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# CK, PCK, TPCK, and Non-intellectual Factors in sustaining an iMVT Innovation for Science Learning

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**Abstract**

Teaching science through inquiry has been a "recommended" pedagogy for science to be more "authentic" and effective. However, how to promote sustainable education change such as inquiry-based learning in school has been challenging. The study is situated on a four-year journey in designing, sustaining, and scaling up an iMVT pedagogy in secondary science in Singapore. Our collaborating science teachers increased from 9 (Phase I, 2007-2008) to 29 (Phase II, 2009-2010). Based on preliminary analysis of surveys, interviews, and classroom observation data of selected cases, we summarized a four-pillar model of teacher competence within a structure/agency framework for desired education change.


*Keywords:* Content knowledge, PCK, TPCK, Non-intellectual factors, inquiry-based science learning, Structure/Agency

## 1. Introduction

Teaching science through inquiry as well as student-cantered approach has been a "recommended" pedagogy for science (NRC, 1996). In Singapore, educational technology has also been highly encouraged to be an integral part of student learning experience to make student learning to be more "authentic" and effective. However, little research has been published about how to capitalize on the policy initiatives to promote desired sustainable education change (Teaching science as inquiry and using ICT in this case) in school. The study is situated on a four-year journey (Phase I, 2007-2008; Phase II, 2009-2010) in designing, sustaining, and scaling up an iMVT (Modelling and Visualization Technology integrated inquiry-based science learning) pedagogy in science (Zhang, Ye, Foong, & Chia, 2010) to fill in the gap; specifically, this paper presents our efforts in exploring the interplay between four-pillars (CK(Content knowledge), PCK (pedagogical content knowledge), TPCK (Technological pedagogical content knowledge, and NIF (non-intellectual factors)) of teacher competence in ensuring the sustainability of the iMVT pedagogy. We intend to provide answers to the following questions: a. What is the desired teacher competence in involving sustainable education change? b. How do teacher CK, PCK, TPCK, and NIF evolve and interplay to ensure sustainability? and c. What does it look like when developing and sustaining an iMVT innovation?

Given the limited space, this paper only provides an overview of our efforts towards the answers to

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the questions above without going to the details. The paper contributes to the literature by presenting our efforts in designing, defining and refining an innovation of iMVT and some initial findings of our current analysis following a design research tradition.

## 2. Theoretical underpinning

In this section we briefly review the literature related to the focus of our study in relation to an innovation for science learning called iMVT; we especially focus on exploring the evolvement and interplay of teachers' PK, PCK, TPCK, and NIF in ensuring the sustainability of iMVT. This is situated in a broader structure/agency framework (Chia, Zhang, & Ye, 2010). We hold the belief that the competence (the four pillars or components) mentioned above influence instructional quality and consequently affect students' learning gains (Baumert et al., 2010). Teacher perception of the worth of the innovation would affect their knowledge belief change, agency that leads to further education change in schools.

### *2.1. Structure/Agency framework*

Introducing innovation and new methods involves a variety of issues and stages (Davis, 2003; Rogers & Olaguera, 2003) and the importance of involving teachers in curriculum innovation has long been recognized (MacDonald & Rudduck, 1971; McIntyre & Brown, 1979). Teachers tend to shape and infuse their own beliefs into the implemented curricula. They might operate their classrooms according to their own particular definitions of teaching and learning (Yero, 2002). 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 (Darling-Hammond & Bransford, 2005). Therefore, teachers have their agency to make or break reform efforts. Vora & Barton (2006) defined *agency* as individual or group effort to influence the surroundings in purposeful ways. The aim is to create, impact, and/or transform themselves and/or the conditions of their lives. Agency is usually coupled with structure in cultural sociology because agency is shaped by structure.

*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 (Sewell, 1992), 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 (Giddens, 1976). We in fact held the same understanding for the structure as both enablers and constrainer. In Figure 1, the thickness of a column indicates the deciding power of a pillar to teacher change or education change. The one direction arrow indicates the sequence of one competence to decide another competence. However, how an individual teacher's competence has led to his/her agency has not been analyzed, which is the focus of this paper.

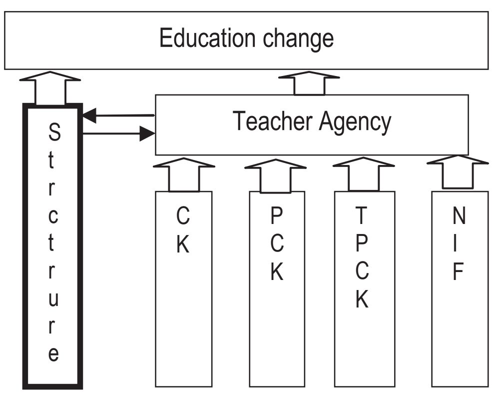

Figure 1. A Structure/Agency Model for Education Change

## 2.2. *Teacher competence*

We refer to *teacher competence* as the characteristics make teachers qualified for their work. It is the knowledge, abilities, and beliefs a teacher possesses and brings to the teaching situation (Medley, 1982). This goes beyond what a teacher knows to teacher's quality in teaching. The four-pillar model of teacher competence is based on the needs for teachers to be able to design and enact our ICT integrated iMVT innovation. Our process and outcomes data of teachers and students are applicable to the analysis of such a framework, which to some extent emerged from our preliminary analysis and literature review.

### *2.2.1. Content knowledge (CK)*

Teacher CK influences how teachers engage students in learning subject matter. For example, teachers with deeper content knowledge in science are more likely to pose questions that are appropriate to student achievement levels, suggest alternative explanations, and propose additional inquiries. Teacher content knowledge influences how teachers evaluate and use instructional materials. When planning lessons on familiar content, teachers are more likely to build a coherent storyline by presenting concepts in a logical sequence. Although little research has been done, teacher CK is probably linked to what students learn eventually (Roehrig & Luft, 2004; Sanders, Borko, & Lockard, 1993).

### *2.2.2. Pedagogical content knowledge (PCK)*

Besides CK, Shulman coined the term PCK to refer to knowledge about how to teach subject matter to students (Shulman, 1986). According Abell, researchers have captured four major characteristics of PCK: a. It includes constituent parts and more experienced teachers tend to employ the components of PCK in an integrated fashion as they plan and carry out instruction; b. PCK is dynamic and can develop over time; c. science subject matter is central to PCK, that is, PCK can be topic specific; and d. PCK is not a free-standing type of knowledge; it involves the transformation of other types of knowledge such as subject matter knowledge, pedagogical knowledge, and knowledge of context (Abell, 2008). PCK is partly developed through action. Therefore, a teacher's PCK can be evolving in nature and it affects and is affected by other types of knowledge.

### *2.2.3. Technological PCK (TPCK)*

Technological Pedagogical Content Knowledge (TPCK) reflects some of the essential qualities of knowledge required by teachers for technology integration in their teaching. At the heart of the TPCK framework, is the complex interplay of three primary forms of knowledge: Content (CK), Pedagogy (PK), and Technology (TK) (Mishra & Koehler, 2006).

### *2.2.4. Technological PCK (TPCK)*

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### *2.2.5. Non-intellectual factors (NIF)*

Human beings are social and emotional. We had realized that the way teachers interacted with us may not be stable and consistent; we often had difficulties to reach teachers. Our observation indicated that some non-intellectual factors have big impact on our collaboration with the teachers. I adopted a framework based on a study on middle school students (Luo, Yang, & Shen, 2008) and another study on college students (Larose, Robertson, Roy, & Legault, 1998) with measurement on student non-intellectual factors. There seems to be little literature on this aspect for teachers, but in higher education, non-intellectual factors have been identified to be as important as intellectual factors and they can predict college student retention and achievements (Larose, Robertson, Roy, & Legault, 1998). There also did not seem to have consensus on what accounts for the non-intellectual factors. According to our observation and data, I have included three non-intellectual factors of the teachers:

- Motivation: e.g. why did they decide to join the project, and what do they expect out of our collaboration?
- Anxiety: this was observable from face to face interaction, emails, phone calls and even the instant messages sent from a teacher's hand phone.
- Attitudes: again, this was observable from our observation and interaction with the teachers.

I did not put self-confidence here because it is very judgmental and difficult to measure. It also can be sensitive to mention and be "threatening" to a teacher's self-esteem. We also talked to a teacher's colleague to confirm our observation. Subsequently, motivation, anxiety, attitudes and other administrative, social, and cultural constrains might have affected teachers' work devotion; this is, how committed they were and how they set priorities. It should be noted that teachers' work devotion to our collaboration changed when the non-intellectual factors and other factors changed.

### 2.3. Methods

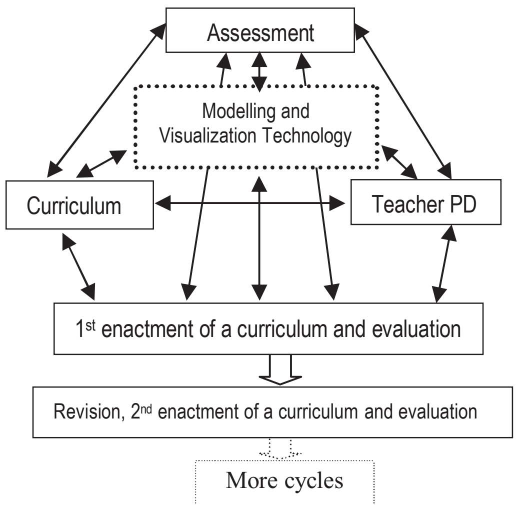


Figure 2. Major design consideration and cycles

For such a school-based research project for sustainable education change, we had to take a holistic and systematic approach. We followed a design research tradition (Brown, 1992; Collective, 2003) when developing our innovation. The iMVT pedagogy in science integrates modeling and visualization technology in inquiry-based learning. There are specific curriculum features to reflect such an integral learning approach (Zhang, et al., 2010). The iMVT pedagogy was developed according to subject characteristics of science and therefore more content relevant to curriculum materials, assessment, and PD models and improve our design over time.

#### 2.3.1. Context and participants

Four representative schools are participated the phase II project. Two of them were the phase I schools. The collaborating teachers increased from 9 (in chemistry, biology, or physics) to 29. They were mostly assigned by school principals. Five teachers from Phase I remained and because our mentor teachers during phase II studies. In this paper, three science teachers from different collaborating schools were chosen to illustrate the interplay. Researcher interacted with teachers intensively through multiple approaches.

### *2.3.2. Data and analysis*

We audio taped and/or videotaped our teacher-researcher meetings when we were co-designing iMVT integrated curricula. Field notes and videos were collected from the 9 experimental and 2 control classes when 6 curriculum units were enacted. Teacher pre- and post-surveys and interview audios were recorded. Emails and even hand phone messages between researchers and teachers were also collected. Our analysis in this paper was mainly the data from the surveys and interviews, which included teacher brief bio, understanding of student learning difficulties of specific topics, iMVT pedagogy, and their ideas about how to design, sustain, and scale up our innovation. Other data were crosschecked with necessary.

## *2.4. The interplay between CK, PCK, TPCK, and NIF*

I have provided brief descriptions of three cases in terms of school type, subject, reasons for the ranking of the four components of a teacher's competence and the interplay between the four components in Table 2. Below I will provide some more data to elaborate the interplay of the four components and how the interplay is related to teacher agency and eventually affect the sustainability of the iMVT innovation in a school. Case 1, Mr. T. was a mentor teacher from phase I. He has been instrumental to our success of phase I in school M. He has contributed tremendous to our biology curriculum development during phase I and demonstrated excellent CK and PCK by after we showed and he tried the recommended iMVT software. He became anxious and made his motivation more explicit when the school faced manpower constrains and his batch of students had poorer performance in tests in an email in Mar. 2010 during phase II. "…I am not interested to do things that have no direct impact to my students' learning. Presenting in conferences is not in my mind… (Email excerpt, Sept. 17, 2010)." He became less collaborative and positive when school situation changed. Case 2, Mr. L. was assigned to work with us. Our observation showed that his students did not pay much attention to his teaching because of low respect. Students told researchers that they could not understand the teacher when we conducted the post-survey in late October, 2011. His principal at a later meeting told researchers that Mr. L. had strong CK but seemed to lack PCK. Our later observation and interaction also revealed his low TPCK. Our project has a total of 19 experimental classes and Mr. L.'s class was the only one that our intervention did not make significant improvement in student learning measured by pre-post tests over the last four years. Mr. Lai had good work devotion to our co-design of curriculum although he had to spend many extra hours on top of his regular workload. Case 3, Ms. D. was also assigned by the school to collaborate with us. However, she was quite motivated to collaborate with us because "…students rarely have opportunities to use chemistry lab and computers (Post Survey, Oct. 2010). She was encouraged to see "my students were enthusiastic when they were introduced to the iMVT tools" (Post Survey, Oct. 2010).

For the sustaining and scaling decisions, we looked at both individual and school level reasons. Three of them all had very positive responses to our collaboration. However, Mr. T. decided not to continue our collaboration after phase I and II because the school HoD science resigned and the new principal faced manpower shortage that also affected Mr. T. workload, thus, the school also could not continue our collaboration. Mr. L. could continue our collaboration but the school will have a new principal and it is unknown about the continuation of the project until new principal took power. The new principal and remaining VP of School C. both supported the continuation of our collaboration, but teacher D. could not participate the next phase of study because of her new teaching assignment. We can see that teacher agency has to work within the affordances of the structure in a school.

Table 2. CK, PCK, TPCK, NIF, and their interplay

(The four levels, Excellent, Good, Average, and Weak, are relative judgment using a sample of 29 teachers of MVT II)

| Case/Subject | CK | PCK | TPCK | NIF | Interplay to Affect Teacher Agency |
|---|---|---|---|---|---|
| Mr. T.<br>Sch. M (Bio.)<br>Catholic school;<br>Students were above the average | Excellent | Good | Weak | Average | His results were good; Weak TPCK prohibited him to apply best pedagogy; he has demonstrated excellent agency in moving our collaboration forward when he had more time in MVT. His agency changed dramatically when the school administration changed and he had less time. Did not want to continue (priority changed) |
| | (30 Years of teaching in his first and the only school; Former HoD science; Bio. subject coordinator; School's time tabling person; Great passion in teaching; Became anxious when students did not do well in biology tests; Could develop negative attitudes towards people) | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Mr. L<br>Sch. G<br>(Physics)<br>Neighborhood School | Good | Weak | Weak | Average | His results were not good. His weak PCK and TPCK made his teaching difficult to understand. He had little influence other colleagues because of low respect from his students and colleagues. No issue to continue if the school wanted to collaborate with us. |
| | (Taught for 26 years; Changed several schools; His principal gave him high remarks on CK; Students said they did not understand his teaching; Great passion in teaching; Patient and collaborative; Did not show negative attitudes even when discussing student complaints ) | | | | |
| Ms. D.<br>Sch. C,<br>(Chem.)<br>Neighborhood School | Average | Weak | Average | Excellent | Her results were good; excellent NIF compensated her weakness in PCK. She has demonstrated her great agency in providing positive feedback to the HoD science and school administration. She has been assigned to biology teaching and cannot continue for the new work demand. |
| | (Bachelor degree in Chem.; Started teaching in 2008; Taught Sec. 3 pure and combined chemistry in 2010; 1st school to teach; Strong motivation to collaborate; Work well with colleagues; always positive) | | | | |

## 3. Discussion and implications

Based on preliminary analysis of our surveys, interviews, classroom observation and other data of selected cases, we summarized a four-pillar (CK, PCK, TPCK, and NIF) model of teacher competence that is needed for desired teacher change and education change. We could see that the different components of teacher competence could cancel or complement each other. We conclude that teacher competence is not the only but the most important deciding factor for their accepting, sustaining, and scaling up an education innovation. Our next step is to analyze how teacher agency is enhanced and/or constrained by the affordances of school structure. This study enriched our understanding of how the Structure/Agency framework can inform design for education change (Chia, et al., 2010). (*The author thanks Xiaoxuan Ye and Daner Sun for their comments and feedback)

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