is rare for a teacher to be equally strong in these three aspects, a team-based approach better optimizes teachers' individual competencies as social scaffolds for design. Expert participation can perturb teachers' fixed mindsets, encouraging them to take pedagogical leaps beyond their current practices (Koh, Chai, Wong, & Hong, 2015). Therefore, we propose that expert facilitation be incorporated as an important form of social scaffolding for teachers to successfully construct new pedagogical practices.

Implementing

Our development framework emphasizes the full cycle of instructional design which includes planning and monitoring the implementation outcomes of the lessons designed as per established lesson design models (e.g. Heinich, Molenda, Russell, & Smaldino, 1999). Contextual factors such as national curriculums, student profiles

as well as the ICT facilities in schools need to be taken into consideration when designing and implementing lesson designs (Koh, Chai, & Tay, 2014). In this respect, the lesson planning guide designed by Chai, Koh, Ho, and Tsai (2012) is being used as a process scaffold to help teachers consider the coherence of their lesson strategies in terms of technological, pedagogical, content and contextual selections. The guide comprises questions to stimulate thinking about various implementation aspects, for example, which aspect of the curriculum does the redesigned lesson address? Are teachers and students familiar with the ICT tools to be used? Do the redesigned pedagogies have any conflict with the current established pedagogies for teaching the topic? These implementation considerations, as well as student performance results from actual lesson implementation act as important feedback for teachers and can sometimes move them to reconsider their framing as well as to re-make their designs.

Reflection-in-action

Existing studies show that lesson design is characterized by the iterative rather than sequential performance of design activities (Summerville & Reid-Griffin, 2008). This implies that teachers can move back and forth between framing, making, and implementing. Even as teachers are “making”, they may learn aspects of the design problem that moves them back to “framing”. Reflection-in-action is therefore the nexus among the three design activities where teachers rationalize incongruent decisions and make compromises among design considerations. It encapsulates the messy and episodic nature of design (Schön, 1983) whereby teachers are ideating, reflecting, and generating new pedagogical practices. This is also the critical event where teachers generate new insights and learnings about their professional practice.

The Professional Development Programme

This professional development framework was used to design a professional development programme that was implemented with three design teams formed by ten teachers from a Singapore primary school. The school participated in the study as part of the school’s programme for integrating 21st century skills into their curriculum. The teachers first attended an eight-hour course conducted by the researchers to learn the conceptions of 21st century skills, application of the meaningful learning rubric, and the lesson planning guide. As part of the course, teachers evaluated their existing lesson plans with the rubric and set goals for redesign. This process was used to kick-start teachers’ engagement in “framing”. Teachers were then divided into subject-based design teams, each comprising three to four members to engage in the “making” of lessons for English, Mathematics, and Science respectively. All the teams participated in weekly hour-long design sessions where lesson ideas for the incorporation of 21st century skills were being developed. Fortnightly, researchers from the local university participated in the teachers’ design sessions. The researchers played devils’ advocate by challenging and engaging teachers in reflective conversations about their design conceptions. Teachers also used the lesson planning guide to plan for implementation. The entire teacher professional development process spanned a school year where the first six months were focused on collaborative design while the latter six months were used for classroom implementation and the evaluation of student learning outcomes. Reflection and sharing sessions were held at the mid and end points of the process.

RESEARCH QUESTIONS

The research questions examined are:

1. What kinds of pedagogical change were implanted through teachers' lessons as a result of the professional development programme?
2. What were teachers' learning from the professional development programme and their perceptions of the programme?

METHODOLOGY

The case study approach was being used as we sought to describe the usefulness of the professional development programme using multiple data sources (Creswell, 1998; Yin, 2003) including observations of teachers' lesson implementation and analysis of teachers' perceptions. Each design team was being considered as a case and the selection of multiple case studies enabled us to assess the outcomes of the programme for supporting lesson design in different content areas. To provide maximum variation for the efficacy of the framework as well as to cater to the project outcomes desired by the school, the design teams were purposively organized into three subject groups focusing on English, Mathematics, and Science respectively. While design teams for Singapore primary school subject areas of mother tongue languages and social studies were not included, the three selected subject areas covered more than half of the subjects of instruction in a Singapore primary school. This we believe would enable us to have good insights about the applicability of the design framework to different subjects. These results will enable the team to gather sufficient feedback on an exploratory basis to enhance the framework.

To answer the first research question, the initial lesson plan designed by the teachers as well as the video recordings of the final lesson design that was implemented were coded thematically by the five aspects of 21st century learning, that is, social-cultural, cognitive, metacognitive, work-oriented, and technological. Two researchers compared their codings for inter-rater reliability till there was full agreement. Teachers' reflections from their slides presented during the sharing sessions were coded thematically to answer the second research question. The coding was done by one researcher and negotiated with an inter-rater to achieve full agreement.

FINDINGS

Research Question #1 – Pedagogical changes enacted

Analysis of teachers' implemented lessons found that the professional development process has enabled all the three groups to enact pedagogical lessons that were more targeted at students' learning difficulties and enhanced in their integration of ICT tools. The opportunities for students to engage in 21st century skills were also enlarged.

English

In their initial conception of this primary five composition writing lesson, teachers only used Titanpad™ as a platform to facilitate students' online collaborative writing. Primary five students worked in groups to write essays and in the process, they had to negotiate ideas, provide peer critique and organize their writing processes in order to produce a final project. In terms of 21st century skills, this initial lesson design engaged students' technological skills, cognitive skills and social skills. Through formal assessment, teachers found that the students' essays were still lacking in content development, largely because students were weak in judging how they could expand the content of their writing.

As part of the lesson revamp, teachers introduced new pedagogical strategies to teach students various ways of “ballooning” their sentences to enhance writing content. This was carried out in two lessons firstly through self-paced learning packages created on Powerpoint™ where students learnt strategies for developing the content of their writing through the use of vivid verbs, adjectives, and adverbs. Students then applied these strategies to gradually “balloon” sentences followed by paragraphs. The use of Titanpad™ was enlarged. Not only did it function as a space for students to share their work, students also used its editorial functions for collaborative writing and its chat function to provide comments as part of peer editing.

It can be seen that the revamped lesson deepened students' engagement of 21st century skills in various aspects. Firstly, the introduction of the “ballooning” strategies through systematic practice by sentence and paragraphs challenged students to make deeper cognitive engagement with the topic. Students were given opportunities and supported with cognitive supports for deeper critical analysis of their writing. Secondly, it provided students with opportunities to practise metacognition as they engaged in self-paced learning materials where teachers provided examples to help them identify and close their learning gaps while learning at their own pace. Even though students' experience with collaboration did not change, the self-paced learning and “ballooning” strategies enhanced students' writing skills to engage in these processes.

Maths

For the group of Maths teachers, the lesson they initially considered for redesign was for the topic of fractions where online manipulatives have been incorporated to help the primary five students to visualize fractional parts. As teachers deepened their understanding of the 21st century dimensions, the teachers chose to create an entirely new lesson for the topic of Averages as the topic afforded teachers greater scope for the integration of multidisciplinary skills and authentic problem-solving. This was because teachers observed that students may not have fully grasped the concept of average when they were taught through formulas. Therefore, the objective of this lesson was for students to apply the concept of average to situations in their daily life. Through the use of Microsoft Excel™, teachers also wanted students to appreciate how ICT is being used to manipulate large sets of data in real-world situations.

The concept of average was first taught through a problem where students worked in groups to brainstorm ways of distributing a bag of sweets equally. The students got to keep the sweets at the end of the lesson. The concept of average as well as its method of computation was introduced through this activity. This activity gave students the opportunity to learn the basic concepts through manipulating a small data set. The second problem introduced students to the computation of averages that involved decimals through the manipulation of a larger set of data with Microsoft Excel™. Students were given the monthly utility bill of the school across a school year and they worked in groups to compute the averages using Microsoft Excel. Students then analysed possible reasons for above-average use of water and electricity in particular months and brainstormed ways for their conservation. The third problem was slightly more open-ended as students had to propose the ideal weight of their school bags. Students brainstormed ways of collecting and analysing data to find out the mass of their peers' school bags in groups. The students then executed their groups' plans and analysed the data to determine if the mass of their school bags were above or below average. The students then individually reflected on strategies for avoiding carrying unnecessarily heavy bags to school.

It can be seen that the re-designed lesson is strong on engaging students with the cognitive, social-cultural, work-oriented and technological aspects of 21st century skills. The three problems that students worked on were authentic and realistic to the world of primary five students. Each problem challenged students to engage more critically with the concept of average and its application in the real-world. The lesson was also anchored in authentic work practices as the students had opportunities to use spreadsheet programmes as workers would at the workplace. Opportunities for the students to practice collaboration and social skills were also considered as they worked to brainstorm ideas for solving the three problems.

Science

The Science teachers worked on the topic of Electrical systems. In the original lessons, teachers taught students about open and closed circuits, the differences between parallel and series circuits, and the characteristics of electrical conductors. Students then conducted experiments to test the effects of different circuit arrangements. This initial lesson design engaged students in some aspects of critical thinking and social-cultural skills through group activities as students learnt by doing and experimenting. However, teachers observed that the students were weak in analysing problems related to circuits and to articulate scientific explanations. In the revised lesson, teachers sought to engage students in higher levels of critical thinking through solving complex problems across four lessons.

In the first lesson, teachers taught the basic concept of close and open circuits. Padlet™, an online stickies programme, was used to gather feedback from the students regarding what they knew about the topic before the lesson and what they learnt after the lesson. This was used by the teachers to assess students' understanding. In the second lesson, teachers had students to explore the parts of circuit as well as open and closed circuits through a computer-based simulation following which they examined their explanations by building actual circuits. The students then practiced the processes of POE (Predict, Observe, Explain) to generate scientific explanations for their observations. In the third lesson, teachers

increased the difficulty level of the problem by asking students to investigate how series and parallel arrangements of the circuit influenced the brightness of a bulb. The students had free play to experiment with their circuit arrangements within which teachers also integrated malfunctioning circuit parts for them to diagnose possible circuit problems. Students could use both the simulations and actual circuits in the process and they had to use the POE process to generate their explanations. The fourth lesson was about electrical conductors. Teachers provided students with different materials such as paper clips, rubber bands, aluminium foil and coins and had them to design circuits to differentiate between the conductors and non-conductors. Students could also use objects from their pencil case for testing. Students had to use the POE process to analyse the materials and generate their explanation as to the characteristics of an electrical conductor.

In this series of lessons, teachers focused on the cognitive and metacognitive aspects of 21st century skills. As compared to the initial lesson, the cognitive aspect was enhanced through the deliberate design of problems that are increasingly complex in nature. Students were challenged to engage in systematic analysis and problem-solving through complex problems where they had to diagnose circuit problems and also to set-up ways to experiment with different materials in order to derive the features of electrical conductors. These problems stimulate students to engage in the 21st century cognitive skills of problem-solving and critical thinking. Computer-based simulations supported students to externalize and test the correctness of their knowledge conceptions. It acts as a metacognitive tool that supports students to engage in the discovery and self-regulation of their learning gaps. Some opportunities for practicing social-cultural skills were also engendered as students worked in groups for the various activities.

Summary

The above analysis shows that all groups were able to enhance their designs in terms of the 21st century skills of social-cultural and critical thinking skills. In addition, the English and Science teachers integrated ICT tools that supported students to engage in metacognitive thinking as they diagnosed their learning gaps. Among the three groups, authentic problem-solving and opportunities to engage in work-oriented practices was most evident in the design of the maths teachers, largely because of the opportunities afforded by the topic chosen.

Research Question #2 – Teachers’ learning and perceptions

English

In terms of lesson design, the learning points that the English teachers gleaned were mainly in the choice of the ICT tools and the ways of increasing self-directed learning in students. The teachers explored a range of ICT tools, searching for suitable ones that afford the presentation of content, i.e. verbs, adjectives, and adverbs, for students’ self-directed learning. They also needed a tool that afforded collaborative writing and commenting among students during the process of writing. The eventual decisions in Google Site™ and Titanpad™ respectively had proven to be correct as the students were meaningfully engaged in the lesson activities.

Through this process, the teachers expressed that the new knowledge gained is mainly in technological knowledge where they can more accurately pinpoint the affordances of ICT tools now. In addition, they also expressed an increase in their pedagogical knowledge in that they are more confident of the pedagogy, and they intend to scale the approach to the Primary 5 level. Finally, the teachers commented that the value of the rubric is in helping them assess the evidence of knowledge for technology integration. This has helped the teachers track if meaningful learning has been achieved.

Maths

For the group of Math teachers, the learning points that they gleaned with respect to lesson design focused on the use of authentic activities to make mathematics meaningful to students. They explored a range of authentic tasks such as use of pocket money, students' height and mass, popularity of food in the canteen before deciding on the use of the school's monthly utility bills and assessing the mass of students' school bags. As the teachers ploughed through the decision-making process, they demonstrated content knowledge where care was taken to ensure ease of data collection, and that the collected data would not skew due to situational factors. Such careful planning had paid-off as the students were not only able to explore the concept of average using integers, they were able to do so using more complex numbers involving decimals. In addition, the benefit of the authentic activity had helped students see the relevance of what they were learning to everyday life. In terms of the ICT tools, the teachers expressed that the assumption they held of the Primary 5 students to be more IT savvy, and thus required little time of familiarity with the tool was flawed. They found that due time had to be given to students to help them gain familiarity with the ICT tools used.

In terms of knowledge gained, the Math teachers expressed an increase in technological knowledge where a range of tools were used to help students collect data as well as to collaborate throughout the process. There is also an increase in pedagogical knowledge as teachers are more confident in discerning which topics are better suited for technology integration. They could also differentiate which aspects of the activity would be better conducted in class as compared to doing them as homework.

Science

The Science teachers' main take-away with respect to the lesson design was in the dilemma they faced in the choice of strategy. They also learned to focus more on the teaching of the subject-matter and its fit with technology as opposed to the use of technology alone.

In terms of knowledge gained, the teachers expressed a deepening of pedagogical knowledge. They reflected that the time they took to explore the use of the pedagogy, i.e. predict, observe and explain (POE) in the lesson package was well spent. This had helped teachers gain confidence and they planned to introduce the pedagogy at earlier stages to other cohorts of students so that students can use this strategy more effectively.

Summary

From the teachers' reflections of their learning, it appears that there is some trending in the increase of technological knowledge and pedagogical knowledge. Through the professional development program, teachers had to explore various tools, and more importantly, to connect them in meaningful ways with pedagogy. This has helped to advance their understanding of ICT tools and their affordances. At the same time, in their efforts to address students' learning in the meaningful manner, teachers have deepened their understanding of the approaches they have taken, hence increasing their pedagogical knowledge base.

CONSIDERATIONS FOR IMPLEMENTING DESIGN-DRIVEN TEACHER PROFESSIONAL DEVELOPMENT

This study has established initial evidence that teacher professional learning based on design thinking principles can support teachers to better integrate 21st century considerations into their lessons. It suggests that teacher professional development needs to engage teachers in design framing, making and implementing of their design, interwoven with continual reflection-in-action. As teachers engage in these activities, they need to be supported with three kinds of scaffolds. First, target scaffolds enable them to set goals for the integration 21st century skills. Second, social scaffolds help teachers to generate ideas and analysis as lessons are being created and finally, process scaffolds help teachers to analyse and strategize implementation plans.

To cope with the multiple competing demands constantly faced in the classrooms, teachers would have developed routines they found to be effective for both classroom management and instruction. Over time, these routines would have evolved into a repertoire of strategies that teacher are comfortable to execute. Engaging teachers in design thinking would essentially require them to break away from their routinized patterns and to reinvent new teaching methods. As such, teachers may be resistant to the changes brought forth by design thinking. In this study, we increased teacher ownership by having teachers to identify topics they found problematic for their students. The rubrics which served as target scaffolds were reviewed by teachers. This helped to foster buy-in for the meaningful learning framework. Based on the teachers' consensus, the rubrics were adopted as process scaffolds. However, the researchers need to constantly refer the teachers back to the target and process scaffolds to prevent them from slipping back to their old ways of thinking. One possible way to fade off the facilitator's support would be having different teachers to role-play as experts. A possible social scaffold in terms of role assignment would be to assign one teacher to be a technologist focusing on the technology-related areas, another to assume the perspective of a pedagogue focusing the pedagogical issues, and the third teacher to be a subject-matter expert that focuses on content.

Engaging teachers as designers could also be problematic as school contexts are not primarily set-up for design work. The curriculum design has pre-specified syllabus requirements which in turn inform the design of the Scheme of Work school schedule. Special arrangements also need to be made to provide teachers with time to engage deeply in design work and this could mean taking teachers away from

their normal duties such as marking. In this case setting, the school leaders were supportive for the design work and a dedicated middle manager was tasked to oversee the multiple logistics and coordination needed.

Moreover, the goal of producing quality test results and the development of 21st century skills is often conceived by teachers as competing goals. It is easy for teachers to recede back to the tried and tested methods when they are not confident that the 21st century processes can be as effective in producing results. While the current emphasis on 21st century learning is rhetorically difficult to refute, the challenge of designing effective pedagogy that can achieve both process and results has yet to be proven by strong research evidences. To gain deep and permanent pedagogical changes in today's classroom, changes in the design of lesson may not be sufficient. Teachers' facilitation skills for fostering self-directed and collaborative learning of authentic problems, and their skills in guiding a class of 40 students to construct deep understanding through inquiry are foundational to successful student learning. Recent literature has put forth the notion of orchestrating classroom learning. In addition, students are also facing the challenges of assuming responsibilities for their learning while parents need to be supportive of the school efforts in making change. There are many risks that may threaten the 21st century learning movement, especially for a highly successful education system like Singapore.

LIMITATIONS AND FUTURE RESEARCH

This study has limitations that can be addressed in future research. Firstly, it was implemented in a Singapore primary school for the subject areas of english, mathematics, and science. The validity of the framework in engendering teachers' pedagogical change in other primary school subject areas of mother tongue languages and social studies has not been examined. Therefore, this study can be replicated with teachers from different subject areas especially those beyond the primary school level such as humanities, natural sciences, design and technical, and computer applications

Secondly, this study has focused on teachers' pedagogical change as well their perceptions. The outcomes of these lessons on student performance were not reported. Each team of teachers participating in this study have collected student performance data related to their lessons. Given the constraints of project time, not all groups have managed to conduct pre and post tests and each group had different definitions of student outcomes according to their lesson design. Although the teachers generally found improved student performance from their data, the researchers were not able to obtain the test scores from teachers for in-depth statistical analysis whereas the project duration also limited the researchers from providing further training on action research to help teachers further analyse the results statistically. In future studies, we propose that tighter corroboration between teachers' enacted pedagogical changes and student performance be planned into the implementation process.

The next area for future research would be to consider the applicability of this professional development process to faculty in higher education settings as well as for corporate trainers in contexts such as blended learning and e-learning through

MOOCs. This study limits the design process to engendering pedagogical change for 21st century learning. Future studies can explore if the use of design thinking concepts can be a useful strategy for professional development beyond this context.

CONCLUSION

This study provides some initial evidence that professional learning can be brought about by development processes that are design-driven. Yet, design is a complex endeavour whereby target, process, and social scaffolds could be required. The frameworks for supporting design-driven professional learning can be further examined.

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