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Promoting Sustainable Teacher Change during Design Research on Seamless Learning

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Abstract: Design research has been the major methodology when learning sciences researchers design and implement interventions to bring education change in schools. However, how to promote systematic and sustainable change in design research remains a big challenge. The study is part of a three-year project that brought a seamless learning innovation to transform primary three (P3) and four science learning. During the first year enactment, we had one teacher and one P3 experimental class. We followed the same teacher and class to Primary four. Another teacher and experimental class joined the project at P4. Audio/video recordings of teacher-researcher weekly meetings, research team weekly meeting minutes, selected audio/video recordings of science lessons and field notes, teacher reflection and interview audios, and student artefacts were collected over about three years of time. We identified teacher to be the major agency for sustainable education change. We apply a Structure/Agency framework and a teacher qualification model when describing and analyzing teacher learning and teacher change during the seamless learning project. Our results showed teacher knowledge, belief, and practice change was facilitated and constrained by the school environment and the change was not of the same pace and synchronized but affected by each other. The paper provides empirical data and analytical framework for teacher change in design research context.

Keywords: Teacher learning; teacher change, Seamless learning, primary science; Structure/Agency

Introduction

Design research has been the major methodology when learning sciences researchers design and implement interventions to bring education change in schools. However, how to promote systematic and sustainable change in design research remains a big challenge. The study is part of a three-year project that brought a seamless learning innovation to transform primary three and four science learning [3]. During the first year enactment, we had one teacher and one experimental class. We followed the same teacher and class to Primary four (P4). Another teacher and experimental class joined the project at P4. Audio/video recordings of teacher-researcher weekly meetings, research team weekly meeting minutes, selected audio/video recordings of science lessons and field notes, teacher reflection and interview audios, and student artefacts were collected over about three years of time. We identified teacher to be the major agency for sustainable education change. We apply a Structure/Agency framework and a teacher qualification model when describing and analyzing teacher learning and teacher change during the seamless learning project. The purpose of the project is to explore how to leverage on the affordances of the mobile technologies to support student-centered mobile learning (seamless learning). However, when we entered the school, a real world, we have found that developing curriculum that integrate mobile technology, teacher preparation, and assessment were so intertwined with how student should learn, these were all the things

we had to consider. We had to work with people, and the most important people were teachers. In that context, this study explores how we can foster desired and sustainable teacher change.

The following research questions guided the study:

1. What are teachers' knowledge, beliefs, and practices before the seamless learning intervention?
2. How do teachers' knowledge, beliefs, and practices change over time during the co-development and enactment of seamless learning?
3. What are the conditions that facilitate teacher knowledge, belief, and practice change?

1. Literature review

1.1 A Structure/Agency framework

Introducing innovation and new methods involves a variety of issues and stages [2][6]. The importance of involving teachers in curriculum innovation has long been recognized [4]. Several studies have found that differences in teacher qualifications across school districts can account for as much of the variation in student achievement as students' backgrounds or socioeconomic status [1]. Therefore, teachers have their agency to make or break reform efforts. Vora & Barton [9] defined *agency* as individual or group effort to influence the surroundings in purposeful ways. *Structure* is a set of rules and resources that actors draw upon as they produce and reproduce societal norms in their activities. It includes virtual schemas, intangible values, beliefs, and ideas that affect actions [7], and tangible resources, such as social class, religion, gender, ethnicity, technology infrastructure in schools. We acknowledge that teacher agency can both enable and constrain how human agents influence the world around them.

1.2 Teacher competence and teacher change

We refer to teacher competence as the characteristics that make teachers qualified for their work. It is the knowledge, abilities, and beliefs a teacher possesses and brings to the teaching situation [5]. This goes beyond what a teacher knows to teacher's quality in teaching. Teacher competence here is based on the needs for teachers to be able to design and enact "the mobilized" science curriculum [11]. Teacher *content knowledge* (CK) influences how teachers engage students in learning subject matter; Teacher *pedagogical content knowledge* (PCK) refers to knowledge about how to teach subject matter to students [8]; Teacher *technological pedagogical content knowledge* (TPCK) reflects some of the essential qualities of knowledge required by teachers for technology integration in their teaching, and finally the *non-intellectual factors* (NIFs), such as beliefs, motivation, anxiety, and attitudes that are relevant to soft skills are also very important to influences a teacher's collaboration with researchers and their actions. We consider CK, PCK, TPCK, and NIFs as a teacher qualification (competence) model that affects education change [10].

2. Research design

2.1 Context and participants

Our collaborative school, North Coast Primary School (all names in the paper are pseudonyms), is a neighborhood school. It had nine primary three classes. At primary three (P3), we chose one of the "mixed ability" classes, Class X. There were 39 students in the class comprising 24 boys and 15 girls. We chose the class because its form teacher, Grace, was recommended to be our collaborating teacher. She coordinated the operation of the class'

activities in school and taught English, Math, and Science (EMS) to the class. She had been teaching in the school for more than three years. The school chose her to teach the experimental class because she felt comfortable in using technology. She was quite receptive to new ideas. She wanted to collaborate with the researchers to enrich her knowledge and skills in using mobile learning to improve student learning. During year two enactment, a P4 teacher, Jean, and her class Y joined the project as an experimental class. Class X and Y remained the same from P3 to P4. Y is a high performance class. Jean was chosen by the principal. She had just started teaching in the school when joining the project.

It might be confusing to tell that the project was three years and we only talk about P3 and P4 enactment. The reason is that before enactment we had to work with teachers to co-design the curriculum. After collecting data, we also need time to analyze and write up the results. Table 1 listed the timeline and topics taught in P3 and P4. Some topics could last for about 10 periods; some might only take 2-3 periods.

Table 1: List of MLE units designed for the mobilized curriculum

Unit ID	Level & time period	Topic
P3-1	Feb. 2009	Classification for living & non-living things
P3-2	Feb. & Mar. 2009	Classification of animals
P3-3	Mar. & Apr. 2009	Plant
P3-4	Mar. & Apr. 2009	Plants & their parts
P3-5	Mar. & Apr. 2009	Fungi
P3-6	Apr. & May 2009	Materials
P3-7	Aug. & Sept.2009	Body systems
P4-1	Jan. & Feb. 2010	Cycles
P4-2	Feb. & Mar. 2010	Matter
P4-3	Apr. 2010	Light & shadow
P4-4	Apr. & May 2010	Heat & temperature
P4-5	Jul. 2010	Magnet

2.2 Data and data analysis

Besides systematic and continued natural observation data, such as audio/video recordings of teacher-researcher meetings, classroom teaching, and artifacts created by the teachers and their students, we have also collected self report data such as field notes and audios when teacher debriefed their experience and ideas after teaching and/or during teacher-research meetings. Their statements also included indicators of their competence. When we track the data over time, patters emerged in terms of the four dimensions of CK, PCK, TPCK, and NIFs. We compare and contrast the data with our observation data to consolidate our assertions. Because we always have at least two researchers to work with teachers and/observe their classes, the inter-rater reliability was on one hand checked by the two of them, and when they report to our weekly meeting with NIE with the whole research team, their observation and interpretation was further checked by the whole team. We defined teacher change as *not so obvious, noticeable*, and *significant*. They should be self-explanatory. As for coding the evidence, as stated above, we used both observation and self-report data to triangulate our assertions. *Agency* was coded as teacher's self-initiated and/or volunteered actions that are relevant to our project work. Support *structure* refers to school's institutionalized and sustainable efforts.

3. Results

We have summarized the degree of improvement of the two teachers and major supporting structure that might have facilitated their changes. We consider the demonstration of agency as part of their change. So we will present the two teachers' stories as two cases. Our main focus will be on the interaction of teacher *agency* and the support *structure*.

Table 2: Teachers' degree of improvement vs. supporting structure

Competence	Teacher Grace	Support Structure	Teacher Jean	Support Structure
CK	Significant	Researcher/Teacher working group; school recognition	Not so obvious	School assigned; researcher/ peer teacher
PCK	Significant		Significant	
TPCK	Significant		Noticeable	
NIFs	Significant		Significant	

3.1 Case 1 Teacher Grace's change

Teacher Grace coordinated the operation of class X's activities in school and taught English, Math, and Science (EMS) to the class. Teaching was not Grace's first job. She was an IT trainer before joining teaching. Therefore, she had more knowledge on ICT. She had been teaching in the school for more than three years when she started working with the research team. She had no formal training in teaching science.

In the real world, Grace had to adjust the understanding of her role on the research team, and thus demonstrated her agency. Here is how she had considered her role at the beginning of the project:

> Grace: For me I thought in terms of content developing would be more of erm, task, might be a smaller role than the other colleagues who are in this content developing team. This is because I was told that I was suppose to mingle, the only, now I know that I am the only class, the only class that's involved in this project. So I think it's more involved in implementing the lessons that were actually created in the class. I think it's more of like, you get the progress and then sharing of the experiences that I have, with my other colleagues. [Interview, Feb. 15, 2009]

She did not consider herself to mainly responsible for curriculum development because the initial decision was that researchers and a teacher task force to be responsible for curriculum development and she adopted and enacted the curriculum. However, when there was time constrain, when other teachers were not able to fulfill their commitment, Grace had to eventually finalize the curriculum and upload the materials to a web learning management system so that her students could download the materials and assignments. Fig. 1 and 2 are the screenshots of a unit called body system as part of the "mobilized curriculum". There are many components and activities in such a unit that integrated the affordances of mobile technology (see [11] for more details). When the support structure was not as strong as she had thought, this led to her agency to take over more responsibilities, and finally led to her being able to develop such "mobilized curriculum" herself. She had thus developed her competence and now she has been a lead teacher to give workshops to teachers in her school and other schools to develop "mobilized curricula".

> Grace: My class is not really very independent. You know they are still at the age where they, even working in groups, there're still arguments. They can't work properly in groups and then they, they have this, I don't want to work with this person, but when the mobile devices come in, it's like more of one to one. Right? Wouldn't it discourage group work? That was one concern that I think. I know that there's this MLE (Mobile Learning Environment) function that they can still use it; but I thought it's really different from group work. Because group work is like, one piece of thing right? So all of us will crowd together and work on this … so arguments will come in as well. So they have to learn to be cooperative. … [Interview, Feb. 15, 2009]

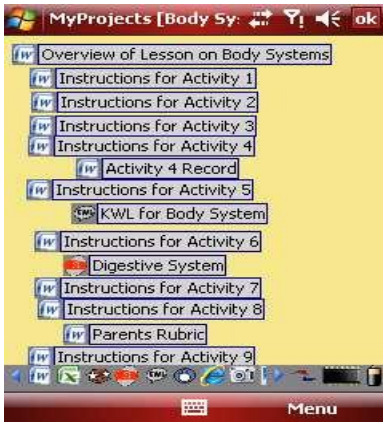

Fig. 1 An MLE body bystem unit

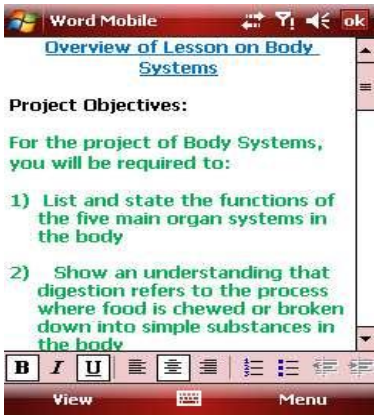

Fig. 2 An overview of the body system unit

The needs from classroom teaching, again, became a structure for her to demonstrate her agency and develop her competence. As stated above, she started to think about how to foster collaboration among students when each student had a smartphone with unlimited access to the Internet. Students were also able to share files between phones and even just looked at each other's screen to share ideas. It was indeed very challenging in the new situation to consider technology affordances, content knowledge, student-centered learning, as well as making sure the class did not miss important objectives required for the whole cohort.

There were obvious changes in class structure when implementing the "mobilized curriculum" [11]. Teacher Grace used to be under pressure to cover the essential learning points through teacher-centered approach lesson by lesson. Supported by part of the "Structure"—the research team, she learned to consider teaching a topic as a small project that lasted for several periods. Now she was able to switch her didactic teaching to student-centered learning. She was inclined to give students more time to construct their understanding rather than feeding them with information. With more time to observe students learning with mobile devices, she learned to identify student learning difficulties when she facilitated student learning (see Fig. 3). The use of the designed MLE lessons gave the teacher more breathing space and she was able to focus on the natural flow of the lessons. In the past, she was task-oriented and aimed to finish predefined drill-and-practice activities in stipulated time. When implementing MLE lessons, she instructed when the situation called for it and she spent more time facilitating the learning processes rather than providing answers. As a result of using the redesigned curriculum using the mobile devices, the teacher shared with the researcher that she had more time to reflect on her lessons even during class. She could think on her feet and improvise on the lessons in real time. This was another instance to show how teacher Grace was able to demonstrate her agency because she was in charge of her class teaching. She had to make decisions from moment to moment. On the other hand, the changed class structure and the curriculum had been changed to be unit-based vs. lesson-based enabled her to have different practices as she had before.

In a later interview with researchers, Grace acknowledged that she herself learned much from the experience of being involved in designing the mobilized curriculum as well as enacting it in class:

> "I feel I do not have enough content knowledge (before the project)...I would say I have gained some content knowledge...through the PD (Professional Development) sessions...it is more fruitful than being a trainee at NIE (the teacher training institute in Singapore) ...""In the past, I taught chapter by chapter...but I did not know I can actually change the order of the content and teach in a different way..."

She further elaborated changes in herself:

"...at the beginning (of the project)...I felt stressful...(now) when I come to class, the stress did not come from content...they came from different sources...it was about technology or questions from the students that I could not predict ....but I feel more confident...I have more content knowledge...".
"In the past, I had to respond to a student's question, so I (sometime) gave an answer anyway even I was not so sure…now, if I do not know, I will say 'I do not know'...because otherwise a student might find the answer (by searching the Internet on their smartphone) and get back to me immediately..." "I changed my mindset…now I feel I am learning with the students...it is OK to say I do not know..." [Interview, Aug. 19, 2009]

In summary, the teacher acknowledged that the curriculum co-designing experience helped her to prepare her teaching in terms of subject knowledge (CK), student learning difficulties (PCK), and the use of technologies (TPCK) (Zhang, 2011). She had also significant change in NIFs, such as whether she had to give student an answer when she was not sure. She was also very persistent to teach the mobilized curriculum although she occasionally switches back to her "old" teaching. This was due to both her own belief change and the structure change (the students had their smartphone could find out answers on their smartphone at any time). The co-design process also allowed researchers to understand tensions between the seamless learning approach and existing concerns of the teacher, such as assessment, in order to develop feasible and evolutionary strategies towards a fundamental switch of pedagogy.

Researchers and teachers had staged priorities in terms of fostering student-centered and inquiry-based learning. There were new challenges when she had students with different profiles. At P4, she also taught another high achieving class Z. Below is a dialog session between researchers and teacher Grace.

Researcher 1: …questioning style. Cos we saw you in the beginning of last year you don't question in this way. So what made you change your questioning technique?...

Grace: Yes! I thought that got good grades is important but getting them to understand the subject topic (is more important) …

Researcher 1: but I think they are so busy already how you going to balance. You have so many things to do in class then you still spend a lot of time doing discussion so do you think you can.

Grace: true.

Researcher 1: how you gonna …?

Grace: I think I rather suffer now right because I thought I feel that erm I did not teach them correctly I should say. Furthermore, this is the first time I'm teaching a high level class and in the past it's always a mix a bit of class … it's more of like what you say. You don't know it's ok as long as I know I give you the information but I think after the PD (Professional Development) sessions that we go through, we actually we do some discussion then I realize that it is really important that that the pupils must understand…
I may not be teaching them in Primary 5 (P5) and Primary (P6) but when they go to P6 er they will still be tested on the topics that they had in P3 and P4. I cannot be sure because they memorize…until now then I realise that you know, P3 and P4 they can actually have held so much of misconception that they thought this is this is correct, but it's actually not correct…
…but you didn't at that point you didn't realize the kids have misconception
…I didn't realise that actually it's true. I didn't realize that they can have misconception because like when I teach right, it's like I give you all the content. Then I know so you should know all these so there cannot be misconception… [Mar. 1, 2010].

From the above dialog we can see that researchers have followed the teacher to her classroom and they tried to understand teacher Grace's ideas. In fact, such dialogs had been almost the daily routine between the two researchers who were almost stationed at the school, and teacher Grace. Their dialogs were always related to real world situation and everything they had to think about many things in relation to curriculum development, enactment, and research. Besides the external needs and intrinsic motivation to bring the best to her students, teacher Grace has also felt the support structure from the principal. For example, at the end of 2009, she was nominated to be the teacher of the year from the school to acknowledge her contribution to the research project. Although we have only presented self-report data, our selection of the data was based on other data, like field notes, meeting minutes, to show

qualitatively the patterns of change in teacher Grace. Therefore, we hope the instances presented here can show the dynamic interaction between the teacher's agency and support structure, which has led to her change in CK, PCK, TPK, and NIFs.

Fig. 3. Teacher listens to students

3.2 Case 2 Teacher Jean's change

Teacher Jean was a novel teacher when she joined the project as a P4 science teacher and a form teacher of class Y. Class Y was one of the three high achieving classes at P4 cohort. According to the two researchers, Jean was resistant to allow her students to talk while she was teaching. Later she had realized talking was unavoidable if she changed from teacher-centered to student-centered teaching. She had moved from didactic to participatory delivery at the second half of the year. She was more willing to let kids learn on their own without too much handholding [Research group meeting minute, Sept. 14, 2010].

At the beginning of the year, she only considered the mobilized lesson plan as supplementary to her own lesson plan although she was supposed to adopt it for her experimental class. Her change was due to both the imposed structure (the commitment to be on the research project) and her own observation when she tried selected activities from the mobilized curriculum. During a magnet unit, she was happy that kids were testing out ideas. They were doing things that she never expected before. She was pretty much intrigued by the magic bullet magnet which her students brought to class. In one of the interviews, she commented "students could learn without being taught". She admitted that student-centred learning was a relatively new concept. She did not feel her training was student-centered. Jean's change, like Grace's, was not stable at the beginning. She could still fall back to her old way of drilling. Although the change of NIFs and beliefs was ahead of their practice change, sometimes we found that only when they taught the way in the mobilized curriculum, she could feel the differences in her students [Research group meeting minute, Nov. 24, 2010]. Jean was a brand new teacher when she became the form teacher of class Y. Y was one of the high achieving class. She was quit firm in controlling the class activities and pace; she did not even allow students to talk and move around in science class at the beginning. Even after more than a month after our collaboration began, she was still resistant to our mobilized curriculum. She believed that she had to teach in order for students to learn well. She was reluctant but stated that she could simply use the mobilized curriculum that developed by Teacher grace and the research team; she requested the researchers to stay in her class to support her. Her change of belief happened during the "magnet" unit when she found out that students could achieve several important objectives when engaging in MLE activities without her teaching! In a briefing interview, she commented that she did not learn how to teach in the MLE way in her training institution but "covering" the content. Jean's content knowledge change was not that obvious probably because she was not involved much in the curriculum development. However, Jean's change in NIFs was quite significant because our data showed big contrast of her self-reported belief change and her change in practices. On the other hand, for sustainable changes, the more than

two years' collaboration like that of Grace was needed. On the other hand, when Jean joined, the support structure has been improved because at least Grace had more things to share with her. Researcher support was also available for her. It was the level of engagement in the co-design of curriculum that mattered a lot for Jean's competence development.

4. Discussion and implications

We apply a Structure/Agency framework and a teacher qualification model when describing and analyzing teacher learning and teacher change during the seamless learning project. Our results showed teacher knowledge, belief, and practice change was facilitated and constrained by the school environment [5]. For example, Jean preferred to drill and asked her students to do worksheets because it was the school's routine for the non-experimental classes. She felt more pressure to deliver good grade because her class was a high achieving class. We have also found that the changes in knowledge, beliefs, and practices in teachers were not of the same pace and synchronized but affected by each other. There had been debates about which one to change first: teacher knowledge and beliefs or teacher practices, our findings showed that teacher change needs the interaction between teacher agency and structure. We have also found that the sustainable and scalable teacher change depends on the stable structure change [11]. Teachers should be open to new ideas because there was nothing for granted. For example, Jean changed her assumptions like "students could not learn without being taught". The paper provides empirical data and analytical framework for teacher change in design research context.

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