Teacher Epistemic Learning in the Innovation Diffusion

Longkai Wu and David Hung
longkai.wu@nie.edu.sg, david.hung@nie.edu.sg
National Institute of Education, Nanyang Technological University, Singapore

Abstract: In this paper, a teacher epistemic learning model for implementation is proposed with the aim to prepare seeded teachers in reflection-for-action and to build their capacities in designing and enacting the curriculum on their own virtue. Fundamentally, epistemic learning is proposed because changing classroom practices is more than a surface or shallow change phenomena, but requires teachers to fundamentally shift in perspective or way of seeing how learning is to be practiced. We describe this epistemic learning model and explore its effectiveness. Various types of data were collected, including surveys, interviews, field notes, and teachers' lesson design artifacts. It is found that the seeded teachers from the five schools, regardless of their own teaching profiles and school contexts, have obtained high degrees of buy-in of the innovation and developed their readiness towards implementation for the future enactments. It is envisioned that such an epistemic learning model will inform the design for teacher professional development, in the pursuit of innovation diffusion, serving a wider community of the teaching practice.

Introduction

Teachers play an important role in the process of diffusion of any curricular innovation (Urhahne, Schanze, Bell, Mansfield, & Holmes, 2010). How teachers perceive the innovation at hand and build their capacity to implement the particular curriculum will determine the success of the innovation to a large extent. At the same time, the characteristics of teachers, together with the characteristics of the innovation and features of environmental context, account for the outcome of diffusion of an innovation (Rogers, 2003). In fact, teachers benefited more when they participated in professional learning in a collaborative form (Cloonan, 2009; Kopcha, 2012) and their school contexts and needs had to be considered (Stein, Smith, & Silver, 1999). In many of the literature, teachers' learning community and network building were highlighted (Scribner, Cockrell, Cockrell, & Valentine, 1999; Sun, Penuel, Frank, Gallagher, & Youngs, 2013). In the context of diffusion of innovation, Dearing, Greene, Stewart, & Williams (2011) proposed the idea of an "implementation registry" in the domain of healthcare, which is an online resource for practitioners within or across different institutions for sharing knowledge about solutions to challenges during dissemination, diffusion and implementation of an innovation. It is more than a normal registry in that it links whether an innovation works with why and how it works. It "fosters innovation and implementation success" by building informal, virtual communities of practice (vCoPs) across institutions. How-to knowledge was identified and captured in vCoPs for practitioners from different working sites to obtain understanding about the innovation so as to decide whether to take up the innovation to address their own challenges and what adaption should be done for their own context.

In our endeavor to achieve the diffusion of a curricular innovation from one seeding school to five more seeded schools, we have investigated the learning of a group of seeded teachers through an across-schools collaborative seeding journey, so as to develop their buy-in and readiness for implementation in their own respective schools. Roger (2003) described this process as an innovation-decision process, which involves five steps: (1) knowledge, (2) persuasion, (3) decision, (4) implementation, and (5) confirmation. The adoption of an innovation is determined by the interplay of factors from multiple levels of the school system such as macro-level ones like the national educational policies and socio-cultural factors of the school's learning ecology, meso-level ones like school-researcher partnerships, and micro-level ones like classroom-based work and interactions (Looi, 2011). In these different steps of the innovation-decision process, teachers would have different experiences and evolve their own understanding of the innovation.

In this paper, we first introduce the background of the innovation diffusion, and then propose a model of teacher's epistemic learning where different types of activities are designed for seeding teachers' comprehensive understanding of the innovation. Different parties, including the school administrators, the early adopter teachers (EATs), school administrators and the seeded teachers (STs) from the five schools, and researchers, were engaged in the learning journey. By examining the learning process and teachers' perception of the innovation, we want to explore the effectiveness of such a model, and hence contribute to the literature about the mechanism of teacher learning in the innovation-decision process, especially in the phases before and after decision of trying out the innovation is made.

Model of teacher epistemic learning

Building on the lessons learned from prior technology-based educational improvement research, we clearly recognize the importance of empowering teachers and building capacity to effect deeper changes in teachers' beliefs, knowledge, and practices (Fishman, 2005). Hence, we propose the model of teacher's epistemic learning in the stages of diffusion of innovation, as shown in Figure 1.

There are several design principles we put forward for the professional development sessions: 1) Sharing of the EATs to the STs from other schools should be participatory; 2) STs will also have a chance to have an lived in or embodied experience of what it means to teach such lessons; 3) STs have the flexibility to personalize the curricular innovation considering the local needs of their own schools; 4) EATs also benefit from a reflective practitioner stance of re-looking and adapting their own innovation and innovation approaches through their active participation and sharing with STs; 5) Communities of practice for EATs, STs and non-seeded teachers to share experiences, challenges, tips and constraints of how to enact a classroom innovation (with researchers as meso-level catalysts but to eventually fade away).

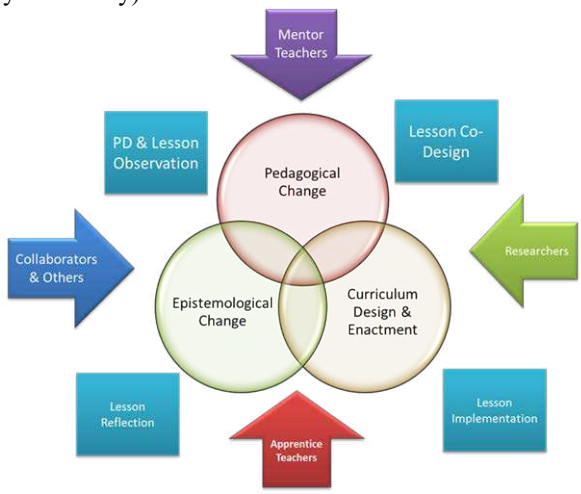

Figure 1. Model of Teacher's Epistemic Learning in Innovation Diffusion.

Based on the design principles, a model is proposed as shown in Figure 1. It consists of four types of activities, and involves different levels of learning agents. 1) In the first activity which we call "infusion", or the kick-off meeting, different parties in the scaling-up project, including all the teachers and school administrators from the seeding schools, as well as the MOE officers, gather for initial understanding of the innovation about "what it is" and "does it work" from perspectives of both researchers and pioneer practitioners. In the meeting, the effectiveness of MSL on students learning was presented to teachers, especially students' improvement on semester assessments in answering multiple choice questions (MCQ), open-ended (OE) questions and the total scores. The objective of the project was made clear to all the parties, as well as the responsibility and key performance indicators. 2) In the "lesson observation" activity, the STs have opportunities to have embodied experiences of the real classroom. The school administrators from each school also observed a few lessons to have a sense of what their own students might be experiencing. 3) The lesson co-design forms a teacher professional learning community where the EAT and STs exchanging ideas on lesson designs for the innovative curriculum, as well as other issues regarding innovation diffusion.

Context and participants

The innovation to be spread in this study is mobile seamless learning (MSL in short) which refers to the synergistic integration of the learning experiences across various dimensions such as formal and informal learning contexts, individual and social learning, and physical world and cyberspace (Chan, Roschelle, Hsi, Kinshuk, Sharples, Brown, et al. 2006).

The five schools were identified by the cluster superintendent based on a few criteria. Some of these criteria are whether there is some basic level of commitment by the school leaders towards using ICT in teaching and learning, how ready are they to embark on such an ICT project, and the support and buy-in by the principals especially whether they will stay in their school long enough to see through the project. The choice of schools is also influenced by the desire to spread the opportunity across a diversity of schools in the cluster. The teachers involved in this project were chosen by the principals.

Twelve STs from the five seeding schools were involved. Nine out of twelve teachers have relatively low level experiences in teaching (equal to or less than six years). Most of them thought that they currently taught in a teacher-centred way, which is about focusing more on knowledge delivery and students passively receiving knowledge, whereas four teachers thought they taught in a somewhat student-centered way by incorporating inquiry-based activities in their teaching.

Findings

Pedagogical change

From the lesson observations, the STs were impressed with the learning culture in the classroom: students were doing inquiries, they were not afraid to ask questions, tended to find evidence to support their scientific claims, explained well to the teacher and their peers about what they were thinking, and collaborated somewhat orderly with good division of labor. As Wilson expressed in the interview, he was very impressed that the students behaved naturally like scientists, which could not be trained and achieved in the traditional way of teaching:

> The way I see Jane's student answers (the questions that Jane asked in the classroom) right, it's very encouraging because that is how a scientist, a researcher, a person who is into doing science (answers). That's how you ask questions and how you answer questions. And that's how she does with her class. She expects them to be (a) mini-scientist.

STs also saw that students were also very skillful at using the mobile devices for learning, whether individually or collaboratively, as Kabir said:

> I think the kids (are) very comfortable using the devices, and they are able to do the collaboration. I think we all saw it in Socrative and all that (activities), (that) they are able to collaborate, answer Jane's questions and then move on from there. So I think that's very important value I see for the 21st century, communications, confidence, and all these things are embedded to do this (MSL).

Thus, from the lesson observation, the STs were able to see that the benefits of MSL not only included the exam performance, but also promoting a cultural change for learning in which students were doing self-directed learning.

The STs had opportunities to see how the teaching in MSL would be different from their current practices. The lesson observation provided STs a chance to see lessons from a different perspective. As Jane reflected from her point of view, when teachers teach in the class most of the time they are actually "blinded by the things that they have to accomplish", but when as an observer, they get "brighter eyes on what is happening in the classroom". As Jane said, some STs did reflect the things they might not be so conscious about when teaching, such as the questioning. In the lesson observation, Rohana paid special attention to the questions asked by Jane in classroom and summarized her questioning styles:

> I think Jane plays a very important role, in the types of questions she asked her pupils. When I stepped into her lessons, I can see that her questions are scaffolds. Er, she started from very simple questions, and she is very dynamic. She will respond accordingly to students' responses. So if pupils are able to show higher-order thinking, she will streamline the questions to ask more complex kind of questions to trigger their learning

When Jane reflected about the elements that led to students' formation of the spirit of inquiry, she talked about the importance of the questions and students' perception change in answering the questions. In Jane's class, she made it a point to let the students know that they could not find the so-called right answers in the textbook, and there were usually more than one answer to a question. She stressed that science is about interpretations and finding evidence to support one's interpretations or predictions. Jane held this belief and she walked the talk in her teaching. Consequently, the STs observed that from the lesson observations, Wilson alluded to one difference in his teaching practices comparing his teaching and Jane's:

> In our class it's very much (about) what they (the students) observe, (what I do in my classroom is) that I get them to observe and to find out and then give them a right or wrong answer. You know. Whereas in Jane's class you see the children really go in depth into each and every animal. Each and every particular group of animals, they go in depth into looking at it. When

> talking about fur, (the students in Jane's class really did research to see) what is fur and what is hair you know. (They) Talk about giving births to young alive, what is the opposite or how other ways do animals give birth or reproduce and further on and further on. That is something that I seldom do in my class.

As we can see from Wilson's example, he began to reflect the difference between his teaching and Jane's, which affects the depth of knowledge gained by students. In Jane's MSL lessons, students were encouraged to research in depth and they were supported in doing so. In this type of learning, teachers played an even more important role by asking appropriate questions to guide students' inquiry than by directly telling them the answer.

Besides learning from Jane about the questioning techniques, STs also reflected that they learnt about the skills of providing guidance to students in this type of classroom teaching, such as how to guide students to get useful information from the vast information online, and "how to gear students towards the position of a scientist" (from Amber).

The impact of the lesson observation on the STs was also reflected by STs' follow-up practices. Rohana already had more than ten years' teaching experiences, but she tried to change her teaching practices after she observed Jane's lessons. Thereafter when she taught back in her own school, she started by asking questions in a different way, and she gave one example of her change:

> For (the topic of) digestion, usually for P3 science, for this kinds of pupils I have not actively using questioning techniques like (those) employed by Jane, usually I will ask what are the different parts of the digestive system. Now I ask something like how could the digestion in stomach help in supplying energy, if I remember correctly. After that I bring in something like how the circulatory system, and the respiratory system also play a part in digestion for example. So more questions drawing linkages or inter-topical linkages, because the theme is about systems, so I try to make as much connections with other different types of system so that it make more sense, and it's more meaningful for them to learn other types of system.

Thus Rohana became more self-conscious about what questions to ask and began to try it out for her students, such as questions that drawing linkages between different topics to make learning more meaningful. She admitted before the lesson observation she was inclined more towards lecture-type teaching so that her students were not so responsive when she changed to ask more questions, but after a few more weeks, students were used to it and became more active in answering and responding.

Curriculum design and enactment

Teachers co-designed the theme of "Diversity" in the nine sessions. For each chapter within the theme, teachers went through the process as described in Figure 2. As not all schools has the same scope and sequence of content, the teachers first standardized the scope, sequence and learning objectives for every topic. The standardization helps the community to implement the curricular in a similar pace so that they can have more meaningful sharing and reflection in the future. The teachers, then, decided the total period for each chapter and discussed students' common learning difficulties and misconceptions from their teaching experiences. One chapter often surrounds one focusing topic (i.e. living and non-living things, plants, animals, fungi and bacteria, materials) and the 5E model (Engage-Explore-Explain-Elaborate-Evaluate) was used by the community to design a learning cycle for one chapter. Some of the schools have already used 5E as lesson design framework, so adopting the 5E model was not difficult for them. The teachers all contributed ideas and the resources they have used for the activity, and appropriated those activities to fit in different stages. After going through all the five stages within 5E, the teachers volunteered to take up one or more lessons to detail down the lesson plan. Jane provided a template for teachers to elaborate the lessons, which comprised three columns: class activity, complementing home activities, and MLE (mobile learning environment) activities. In "class activity", the teachers described teacher's and students' activities respectively, while in "complementing home activities" teachers designed activities that students could do out of classroom with aids of the mobile devices before or after the lesson, and in "MLE activities" teachers specified the application they planned to use, the purpose and the objectives of using it. The last two focuses encouraged the teachers to integrate the characteristics of mobile learning, which is leveraging the mobile devices for students' learning and linking formal and informal learning. Besides, Jane also suggested teachers to consider about differentiated instruction while designing to cater to all students with different competency and needs.

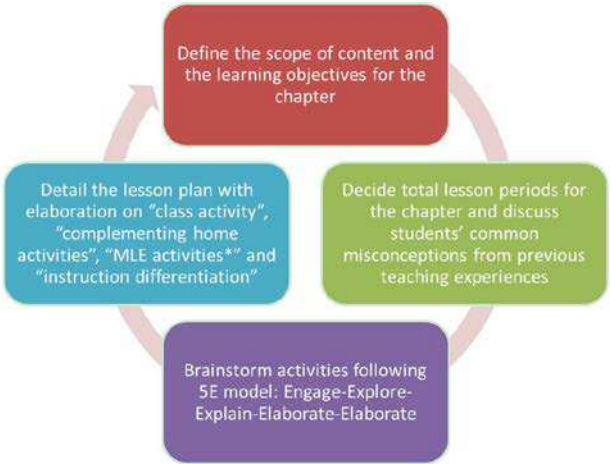

Figure 2. Lesson Co-Design Process Experienced by the Teachers' Community.

In the co-design sessions, teachers not only discussed teaching, but also their understanding of the concepts. Some STs commented that through discussion in the lesson co-design, they gained clarification of certain science concepts, and hence improved their content knowledge. The diversity of the school context also provided teachers with more ideas to integrate the innovation and improve their lesson design. Anna mentioned that the community of the five school teachers was different from their own school teachers learning community, and the knowledge gained regarding designing learning journeys was valuable to her:

> In our school, we know what we are doing, but we don't know about other schools. Let's say for teaching the same subject, (we don't know) how they (other schools) extend it, (and) where are the learning journeys that they bring their pupils to. For example, when we talk about animals, we mentioned we went for farm-hopping to the various farms, and I think some of other schools say 'oh, okay, we go to the mushroom farms', and there are some schools saying instead of farm hopping they went to zoo. So these are the things we learn from one another. And they even share, you know, when they teach certain topics what the major misconceptions are. What are the things that pupils are always not familiar with? Because every school's cohort is different, we get this type of knowledge, which is very valuable.

In the community, Jane was the only person that had years of experiences collaborating with researchers designing and implementing the mobilized curriculum, hence she is the best person to share the design experiences with the STs because of the "practitioners' sympathy", that is, as teachers, they share similar considerations and concerns. In the lesson observation, the STs observed her exemplar practices, but in the co-design session she also shared with the STs about her own challenges and failures and the observation of her mentees in the leading school. She always cheered the STs up and hoped them to hold a positive attitude toward technology integration, and at the same time advised the STs to be patient since change is difficult and takes time. The co-design benefited not only the STs, but also Jane. She reflected that when designed the lessons with the five school teachers, she applied a more "macro-view", which was different from the "micro-view" way in her own school. In her own school's lesson design, it is "activity per se" in which teachers discuss in detail about every activity, whereas with the STs, it is "learning objective per se" in that she only defined the main learning objectives for specific topics and sequences of topics to maintain the possibility for sharing in next year . She described the way that the STs and she co-designed the lessons for Material:

> For example when we were talking about (the topic) material, then the teachers said 'why not we have activities like telling a story about Cinderella. So (it's) about the shoes of Cinderella… we can talk about material use to make that glass slippers and why Cinderella have that glass slippers.. Then you look at technology (about) how I can actually tell the story? Do I have to bring a physical book? If the teachers don't tell the story then someone said 'how about looking for one online virtual story or from Youtube and get the students to watch at home?' You know like a flipped classroom then that part will come in at the later stage… I think generally that the teachers are quite ok in suggesting this kind of activity. So they actually give even other suggestions like using other technology which they think can better help the students. Yeah, so

> I thought for the seamless part of the activity, we are really looking more on how technology can support that instructional objectives… so generally it's quite automatic in them. I don't really need to tell them that "ay, you need to have this," and "ay, can it be done without technology?"

It can be seen that Jane took different approaches to preparing the teachers, which was leaving decision of activity details, resources and application to the STs so as to shift the ownership of curriculum design to them step by step. Jane also reflected that the dynamics between her and the STs were different from her and her school teachers. When communicating with the STs, she avoided to telling them what to do but suggesting them to try out something since the context was very different.

Epistemological change

STs described their perception of the core elements of the innovation. We count the frequencies of the key words shown in STs' responses, and the following words were used to describe the innovation with frequencies shown within the round brackets: inherent or intensive use of technology (8), student-centered and teacher as facilitator (4), self-directed (4), beyond classroom, or in and out of classroom (4), life-long learning (1), 21st century skills (1), and enhance students' interests in science learning (1). Thus when teachers were first introduced to the MSL, they seemed to be more impressed by the inherent use of technology in learning, which was absent in their own schools. They also saw the learning happening not only in the classroom, but also enabled by the mobile devices to happen beyond the classroom. Teachers saw the self-directedness in MSL because it encouraged students to ask questions and to initiate their own learning.

In the interview, teachers' ideas were further clarified. Most of the STs especially acknowledged the "seamless" element in the package and viewed it as a linkage between formal learning and informal learning. Wilson stated in the interview that the unique part of MSL was that the mobile devices served as a means to make learning a really 24/7 thing:

> I think (the unique part of MSL) is that the students who are embarking on this programme have a means to an end. They have the means to do (inquiry), (and) they have been given a means to explore, research and to be able to do their research easily, how to say, validated, by their teachers, (and) by their peers. Using the mobile device, and like what the programme's name suggest, it is really seamless because they don't just do it in school. They do it at home, (and) they do it on the way home. You know, they can do it anywhere they wish to. So that's where I see the difference (between MSL and learning in my school), because right now here in school (the situation) is I (only) have 3 periods to teach. And after that they have other subjects to do and after they go home I also don't know what (they do at home). I mean I give them homework, but whether or not they revise and do, that's at home, (and) I am unable to access. But with MSL, because they have their mobile device, (so) whatever that they uploaded from home I also know. I mean I can tell that they are doing something at home.

Winston appreciated one uniqueness of the MSL in that the teacher could evaluate and monitor students' learning progress even they might be doing it at home. Other teachers also mentioned the value of MSL lies in students' easy access to vast information online. With the mobile devices, students can search information on the site. But that was not the case in other school. As Joanna mentioned, she once provided assignments asking students to search for information when at home, but some of her students were forbidden to use computer by their parents during week days.

STs also mentioned "self-directed learning" a lot, which is advocated by MOE as one of the desired student outcomes in 21st competencies. Anna gave an example of what she envisioned for her students, and elaborated her understanding of self-directed learning:

> I mean you see it's like, we can give them a topic, and off we go, whether at home, along the road, even when they are in canteen with their friends, they may discover certain things, and then there they post. We can have the discussion forum. They may even notice something during holidays, even post and we have discussion. So that's what we mean by self-directed learning. It's no longer always teachers asking you must do this you must learn this, maybe the child can even post pictures of a creature that looks like an insect but doesn't have the full characteristics of the insect, but we can all discuss this. And teachers (perform) as facilitators. Of course trying to guide them to the right direction if they are too off-track, and maybe at the same time to facilitate the quality of discussion.

So STs see the potential of MSL as a means for students to become self-directed learners. They can spot problems, ask questions and initiate their research, which changes learning from passive receiving to constructing knowledge. Teachers recognize their role as facilitators, which might be quite a shift for them since most of them have been teaching in a teacher-centred way.

Despite of the affordances provided by the technology, teachers recognized that they key factor that leads to the success of the innovation is the teaching of the teacher, as expressed by Kabir:

> It is how you use it to teach, I think that's the key factor. It's not just using technology for its own sake, it's that how we use it in a way that students are engaged and learn further, and learning is enhanced. So the way how teachers use it to enhance the learning is most important. Of course we have other things, but this is the most important one.

Discussion and conclusion

In this paper, we situated our study in a diffusion of MSL from one school to five more schools and proposed a model of teacher's epistemic learning to get their buy-in and prepare them for the future implementation. In the findings, we articulated how each activity in the model helped the STs to evolve their gradual understanding of MSL and what knowledge they have gained through interactions with teachers and school leaders from the leading school, and researchers. It was found that the learning experiences presented and hence convinced teachers of the advantages of the curricular innovation to teachers and students, as well as feasibility of implementation in their own school, which led to the STs high degree of buy-in of the innovation.

Research showed that teachers' perceptions of the five attributes of an innovation were critical for their adoption decision making and implementation. Through the embodied learning experiences, teachers were able to see many facets of the innovation and built their own understanding of the characteristics of the innovation. (Dearing, 2009) suggested an "exemplary demonstration" in a convincing manner to influence adoption decisions and thus increase the likelihood of diffusion, and in our study the infusion and lesson observation served the purpose of demonstration and enabled teachers to *observe* the *relative advantages* of MSL, specifically, students' significant improvement in answering open-ended questions and their engagement, enthusiasm, and scientist-like mind of thinking in the classroom. The curriculum design activity rendered them a sense of ownership of the innovation and let them see the *compatibility*; the understanding of the innovation highlight more on the pedagogy rather than the use of applications, as well as assurance of systemic supports got from Q & A sessions convinced them of the *simplicity* of the innovation. The curriculum package, which was a collective product of the community, make the innovation more *triable* at the first stages of implementation. The three types of knowledge described by Roger were also provided for the teachers through those learning experiences, such as how-to knowledge in the lesson observation in terms of how to ask scaffolding questions, how to manage a MSL classroom, and how to guide students to think and talk like scientists. It is also provided through the lesson co-design on how to design the MSL curriculum, and on how to integrate the package into individual school's existing package.

Compared with other teacher professional development programmes, our model not only emphasizes teacher's professional learning, but also provides infrastructure support through creating opportunities of communications between school leaders and teachers within and across schools. Teachers need to deal with multiple issues when implementing, but our learning model had endeavored to establish the systemic supports (from school leaders to the IT technicians and teaching assistants etc) for teachers to alleviate them from administrative matters and to enable them to focus on improving curriculum and instruction. Being different from other teacher PDs in the form of innovators/researchers-to-practitioners interaction, our model highlights the interactions between practitioners to practitioners-to-be. Teachers share similar considerations and concerns when adopting an innovation, so the advice and tips from peers would be more pragmatic and targeted. The learning within the community of practices benefited teachers in the preparation as we showed in the lesson co-design sessions, and will impact the future implementation and even dissemination within each individual school. The model we proposed here not only applies to the diffusion of educational innovation as in our case, but also to the diffusion of innovation in other domains. Thus, to prepare for adopting a potential innovation, the learning cycle should incorporate the following core elements: *effectiveness demonstration, embodied and epistemic learning journey*, *shift of ownership*, *learning community building,* and *systemic support provided*.

References

Dearing, J. W. (2009). Applying Diffusion of Innovation Theory to Intervention Development. *Research on Social Work Practice, 19*(5), 503-518.

Fishman, B. (2005). Adapting innovations to particular contexts of use: A collaborative framework. In C. Dede, J. Honan & L. Peters (Eds.), *Scaling up success: Lessons learned from technology-based educational innovation* (pp. 48-66). New York: Jossey-Bass.

Freeman, M. (2012). To adopt or not to adopt innovation: A case study of team-based learning. *International Journal of Management Education (Oxford Brookes University), 10*(3), 155-168. doi: 10.1016/j.ijme.2012.06.002

Fullan, M. (2001). *The new meaning of educational change*. London: RoutledgeFalmer.

Jephcote, M., & Davies, B. (2004). Recontextualizing Discourse: exploring the meso-level. *Journal of Education Policy, 19*(5), 547-564.

Jones, B. L., & Bjelland, D. (2004). International experiential learning in agriculture. *Proceedings of the 20th Annual Conference, Association for International Agricultural and Extension Education*, 963–964. http://www.aiaee.org/2004/Carousels/jones-carousel-NEW.pdf

Kintsch, W., & Van Dijk, T. A. (1978). Toward a model of text comprehension and production. *Psychological review, 85*(5), 363.

Kopcha, T. J. (2012). Teachers' perceptions of the barriers to technology integration and practices with technology under situated professional development. *Computers & Education, 59*(4), 1109-1121.

Lavonen, J., Juuti, K., Aksela, M., & Meisalo, V. (2006). A professional development project for improving the use of information and communication technologies in science teaching. *Technology, Pedagogy and Education, 15*(2), 159-174.

Looi, C.-K. (2011). *Sustained Innovation in Classroom Practices: The Role of Educational Researchers as Meso-Level Actors*. Paper presented at the Beijing Forum 2011, Beijing, China.

Looi, C.-K., Zhang, B., Chen, W., Seow, P., Chia, G., Norrist, C., & Soloway, E. (2011). 1:1 mobile inquiry learning experience for primary science students: a study of learning effectiveness. *Journal of Computer Assisted Learning, 27*, 269-287.

Makinster, J. G., Barab, S. A., Harwood, W., & Anderson, H. A. (2006). The Effect of Social Context on the Reflective Practice of Preservice Science Teachers: Incorporating a Web-Supported Community of Teachers. *Journal of Technology and Teacher Education,, 14*(3), 543-579.

Margolis, J., & Doring, A. (2012). The Fundamental Dilemma of Teacher Leader-Facilitated Professional Development: Do as I (Kind of) Say, Not as I (Sort of) Do. *Educational Administration Quarterly, 48*(5), 859-882. doi: 10.1177/0013161x12452563

McNeill, K. L., & Krajcik, J. (2008). Scientific Explanations: Characterizing and Evaluating the Effects of Teachers' Instructional Practices on Student Learning. *Journal of Research in Science Teaching, 45*(1), 53-78.

Ministry of Education, S. (2008). MOE Launches Third Masterplan for ICT in Education. http://www.moe.gov.sg/media/press/2008/08/moe-launches-third-masterplan.php

Montecinos, C., Pino, M., Campos-Martinez, J., Domínguez, R., & Carreño, C. (2013). Master teachers as professional developers: Managing conflicting versions of professionalism. *Educational Management Administration & Leadership*. doi: 10.1177/1741143213502191

Mustafa, J., & Al-Mothana, G. (2013). Using the Diffusion of Innovation Theory to Explain the Degree of English Teachers' Adoption of Interactive Whiteboards in the Modern Systems School in Jordan: A Case Study. *Contemporary Educational Technology, 4*(2), 138-149.

Reiser, B., Tabak, I., Sandoval, W., Smith, B., Steinmuller, F., & Leone, A. (2001). BGuILE: Strategic and conceptual scaffolds for scientific inquiry in biology classrooms. In S. M. Carver & D. Klahr (Eds.), *Cognition and instruction: Twenty-five years of progress* (pp. 263–305). Mahwah, NJ: Lawrence Erlbaum.

Rogers, E. M. (2003). *Diffusion of innovations* (4th ed.). New York: Free Press.

Scribner, J. P., Cockrell, K. S., Cockrell, D. H., & Valentine, J. W. (1999). Creating professional communities in schools through organizational learning: An evaluation of a school improvement process. *Educational Administration Quarterly, 35*(1), 130-160.

Stein, M. K., Smith, M. S., & Silver, E. A. (1999). The development of professional developers: learning to assist teachers in new setting in new ways. *Harvard Educational Review, 69*(3), 237-269.

Sun, M., Penuel, W. R., Frank, K. A., Gallagher, H. A., & Youngs, P. (2013). Shaping Professional Development to Promote the Diffusion of Instructional Expertise Among Teachers. *Educational Evaluation and Policy Analysis, 35*(3), 344-369. doi: 10.3102/0162373713482763

Urhahne, D., Schanze, S., Bell, T., Mansfield, A., & Holmes, J. (2010). Role of the Teacher in Computer-supported Collaborative Inquiry Learning. *International Journal of Science Education, 32*(2), 221-243. doi: 10.1080/09500690802516967