S. L. Wong et al. (Eds.) (2010). Proceedings of the 18th International Conference on Computers in Education. Putrajaya, Malaysia: Asia–Pacific Society for Computers in Education.

A Tripartite Model of Co-designing for an iMVT Integrated Science Curriculum

Xiaoxuan YE, Baohui ZHANG[*] & Pei Chun CHIA
Learning Science Laboratory, National Institute of Education, Singapore
*baohui.zhang@nie.edu.sg

Abstract: Curricula that substantiate innovative pedagogies are crucial for sustaining and scaling up education reform efforts. However, when researcher-designed curricula are enacted by teachers, the results might not be what researchers expected. Both researchers and teachers need to understand national curriculum policies in order to align their selection, design, and enactment of certain curricula. A co-design strategy, thus, is ideal in order to address the challenges. In this paper, first we describe a tripartite model of curriculum co-design process for a secondary chemistry unit through collaboration among a Singapore MOE chemistry curriculum specialist, researchers, and teachers when developing an iMVT integrated curriculum. This was also intended as a means for teacher professional development to build teacher competence in adopting, sustaining, and scaling up our innovation. Secondly, we intend to find out a mechanism behind this tripartite collaboration to theorize a co-design model by analyzing the interactions among the three parties over about six months of time following a design research tradition. The study contributes to the literature by proposing and evaluating a tripartite model for curriculum development and teacher professional development.

Keywords: Co-design, a tripartite model, curriculum development, iMVT innovation, technology, secondary chemistry

Introduction

It is well-known that teachers tend to teach to the text and plan for students learning according to curriculum materials. Therefore, the curricula are crucial in schools for teachers to adopt an education innovation. Researchers in the learning sciences tend to develop curriculum materials that engage students in inquiry, make use of technology, and enhance students' learning experience in a context of design-based research [1]. However, the ideas may not be well understood by school teachers because usually the designers and enactors of a curriculum are different people with different expertise and emphasis [2]. One way to bridge the gap is to involve the teachers in the process of curriculum development to advance their understanding of the innovation [3]. In 2009, Singapore National Institute of Education (NIE) has advocated an 'enhanced partnership model' within the Teacher Education Programme to strengthen the tripartite relationship between the key stakeholders that determine the quality and excellence of teacher education – Ministry of Education (MOE), schools , and NIE [4]. In our project, we make use of this strategic relationship between the three parties to develop a model for co-designing and sustaining our pedagogical innovation called iMVT (Modeling and Visualization Technology integrated inquiry-based learning) [5]. We engage a chemistry curriculum specialist from MOE, the teachers from four collaborating schools, and researchers from NIE with support from international collaborators into a co-design process in order to design and enact iMVT integrated curriculum materials and research. Besides addressing student learning difficulties in chemistry topics, this tripartite model of curriculum co-design is also considered a means to address teacher learning of the innovation. We eventually built a community of practitioners with teachers' participation in order to sustain and scale up the educational innovation. The following research questions guide the research:

- What does the tripartite curriculum co-design process look like?
- How do the interactions among different parties lead to quality curriculum materials?

In this paper, we first briefly state the theoretical underpinning of the iMVT innovation and the co-design process, then provide the context of the study, our data and data analysis. The result section answers our research questions in details. We concluded that this study contributes to the literature by providing a model for building a community of practice in order for teachers' adopting, sustaining, and even scaling up an ICT –based innovation.

1. Theoretical underpinning

Although the inquiry process provides students a more authentic experience during science learning, there are many challenges to the successful design and implementation of inquiry-based curriculum [6]. Adapting scientific models and visualization tools in education has become a hot topic of recent science education research not only with physical models [7] but also computer models. Modeling-based inquiry [8] is a specific pedagogical approach that focuses on computer modeling to investigate phenomena that might be difficult to do without technology. Although learning sciences through the i, M, V, T as described above have not been uncommon, putting them together to form an iMVT framework can be a new paradigm to reshape the science learning pedagogy when using technology. iMVT can be an innovative pedagogy that applies to chemistry, biology, physics, and perhaps other subjects. It is a collaborative inquiry-based pedagogy to address student science learning difficulties [5] and it has.shown to be an effective way to facilitate students' understanding in several Singapore secondary schools using different learning sciences research designs [9-10].

In recent years, a collaborative approach to develop innovations has been explored by researchers in the learning sciences. Penuel et al. [11] defined the co-design process and described seven characteristic features of co-design as a method. Besides as a way aiming to develop curriculum materials and assessment tools [3] [11-12], co-design process is also perceived as way to build community and common language among researchers and teachers, as well as a form of teacher professional development [11]. There are many reasons to involve teacher into the co-design as co-designer rather than transmitters [13], but at the same time, there are hurdles impeding teachers in becoming participators in the co-design, such as the unfamiliarity with the changed roles and few materials to support their participatory relationship with curriculum materials [14].Some key tensions revealed from the previous studies of co-design process, such as teachers' limited time committed to the project [11] co-design process, but little was done to specially describe how the tensions were resolved.

2. Context

The current research study is a part of a larger designed-based research project (MVTII) [15] aiming to sustain and scale up the iMVT innovative pedagogy from the MVT [16]. We argue that this innovative pedagogy applies to all the science subjects and we work with more than twenty teachers in four collaborating schools in Singapore to develop curriculum materials in chemistry, physics and biology. In this paper, we focus on the first cycle of our chemistry design work that has finished in March 2010 with one teacher Mr. Woo (all names are pseudonyms) in one collaborating school. He has eight years' teaching experience and is currently holding the duties of the head of department for Science in his school. Besides normal teaching, he also has administrative commitments in the school. For chemistry, we were fortunate to collaborate with one of the few chemistry curriculum specialists from CPDD (Curriculum Planning & Development Division), MOE in Singapore. The curriculum specialist, Ms. Ai, has been working on curriculum policy and preparing teachers for curriculum enactment at CPDD for ten years. She was an ex-teacher and she knows the Singapore education system and teacher needs very well. The topic is *Particulate Nature of Matter* for secondary one student, which is commonly regarded as a challenging topic for secondary students because there are many abstract concepts and hence difficult for students to understand. The design of this topic started from October 2009 and went through several iterative revision and refinement process among the tripartite parties until it was enacted in February 2010. The curriculum development is mainly led by a researcher and the project principal investigator with chemistry education background. Two international collaborators also gave valuable comments and feedback on some drafts of the curriculum. The implementation lasted about 7.5 periods (one hour for each period) including the pre-test and post-test of content understanding and pre-survey and post-survey of students' understanding of models and modeling. Researchers and MOE collaborator followed through the classroom implementation to provide on-site support during the lesson and also gave quick feedback to the teacher after the lesson.

3. Data and data analysis

During the process of co-design, every party in this tripartite relationship communicated with each other through various modes including mobile phone SMS messages, phone calls, emails, and face-to-face communication, such as teacher-researcher working sessions. All these communication records were collected, transcribed and analyzed to examine the frequency and content of communication, and the synergy among different modes, hence revealing how the tensions have been resolved. Teacher interviews before and after the implementation were also transcribed to examine how the interactions worked for teacher learning and knowledge and belief change.

4. Results

Past research has revealed different kinds of tensions in the co-design process due to the relatively complex collaborating system. Our co-design process was iterative in nature. Table 1 presents a summary of continuous phases we have gone through and the tensions revealed in different phases of the first cycle of co-design, from which we can also infer about different roles that the three parties played out. To initiate the curriculum design process, researchers came up with a general template of iMVT integrated curriculum package (the student workbook as the main product). It was circulated and finalized by the research team, then shared with MOE collaborator and teacher. When choosing the suitable software, teachers were more concerned about students' capabilities to learn through such a software rather than teaching strategies, while researchers from an analytical stance considered more about the software's usability in modeling process. The depth of the content is determined based on the school's scope and discussed within three parties after several rounds of communication. After settling down the scope and sequence, researchers initiated the first draft of workbook and engaged in several cycles of revision with the teacher and MOE collaborator before its implementation. After the final revision, the teacher conducted the lessons while researchers and MOE collaborator observed the process and provided on-site support. One more round of revision and refinement has been done after observing students' reactions to the activities, their performance in the test and teacher's feedback on the practical issues, and a similar unit has been developed based on this topic and readily be enacted by another collaborating school.

Table 1. Major tasks and participants in different phases and tension revealed

Time	Major Tasks	Participants	Tension
Sep.'09 -Nov.'09	Develop a general template for all the three science subjects	Researcher, MOE collaborator	Different views on types and organization of students activities
Oct.'09 -Dec.'09	Search for the suitable simulation utilized in curriculum	Researcher, teacher	Different focuses when integrating the technology
Nov.'09 -Jan.'10	Continuously co-design and revise the workbook	Researcher, MOE collaborator, teacher	Teacher's time constraint between co-design and normal teaching schedule
Feb.'10	Implement the curriculum	Teacher, Researcher, MOE collaborator	Different interpretation of the iMVT pedagogy between teacher and researcher
Feb.'10 -Apr.'10	Further revision and refinement of the workbook	Teacher, Researcher, MOE collaborator	Teacher's time constraint and different perspectives of refinement among the three parties

'Teachers never have enough time' has been reported as one tension revealed in the co-design process [11], and this is especially true for our collaborating teacher. Besides the teaching, he has other administrative and research commitments in school. What's more, in the tripartite relationship, we had to coordinate the busy time schedule among three parties. In order to resolve this tension, alternative ways of communication other than face-to-face working sessions were taken to facilitate the conversations among the three parties. As shown in Figure 1 and 2, intensive communication among the three parties existed before and during the iMVT implementation. Emails were used to exchange the ideas on curriculum feedback, acquire students' information as well as updates for project progress, and the teacher always responded promptly and sometimes even initiated the discussions. SMS messages were more used for the logistic matters, such as arrangement of classes and reminder of meetings. Different modes were utilized synchronously to improve the efficiency and effect of the interaction. Researchers interacted with the other two parties through multiple modes, while teachers and MOE collaborator mainly through face-to-face working sessions. Four working sessions were held before the implementation period and each of the working session lasted 1.5-2 hours, where all the three parties exchanged the ideas and discussed about the details of curriculum. During the implementation, researchers went to school and provided on-site support to teacher and exchanged ideas of improvement of curriculum after each lesson.

Another key tension that affected the productivity and success of the co-design was the different expertise that different parties brought in. With different professional background, three parties tend to give feedback from different perspectives to improve the productivity of the co-design. There are in total 11 ongoing versions of workbook with track changes from different parties, 3 of them came from MOE collaborator and 3 were contributed by teacher. All the comments and track changes (not including grammatical revisions) were looked into and analyzed to examine the different expertise that the three parties bring in. Our analysis found that three parties demonstrated different expertise and focus of the curriculum. Researchers were more concerned about the overall framework of the innovation and the scientific accuracy of instructions and questions. The MOE collaborator provided insight about the process of students' knowledge development, for example, in one document, she reminded the researcher to go over the science syllabus requirement on this topic to get an idea of how the ideas should be connected to students' previous knowledge in primary school and proceed to the next level. It is worth mentioning that after reading the literature papers that researchers have recommended to her, MOE collaborator gave valuable advices on how to make this innovative pedagogy more practical in the Singapore context. After the framework was shaped up, the teacher was then pulled in to revise the workbook. He cared more about more practical and detailed issues such as the formatting of the questions to be in line with O' level syllabus. During the process, he also contributed the resources he has used from his previous lessons to make the package more comprehensive.

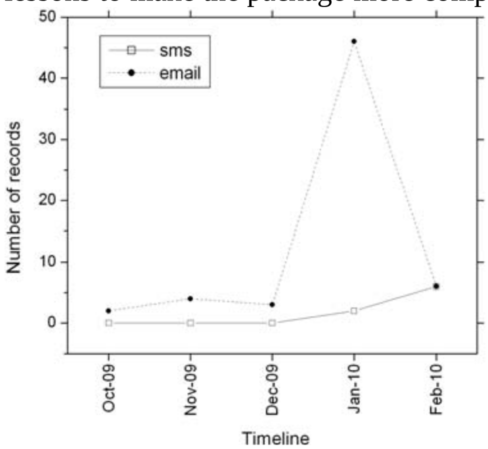

Figure 1. Communication records between researchers and the teacher

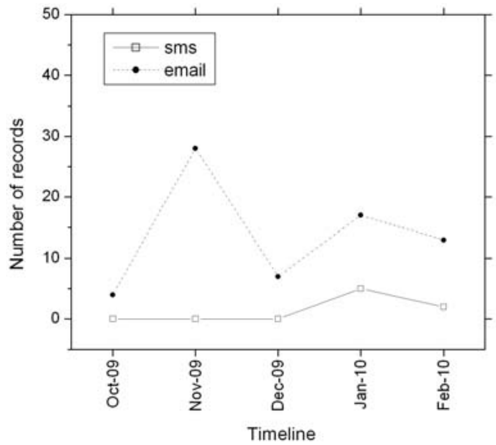

Figure 2. Communication records between researchers and the MOE collaborator

Teachers often see researchers' solutions as too theoretical and not practical enough for real classrooms, while researchers often view teachers' limited content knowledge as a barrier to their contributing effectively to design efforts [17]. Whereas, MOE collaborator at a middle stance knows the situation of schools and teachers' practical concerns, at the same time she is more ready and able to take in the innovative ideas. The MOE collaborator was invited to the workshops, the working sessions where we interacted with teachers, and the researcher's group meeting. She knows the Singapore school system well and is aware of teacher's concerns and constraints, at the same time she also understands the goals and principles of the research. As a mediator, MOE collaborator bridged the gap between the researchers and teacher by translating researcher's ideas using her interpretation and considering the teaching practical issues from teacher's point of view in the working sessions. Hence, the teacher got access to more authentic understanding of the innovation in real context from various channels rather than only from researchers. Further more, he was in a sense encouraged to implement the innovation with the support from people from government level. At the outset of the collaboration, teacher might have doubted about the feasibility and advantages of the innovation, but MOE collaborator convinced the teachers using her own understanding and experience with other school teachers. The teacher thought people have talked about 'inquiry' all the time and everywhere, and wondered whether it's worthwhile to try the iMVT out. The MOE collaborator stated, "*you said many schools are conducting (inquiry) because of our curriculum framework… the way we reach inquiry, I think the problem ah, is still time, no time to do this no time to do that, even down to actually bringing our students down to concepts", "I suppose I must deal that this way of doing inquiry, there's something special, it's our modeling… so far I haven't seen someone actually use computer, plus modeling to do inquiry*". She also played the role of facilitating the bonding of researchers and teacher such as she found a way to initiate the conversation between researcher and teacher as shown in following excerpt from transcript of one of the working sessions. "*You know, so my concern is when I look at the workbook, all of us must have good ground work and background knowledge before we go to design. It is very difficult, maybe on the part of X (one researcher's name), to try to understand what she is going to provide in the* *worksheets and what sec. 1 students know. …so where is the starting of the whole science curriculum, maybe you can share with us so that she can understand better*".

The involvement in the co-design provided teacher a platform to think through systematically the relation between pedagogy and content and chances to talk with researcher to promote their understanding. The technologies may have their own propensities, affordances and constraints, which present challenges to teachers who are willing to integrate more technology in their teaching [18]. The teacher also pointed out '*the downside of technology*' that teacher needs to '*have a lot of time, in a way wasted, to help students to manage*' the technical issues. In order to tackle the problem, researchers and teachers exchanged ideas and discussed about how to optimize the technology to be utilized for students. With the criteria for searching software provided by the researchers, the teacher also searched and recommended the possible simulations, and contributed his ideas on teaching strategies. He showed improved understanding of the pedagogy framework and expressed enhanced understanding of technology in education after co-design process. When talking about the understanding of iMVT, he put emphasis only on power of technology but kind of ignored the strength of its integration with pedagogy in the pre-survey as saying that "*it allows the users/learners to explore information and data in a meaningful and authentic way to gain greater understanding and insights regarding the scientific data/information… for example, the use of MVT to teach electrolysis will enable students to discover for themselves without using actual laboratory equipment……*", but after several working sessions and co-design experiences, he stated the iMVT innovation more comprehensively and expressed explicitly its advantage in pedagogical usage in the mid-survey that "*the use of modeling and visualization tools for the learning of sciences is not new, however, to incorporate them onto a common platform for students to collaborate… there could be greater interactions (peer teaching) taking place and hopefully with the combination of self-discovery coupled with collaborative learning, students would be able to achieve deep learning*", *"The visual and interactive nature (such as manipulation) of the objects in the tools would also bring in a higher degree of authentic learning"*. After carrying out the iMVT lessons, the teacher appreciated the pedagogy "*a worthwhile approach*" though some practical issues existing, and he expressed his willingness to continue using this materials with other classes and revise based on the responses from students.

With the processes as described above, we concluded the interactions of three parties in the tripartite relationship as shown in Figure 3.

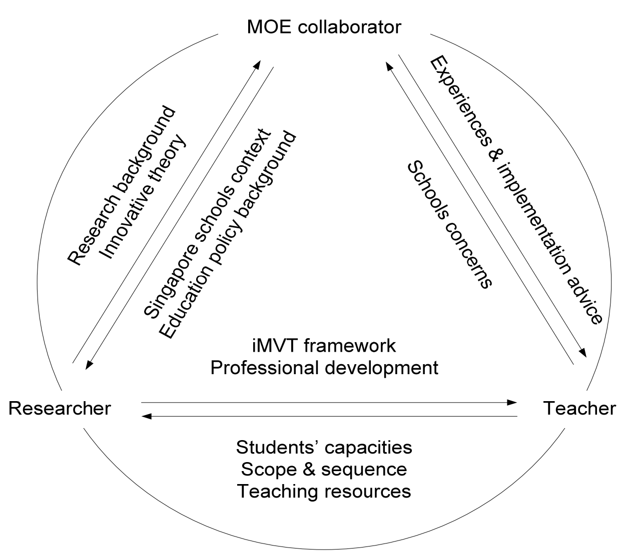

Figure 3. The tripartite relationship in iMVT curriculum co-design process

5. Conclusion and Discussions

Multiple tensions existed between teachers, and researchers due to their backgrounds and emphases. Our study revealed that the key tensions persist along the collaboration journey, but we resolved the tensions by the tripartite relationship model where each party demonstrated the agency [19], especially the MOE collaborator's role to bridge the gap between researchers and teachers. It is definitely challenging to introduce a new party in the collaborating cycle resulting in a more complex system. However, it is necessary that every party's strengths are optimized and brought out into this collaboration to make the system work smoothly and successfully. The model provides a new way of collaboration and work out a way to effectively address the long-standing tension between researcher and teacher [11, 14]. The tripartite model generated here might be adoption-limited in a way that it's a model formed in a very unique set-up of education ecosystem, where the three parties from research, practice and policy level worked closely to achieve the desired outcomes of education. Although not every research team has the luxury to invite an MOE curriculum specialist or people of such caliber to be a collaborator, we believe that different parties in this tripartite model can be replaced by the ones that function equally when researchers in other context want to adopt the model. A party who holds administrative responsibilities in supporting teachers' understanding and enacting national or state curriculum, and has experiences of teacher training could substitute the role of the MOE collaborator in our project. What's more, professional development has always been viewed as an important approach to the sustainability of an innovation and consistency between designed curriculum and enacted curriculum [20]. In our project, we have proposed the tripartite model of co-design where teachers were engaged in the design process of innovative curriculum and shown the evidence of teacher's development of capacity. This contributes to the literature of professional development. The interaction in the co-design was definitely not only uni-directional. It's not only about the benefits researchers or MOE collaborator bringing to the teacher, but also the influences each party bring to another one.

Acknowledgements

This research was funded in part by the Office of Education Research at the National Institute of Education, Nanyang Technological University, Singapore (Grant #: OER 22/08ZBH). We thank our MOE collaborator and the collaborating teacher for working with us on the project. We also thank Dr. Lyna Kwan and other team members for their constructive feedbacks.

References

[1] Singer, J., et al., *Constructing Extended Inquiry Projects: Curriculum Materials for Science Education.* Educational Psychologist, 2000. **35**(3): p. 165.

[2] Remillard, J.T., *Examining Key Concepts in Research on Teachers' Use of Mathematics Curricula.* Review of Educational Research, 2005. **75**(2): p. 211-246.

[3] Edelson, D.C., *Design research: What we learn when we engage in design.* The Journal of the Learning Sciences, 2002. **11**(1): p. 105-121.

[4] NIE, *A Teacher Education Model for the 21st Century*. 2009, National Institute of Education: Singapore.

[5] Zhang, B.H., et al., *Developing an iMVT Pedagogy for Science Learning*, in *9th International Conference of the Learning Sciences*. 2010: Chicago.

[6] Edelson, D.C., D.N. Gordin, and R.D. Pea, *Addressing the Challenges of Inquiry-Based Learning through Technology and Curriculum Design.* Journal of the Learning Sciences, 1999. **8**(3): p. 391-450.

[7] Lehrer, R. and L. Schauble, *The development of model-based reasoning.* Journal of Applied Developmental Psychology, 2000. **21**(1): p. 39-48.

[8] Hay, K.E., B. Kim, and T.C. Roy. *Virtual reality modeling-based inquiry: Conceptual coherence and alternative theories trials.* in *Annual Meeting of the American Educational Research Association*. 2004 San Diego, CA.

[9] Zhang, B.H., et al., *Exploring the representational affordances of two types of modeling tools*, in *Annual meeting of the American Education Research Association*. 2008.

[10] Zhang, B.H., et al., *Exploring modeling and visualization technology (MVT) enhanced biology teaching and learning in Singapore*, in *The International Conference for the Learning Sciences (ICLS)*. 2008: Utrecht, the Netherlands.

[11] Penuel, W.R., J. Roschelle, and N. Shechtman, *Designing Formative Assessment Software with Teachers: An Analysis of the Co-design Process.* Research and Practice in Technology Enhanced Learning, 2007. **2**(1): p. 51-74.

[12] Maldonado, H. and R.D. Pea, *LET's GO! to the Creek: Co-design of Water Quality Inquiry Using Mobile Science Collaboratories* in *6th IEEE International Conference on Wireless, Mobile, and Ubiquitous Technologies in Education*. 2010. p. 81-87.

[13] Connelly, F.M. and M. Ben-Peretz, *Teachers, research, and curriulum development*, in *The curriculum studies reader*, D.J. Flinders and S.J. Thornton, Editors. 1997, Routledge: New York. p. 178-197.

[14] Gunckel, K.L. and F.M. Moore. *Including Students and Teachers in the Co-Design of the Enacted Curriculum*. in *NARST Annual Meeting*. 2005. Dallas, Texas.

[15] Zhang, B. and S. Foong, *Sustaining and Scaling up Modeling and Visualization Technologies Enhanced Inquiry-based Science Learning (MVT II)*. 2009, Office of Educational Research, National Institute of Education: Singapore.

[16] Zhang, B.H., M.J. Jacobson, and B. Kim, *Enhancing Inquiry-based Science Learning through Modeling and Visualization Technologies (MVT)* 2007, National Institute of Education, Nanyang Technology University, Singapore.

[17] Shrader, G., et al. *Participatory design of science curricula: The case for research for practice*. in *Annual Meeting of the American Educational Research Association*. 2001. Seattle,WA.

[18] Koehler, M.J. and P. Mishra, *What is technological pedagogical content knowledge?* Contemporary Issues in Technology and Teacher Education, 2009. **9**(1): p. 60-70.

[19] Sewell, J., William H., *A Theory of Structure: Duality, Agency, and Transformation.* American Journal of Sociology, 1992. **98**(1): p. 1.

[20] Kubitskey, B. and B.J. Fishman, *A role for professional development in sustainability: linking the written curriculum to enactment*, in *7th International Conference of the Learning Sciences*, S.A. Barab, K.E. Hay, and D.T. Hickey, Editors. 2006: Bloomington IN. p. 363-369.