The effect of the interdisciplinary agenda on science learning

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Abstract

There have been a strong push at the policy level in many countries to promote interdisciplinary approach in the teaching of the STEM subjects. This study explores whether and in what ways the quality of the science teachers' pedagogical practices change when teaching in an interdisciplinary context. A pilot study has been conducted in five secondary schools in Hong Kong. The eight science and engineering practices in the US NGSS are used as the quality criteria in the analyses of data collected during the lesson design, implementation and reflection phases during the curriculum innovation process. Findings show that the science teachers demonstrate a strong science identity in the interdisciplinary context, but no significant changes in the quality of the lessons.

Introduction

This study investigates whether and how an emphasis on interdisciplinary knowledge integration in STEM education influences the quality of science teachers' pedagogical practices. K-12 STEM education has traditionally focused on science and mathematics education (Bybee, 2010). This has been broadened in recent years to include technology, engineering and computer science, accompanied by an emphasis on integrated STEM (Bryan, et al., 2015; Bybee, 2014; English, 2016; Johnson, 2013; Kelley & Knowles, 2016; Laboy-Rush, 2011; Moore, et al., 2015; Sanders, 2009). Integrated STEM highlights the importance of connecting knowledge and practice from different STEM disciplines in solving real-life problems (Bryan, et al., 2015; Johnson, 2013; Kelley & Knowles, 2016). While integrated STEM addresses the value of interdisciplinary learning, little is known about how the learning in science classroom is influenced by the additional foci on the integration of knowledge and practices from other STEM disciplines like mathematics and engineering.

While it is widely believed that integrated STEM education can enhance student learning through interdisciplinary approach (e.g. Moore, et al, 2015), more empirical research is needed to justify it. This study analyzes data from two government-funded intervention projects which target grade 4-9 students. Both projects use Design-based Implementation Research (DBIR) (Fishman, et al., 2013; Penuel, W., 2015) as a model of research-practice partnership to foster teacher capacity in designing lessons to enhance student self-directed learning (SDL). The first project, SDL-Science, focuses on the use of SDL and scientific inquiry (SI) for designing science lessons, while the second project, SDL-STEM, additionally emphasizes on interdisciplinary approach to designing STEM lessons. As interdisciplinary approach is addressed, SDL-STEM targets teachers from different STEM disciplines, including teachers from mathematics, computer science or other STEM-related subjects in schools. The SDL-STEM project is in relation to the curriculum reform on STEM education in Hong Kong (EDB, 2016). A distinctive feature of STEM education policy in Hong Kong is that there is no standard framework or prescribed curriculum. The policy document makes emphasis on the importance of integrating knowledge from different STEM disciplines (EDB, 2016), but only guidelines are provided for teachers. Schools can choose to develop their STEM curriculum based on a single subject or through interdisciplinary teacher collaboration. Irrespective of the implementation model, a guiding principle is the interdisciplinary approach — connecting learning elements from different STEM disciplines.

This study used data collected from five secondary schools that participated in SDL-Science project during 2016-2017 and joined the SDL-STEM project in 2017. The design of the STEM curriculum units were led by science teachers in these five schools in the SDL-STEM project. We investigated the differences in the quality of the science learning opportunities offered to students between these two projects in the five schools, using the eight Science and Engineering practices proposed by NRC (2012) as the quality criteria.

Multiple data sources were used in this study, including videos of classroom observation, student focus-groups and audio-taped discussion in the debriefing session after each classroom observation, lesson plans and materials co-designed by school teachers, and student works on e-learning platform. We compared the lesson designs in the two projects in terms of the eight Science and Engineering practices. Teachers' lesson design intentions in lesson plans and teaching materials were cross-examined with what on the e-learning platform, what students performed in the observed lesson, and the work done by students. We complemented our analysis by looking into teacher narrations in debriefing sessions. The finding of this study will contribute to exploring the effect of interdisciplinary approach to science learning. The conclusion and implications of the findings will be discussed in the closure.

Theoretical perspectives

We focus our study on the design of science learning before and after using interdisciplinary approach. There are many possible analytical lenses to examine science learning such as scientific literacy (Bybee, et al., 2009), scientific reasoning (Osborne, 2013) and scientific inquiry skills (Gobert, et al. 2013). A growing view is to address the socio-cultural dimension, the epistemic practice of science community (Kelly, 2018). Bao, et al. (2009, p.29) argue that "how we teach" is more important than "what we teach" in order to build students' high thinking abilities like reasoning skills. The matter of "how we teach" is about the design of the science learning and what practice students can exercise.

Before the emergence of integrated STEM, inquiry-based approach is a practice to engage students in science learning. NRC (2000) suggests five processes in scientific inquiry (SI). In the context of integrated STEM, NRC (2012) proposes eight Science and Engineering practices that also addresses the components of mathematics and engineering design practices in addition to SI:

1. asking questions and defining problems,
2. developing and using models,
3. planning and carrying out investigation,
4. analyzing and interpreting data,
5. using maths and computational thinking,

6. constructing explanations and designing solutions,
7. engaging in argument from evidence,
8. obtaining, evaluating and communicating information.

These eight practices echo the scientific reasoning practices identified by Fischer, et al. (2014). This study will adopt these eight practices to examine the science learning of our project schools as these schools design STEM education topic within science department. Similar to the NRC (2012) framework, learning elements from other disciplines like mathematics, computational thinking and engineering practices can blend with science learning among our project schools. Yet, the SDL- STEM project school teachers need to design their school-based STEM lessons instead of having prescribed curriculum as the project is in the framework of Design-based Implementation Research (DBIR) (Fishman, et al., 2013; Penuel, W., 2015).

This study explores the effect on science teachers when they design lessons under the interdisciplinary agenda. Would any significant difference be in the occurrence of the eight practices because of the interdisciplinary agenda? Science teachers' intentions of their lesson designs in the context of the SDL-STEM will also be analyzed through their narrations in the debriefing session. What teachers have done and what teachers have talked about their designs will give us complementary perspectives for grasping what they intend to address in their lesson designs.

Methods

Two implemented science topics at grade levels 7-9 from each of the five project secondary schools were selected. One science topic was implemented in the first SDL-science project addressing solely science education. Another topic was implemented in the second SDL-STEM project with the emphasis on interdisciplinary approach.

Teachers' intentions for their designed lessons were analyzed with two different methods. The first method was to analyze their lesson plans and teaching materials. A coding scheme was set up to analyze teachers' intentions in their lesson designs as revealed in their lesson plans and teaching materials, drawing on the framework of the eight Science and Engineering practices (NRC, 2012). This was cross-examined with what was actually practiced as observed on e-learning platform, in the observed lessons and students' works. Analyses were assisted by the rubric in appendix F of Next Generation Science Standards (NGSS Lead States, 2013). Only those intentions that were revealed in the actual practice were counted.

Two research team members coded different schools independently at start. Then they discussed their interpretations with another research team member. Different interpretations were regulated until a total agreement was reached. Then the coding process was continued with iteration until no dispute was on the codes. The code results were cross-checked with project staff who worked closely with those schools for the project implementation.

Another method is to examine their narrations in debriefing sessions which were audio-taped and transcribed. Teachers were not demanded to recall all aspects in the debriefing session as this was not the purpose of the debriefing session. They were encouraged to discuss what they thought was worth noting. Their major concerns for the lessons were explicated or implicated in the issue they uttered. The analysis focused on what disciplinary or interdisciplinary issues are in their concerns.

Results

The coding results are integrated in table 1 (see Appendix) and summarized in table 2 (see Appendix). Both projects show similar patterns, with some practices occurring more frequently than the others. The practices of both “asking questions and defining problems” and “engaging in argument from evidence” are rare in both project implementations. The practice of “developing and using models” is slightly lesser in the interdisciplinary context. Although such a preliminary analysis cannot confirm whether any small variation is significant, it does demonstrate that the above practices are not common.

All schools showed the following practices in both of their implementations: “planning and carrying out investigation”, “analyzing and interpreting data”, “constructing explanation and designing solutions”, and “obtaining evaluating and communicating information”. Although some of the implementation topics are about designing artefacts instead of studying natural phenomenon, students still had to investigate the effect of the change of one or more variables in the process. Emphasizing SDL, teachers let students plan for their investigation and analyze their data for their artefacts. The previously accustomed science practices are transferred to the interdisciplinary context.

The analysis of teacher narration shows that although interdisciplinary approach is addressed in the SDL-STEM project, science teachers are more concerned about the science process in the students’ learning journey. The following quote from teacher A is exemplary.

“I agree that it is better to cooperate with design and technology subject for this topic. The whole investigation is enriched. Before this observed lesson, I noticed that students had spent more time on making the mini device but they had thought less about the dependent variable. That is lesser on science…”

Teacher A from school S1

The STEM topic involved the making of a mini device. When the making process was assisted by design and technology subject, the science lesson was more about the effect of some variables in the device by conducting a fair test. As a science teacher, teacher A was worried about the learning elements in science like “dependent variable” and “investigation”.

For science teachers, the emphasis is still on the design of science learning even in the interdisciplinary context. Teacher B talked about her struggles.

"If one's planning is insufficient, science investigation cannot be good. That is even if they (students) can follow the procedure and learn it well, what we prioritize is to let them think how to do it. We discussed this morning. Let have F.1 students (seventh graders) learn how to prepare their learning while F.2 (eighth graders) learn making notes and getting points. But when should we let them think and design their experiment? Lacking this part is not so science."

Teacher B from school S2

When teacher B accounted for her struggles in the design of the lesson, her concern falls on scientific investigation and how to get students ready for designing experiment. Science teachers in these five schools are more concerned with the science elements in their lesson designs. They noticed whether the teaching materials contained enough science elements (teacher C, appendix 1) and how well students exercised their scientific investigation skills (teachers D, E & F, appendix 1).

Conclusion and Implication

This study explores the effect of the interdisciplinary agenda on science learning. Results of the preliminary analysis show that the occurrence of the eight Science and Engineering practices are consistent regardless of the project context. This consistency echoes with the unchanging emphasis on science process among these science teachers in the interdisciplinary context. They transfer their accustomed science practices from the context of natural science to interdisciplinary context and keep their own disciplinary agenda.

The preliminary analysis of this study contributes to showing that the interdisciplinary discourse might have insignificant effect on science learning in terms of the eight Science and Engineering practices (NRC, 2012). There are still other aspects worth researching on but with limited space, this study focused on this socio-cultural dimension. The result leads us to think about disciplinary agenda and agency amid the growing emphasis on interdisciplinary STEM. Science teachers can have the same struggles as teacher B even without the articulation of integrated STEM. They might have the same science agenda of teacher A in the interdisciplinary collaboration. Both are related to the disciplinary identity of science teachers.

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Appendix

Table 1. The coding results.

School	Project	Asking questions and defining problems	Developing and using models	Planning and carrying out investigation	Analyzing and interpreting data	Using maths and computational thinking	Constructing explanations and designing solutions	Engaging in argument from evidence	Obtaining, evaluating and communicating information
S1	SDL-science	0	1	1	1	1	1	0	1
	SDL-STEM	0	1	1	1	1	1	0	1
S2	SDL-science	0	1	1	1	0	1	0	1
	SDL-STEM	0	0	1	1	1	1	0	1
S3	SDL-science	1	1	1	1	1	1	0	1
	SDL-STEM	0	0	1	1	1	1	0	1
S4	SDL-science	1	1	1	1	1	1	0	1
	SDL-STEM	1	1	1	1	1	1	1	1
S5	SDL-science	0	0	1	1	0	1	0	1
	SDL-STEM	0	0	1	1	0	1	0	1

Key:

0 = not in the actual practice

1 = in the actual practice

Table 2. The distribution of the eight practices in the two DBIR projects.

Practice / No. of Sch. demonstrating the practice / Project	Asking questions and defining problems	Developing and using models	Planning and carrying out investigation	Analyzing and interpreting data	Using maths and computational thinking	Constructing explanations and designing solutions	Engaging in argument from evidence	Obtaining, evaluating and communicating information
SDL-Science	2	4	5	5	3	5	0	5
SDL-STEM	1	2	5	5	4	5	1	5

Appendix 1

Other excerpts of selected teachers' narrations in debriefing sessions.

"They have previously watched a video about throwing a bath bomb into a tub and then a lot of bubbles were produced. They have also watched another video about how to make a bath bomb, but that video clip was more like a cooking tutorial instead of focusing on the science aspect. So in Lessons 1 and 2, we gave them several objects to add in, and they have to try the active ingredient. Which of the objects give bubbles? Some other objects are useless. Then we have also done Activity 4. They would first find 6 combinations by themselves and try."

Teacher C from school S3 (Co-teaching with teacher D in the observed lesson)

"I am very much impressed that they really kept on revising today. After they had finished the first two trials, I asked them, 'What do you think is the best ratio between the acid and baking soda?' They said, '1:1'. It was strange, so I asked, 'Why do you think that 1:1 is the best? What ratios have you tried?' They said they had tried 4:4, 1:7 and 7:1. I said, 'These ratios seem a bit extreme. Why don't you try some others?'. They were suddenly enlightened, and said, 'Then let me try 2:5 and 4:3. Those may also work.' So they continued with the trial. At the end I asked them whether they had made any new discovery. 'Yes, I have indeed found something different,' they said."

Teacher D from school S3 (Co-teaching with teacher C in the observed lesson)

"Some groups are special. They remembered the teacher had said that this was only the case for Pak Choi (Chinese cabbage), and therefore that the pH value for it (Pak Choi) was not very reliable. Since it only applied to Pak Choi, it could not be generally applied to other kinds of vegetables. They also thought this way, and therefore the student said, "It was a pity." So they have to grow some more vegetables for verification. In this scientific inquiry, they had this discussion time which helped them not only further evaluate their performance but also think more about some details of life."

Teacher E from school S4

"Initially, I reserved a lot of time for the three trials. However, they (students) might encounter some difficulties in practice. In fact I did not practically look into what happened. Maybe they (mealworms) stuck and moved relatively slowly. The prior preparation also took a long time. For example, I already showed how to do the calculation. I was worried that they (students) might forget it today."

Teacher F from school S5