Chapter 17
Exploring the Process of Problem Finding in Professional Learning Communities Through a Learning Study Approach

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Abstract Professional learning communities (PLCs) have established their niche as a key driver of teacher professional learning for about two decades. Collaborative problem solving, usually in the form of reflective inquiry, has been identified as one of the key features of successful PLCs. One approach that PLCs use in carrying out collaborative problem solving (CPS) is the learning study. In using the learning study approach for CPS, two key processes are involved – problem finding and determination of the solution procedure. Noting the imbalance in the extant literature in favor of the latter, this article seeks to explore how the process of problem finding takes place, as a PLC formed by biology teachers follows the learning study model. We focused on how members of this PLC negotiate to determine the object of student learning and, in the process, find the problem that would be addressed by the team. The findings and insights that were presented in this article were drawn from multiple data sources (e.g., minutes of meetings, field notes, teacher journal entries, and teacher interviews) that detail teacher interactions in four consecutive meetings of a PLC located within a Singapore school. On the basis of our findings and the relevant literature, we formulated recommendations to facilitate problem finding of a PLC via learning study.

Keywords Professional learning communities • Collaborative problem solving • Learning study • Problem finding

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Introduction

Contemporary educational landscape that is responsive to teachers' evolving professional development (PD) needs, such as those arising from meeting the challenge of developing competencies among learners and working in education system suited for the twenty-first century, usually features collaborative social structures, such as professional learning communities (PLCs). The term "PLC" usually connotes a practice-situated PD initiative that helps build teachers', as well as schools', capacity and effectiveness to improve students' learning (Sigurðardóttir 2010). A PLC comprises a group of professionals who engage in collaborative learning activities that are guided by a common vision of implementing student-focused teaching (Stoll et al. 2006; Wood 2007). Serving as a social sphere wherein teachers can co-construct and share new knowledge (McLaughlin and Talbert 2001, Wood 2007), effective PLCs also encourage teachers to negotiate and take control of the content and path of their own PD, while they engage in a collaborative inquiry into their practice (Nelson et al. 2008; Scribner et al. 2007). Through these activities, PLCs can support not only teacher growth but transformation of knowledge, beliefs, and praxis (Nelson et al. 2008; Pella 2011; Sigurðardóttir 2010).

The effectiveness of PLCs is largely underpinned by several supportive conditions that favor the emergence of sustainable collaborative activities, which are focused on student learning. It is important for researchers, educators, and policy-makers to gain a sound understanding of the nature of these collaborative activities, including the environments in which these activities take root and flourish, so as to develop ways and means that can scaffold and enhance the likelihood of PLCs to reap their intended outcomes. In Singapore, PLCs have been increasingly gaining popularity as a means to address classroom- and school-based problems and for improving instructional practice. An investigation of the processes that take place during PLC activities would be valuable as it can help identify areas of strengths and areas that need improvement. Through a Singapore case of learning study, this research endeavor aims to contribute to the existing knowledge base on PLCs by focusing on a team of four Singapore teachers participating in collaborative problem solving (CPS). We are particularly interested in the problem finding process, which is a key aspect of CPS that has been given scant attention in the literature, especially at the group level. Noting the strong influence that the problem finding process exerts on the outcome of the problem-solving process (Lee and Cho 2007) and how this influence increases as the degree of structure of the problem decreases (Mumford et al. 1994), understanding the problem finding process within the context of ill-structured and real-world tasks, such as those experienced by teachers working together as a community to solve day-to-day classroom problems, would yield distinctive insights that may enhance the efficiency of CPS in authentic contexts.

In the context of learning study, this study aims to answer the following research questions:

1. How does a PLC, formed by Singapore biology teachers, collaboratively identify problems as experienced through the crafting of a learning object (i.e., students' capability to be developed)?
2. What are the aspects of the teachers' experiences that facilitated the problem finding process?

CPS in PLCs

CPS, which we equate with *collaborative inquiry*, has been considered as a distinctive component of successful PLCs (Hipp et al. 2008; Nelson et al. 2008). Drawing upon Jonassen's (1997) conceptualization, a problem involved in CPS can be defined as an unknown that arises from any situation in which a group has a "felt need" to fulfill in order to achieve a particular goal (p. 66). The CPS process which is carried out in school PLCs involves an ill-structured problem situation (see Slavit and Nelson 2010). In these situations, the problems are usually emergent, with unclear goals, constraints, concepts, rules, and principles; have multiple solutions (Jonassen 1997; Voss 2005); are context dependent; possess parameters that are less manipulable; and require construction of multiple problem spaces (Jonassen 1997). A problem space refers to the gap between an initial state and a goal state, along with the set of possible actions needed to move from the initial state to the goal state (Newell and Simon 1972).

Consistent with Jonassen's (1997) description of the different stages involved in solving ill-structured problems, the CPS process commences when the problem or question –"the focus of inquiry"– is explored and identified (Nelson et al. 2008, p. 3). In ill-structured problem situations, the initiation or formulation of problems, or *problem finding*, is necessary because the problem is entrenched in the information on hand (Lee and Cho 2007). As CPS participants engage in selecting the problems existing in their contexts (Nelson et al. 2008; Slavit and Nelson 2010), they also negotiate about and challenge their individual and collective assumptions (Slavit and Nelson 2010). It also needs to be emphasized that the problem finding or focusing phase usually takes place at, but not confined to, the initial stage of the process.

The succeeding phases of the CPS process comprise the planning, implementation, and evaluation of the solution procedure (Slavit and Nelson 2010), which is meant to reduce or close the chasm between the initial and goal states within the problem space (Newell and Simon 1972). The evaluation phase can take place in all parts of the CPS process and may lead to the modification of the problem being addressed. The dissemination phase is carried out after the evaluation results are found satisfactory (Slavit and Nelson 2010). As participants take part in CPS within the context of PLCs, they are likely to develop a shared understanding of pedagogical goals and issues (Roschelle and Teasley 1995), adopt an inquiry stance (Nelson

et al. 2008), and forge an inclusive working culture. To enhance the likelihood of positive outcomes through CPS, it is important to have a "common ground" which serves as an anchor for participants to reconcile their multiple perspectives (Schwartz 1995).

Although the extant literature on problem solving involves a number of studies that focused on the latter phases of CPS, there is paucity of published articles that dwell on the process of problem finding (Lee and Cho 2007). The dearth of information available in relation to problem finding is more pronounced when the units of analysis are groups, rather than individuals (Reiter-Palmon and Robinson 2009), such as in relation to PLCs. We have found a few studies of this kind, but they merely involved cursory description of the problem finding stage. A pertinent example would be the research report of Slavit and Nelson (2010), which presented a thorough discussion on the implementation and assessment of CPS but included only a brief description of how participants engaged in multiple rounds of identifying the research problem. In another study, Padwad and Dixit (2008) explored how teachers perceived classroom problems and how their participation in PLCs improved these perceptions. Focusing on the problem finding process, Bray (2002) underscored some criteria for selecting problems to be focused on during CPS. Bray emphasized that the problem has to be interesting to participants, should not have a readily available solution, and has the richness to open up opportunities for participants to learn. Nokes-Malach et al. (2012) added that the problem should neither be too easy nor too difficult. Although focused on the emergence of distributed leadership during PLC meetings, Scribner et al. (2007) were able to collect empirical evidence indicating that effective problem finding, as well as problem solving, can be facilitated when the PLC group develops a collective understanding of its objectives and its members are given the level of autonomy that is appropriate for these objectives.

In enacting CPS via PLC efforts, participants usually adopt the lesson study and learning study approach. With particular focus on the planning, implementation, and evaluation of research lessons (Chong and Kong 2012), these approaches provide a common space where teachers are given the chance to collectively deal with classroom difficulties (Pang and Marton 2003, 2005) and learn through their engagement in the process.

Learning Study and CPS

The learning study is a teacher PD approach that is gaining attention worldwide (Holmqvist 2011; Runesson et al. 2011). Similar to the lesson study approach (Lewis et al. 2009; Stigler and Hiebert 1999), both approaches utilize the teachers' own classroom contexts as sites for teacher research (Borko and Putnam 1996), where pedagogical arrangements that were collaboratively determined can be tried out (Pang and Marton 2003, 2005). In promoting teacher collaboration (Runesson et al. 2011), teachers are encouraged to pool resources and knowledge to jointly

tackle curricular and pedagogical challenges; in this view, learning studies provide opportunities for teachers to solve authentic problems related to their own teaching and learning.

A key feature of learning study that differentiates it from lesson study is the application of a theoretical framework to shape teachers' learning study experiences (Holmqvist 2011; Pang and Lo 2012) and to concurrently enhance student learning (Lo et al. 2006). According to Pang and Marton (2003), learning study has compensated for the lack of theoretical frame in lesson study, by adapting design experiment's (Collins 1992, 1999) idea of combining the instrumental and theory-oriented aspects of (teacher classroom) research. In a learning study, researchers or in-school consultants usually serve as resources to help teachers understand and use relevant theories of learning to frame their lessons (Holmqvist et al. 2007).

A cycle of learning study can be deemed to have five key phases that mirror the general CPS stages described above:

Problem Finding Phase (Focusing Phase)

In this phase of the learning study, the teachers formulate specific goals, consider curriculum and standards, and identify a topic of interest (Lo et al. 2006). The process of problem finding primarily includes the step of determining the *learning object*, which directs teachers to discuss and decide on what is worth tackling and what is worth for students to learn. Moving beyond helping students to master content knowledge, focusing on a learning object encourages teachers to determine the capability students are to develop through the research lessons (Marton and Booth 1997); this is premised on how learning study privileges students' development of capabilities (which may promote more "enduring" understandings) over mere content mastery, where the former promotes learning of a more meaningful and transferable nature as opposed to the latter (Erickson 2008). In the context of learning study, the object of student learning may often be derived from the teachers' anticipated difficulties in teaching various topics or from the learning difficulties students faced.

The learning object can be further understood through the identification of its critical features (Lim et al. 2011) – commonly known as critical aspects. For example, in Pang and Marton's study (2005), in order to determine the change in market price of a commodity (i.e., learning object), 16–18-year-old students can deepen their understanding of how price is determined by demand and supply and relative magnitudes of changes between the two, all of which form the critical aspects.

Planning the Solution Procedure

In this planning phase, teachers collaborate to plan the research lessons using a theory as a framework. Pretests may also be administered to students and the results may be used to guide the lesson planning. In this phase, the learning study

approach assumes a certain degree of structure and partly deviates from the usual approach in solving ill-structured problems.

Implementing the Solution Procedure

This phase in CPS typically coincides with the research phase in learning study. The research lessons are implemented, with one teacher teaching the lesson while the rest of the team collects data. The lesson observations may focus on what students learned in relation to the teacher's pedagogy.

Assessing the Solution Procedure

During this phase, posttests may be administered to students. Post-lesson discussions are also conducted to discuss the research lessons and the solution procedure. Feedback to improve the delivery of subsequent lessons is also discussed.

Dissemination Phase

The last phase involves the dissemination of the research findings, along with the problem finding and formulation of solution procedure.

Worthy of mention is how previous learning studies have paid little attention to detailing the process of determining the learning object. An exception may be Holmqvist's (2011) study, where she investigated how teachers in Sweden developed an increased ability to analyze the critical features of the learning object through reiterative cycles of the learning study. Nevertheless, the process of determining the learning object, as part of a problem finding process, still presents a gap in learning study literature. As such, we deem that the process of collaborative problem finding warrants greater attention. Furthermore, previous studies have underscored clear goals – such as the learning object – as being crucial to teachers' positive competence development (Seidel et al. 2005).

Methods

Singapore Case of Learning Study

The Singapore case of learning study is situated in the context of four Grade 9–10 biology teachers collaborating to plan and teach new genetics content in the curriculum; the learning study was supported by a researcher-facilitator (first author). The

teachers taught in an independent school comprising high ability students. The school and teachers were chosen due to their availability. The school had an ongoing teacher PD program where an hour a week was allocated for teachers to collaboratively plan, teach, and evaluate the lessons as a way to improve teaching practice. Thus, the teachers welcomed the learning study as a potential PD approach they could participate in during the allocated hour, as supported by the school leaders. The teachers had varying teaching experiences: both Amy and Pam taught biology for 3 years (total years in teaching), while Chris taught biology for 5.5 years (out of a total of 14 years) (names are pseudonyms). Kate taught biology for 7 years (out of a total of 15 years). The four teachers belonged to the same PD group as organized by the school leaders; this was based on the subject and grade levels taught. Although this was the first time the teachers participated in a learning study, the teachers often worked together as a team as they functioned as the biology department. Nevertheless, the opportunities to deliberately collaborate to promote teacher PD were mostly confined to the allocated PD hour.

The teachers wanted to address the challenges in working with a new genetics curriculum; the new content constituted a 6-year cycle by central authority to develop, implement, and evaluate new biology curriculum. In view of the importance of genetics to everyday life and to scientific literacy, this new curriculum included new aspects of genetics that may be unfamiliar to teachers.

In the context of a learning study, the teachers participated in the process of problem solving as detailed in the previous section, namely, the problem finding (determination of learning object) and the planning, implementation, evaluation, and dissemination of the solution procedure. This paper focuses only on the problem finding phase.

Consistent with previous learning studies (e.g., Pang and Marton 2003, 2005), we implemented a learning study model that included the introduction to the theory of variation. The theory was introduced as offering a perspective to learning during the problem finding phase and in the latter stages of the learning study process. Through this theory, learning can be appreciated as increasing one's capability to experience a learning object in more advanced or complex ways than before (Marton and Booth 1997), the demonstration to identify critical aspects about the learning object. Simultaneously, how the theory served as a pedagogical theory and tool (Elliott 2012; Pang and Lo 2012) was underscored, where the theory underpins the design of *patterns of variation and invariance* (see e.g., Pang and Marton 2005). In designing these patterns, aspects that are varied can be brought to the attention of the students, while the rest of the aspects are kept invariant and thus relegated to the background.

Data Collection and Analysis

Employing *interpretative case study* (Merriam 1998) as the method of inquiry, the analysis of the study entailed the construction of a narrative description of the meetings and a thematic approach to data analysis (Creswell 1998; Miles and Huberman 1994). With the intent to explore and theorize about the phenomenon

(Fernández 2010) of how teachers experienced the process of problem finding in a learning study, a range of data were collected and simultaneously analyzed (Merriam 1998; Miles and Huberman 1994). The multiple sources of data served as a source of triangulation (Lincoln and Guba 1985) to establish credibility of the findings. Our attempts to guard against bias and ensure reliability of the findings included our regular engagements in in-depth discussions of the analysis and constructed themes: this approach allowed for a collective and consensual interpretation of the data set to be developed (Corbin and Strauss 1990; Stake 1995). In drawing from the researcher-facilitator's own notes, the interpretations made were also often questioned by the second author of the paper, who also served as a critical friend (Lincoln and Guba 1985).

The findings presented in this chapter were drawn from a larger study that examined the personal learning experiences of teachers who participated in a learning study (Tan 2014a, b; Tan and Nashon 2013). The learning study lasted 22 weeks and comprised 11 meeting sessions (total of 12 h), four post-lesson discussions (total of 4 h), and eight lesson observations (total of 10.5 h). In this chapter, we analyzed a portion of this data collected. We included 4 h of audio-video recordings of four meetings, during which the problem finding process took place; 12 transcripts of semi-structured interviews with individual teachers (approximately an hour each) that detail their experiences before and after the learning study; teachers' reflective journal entries; and minutes of meetings, field notes, and the researcher-facilitator's own notes.

A narrative description was constructed based on the following. First, audio-video recordings were viewed in tandem with the reading of the researcher-facilitator's field notes. This stimulated recall and allowed for a chronological account of the events that took place in the meetings to be constructed. Second, thorough reading of interview transcripts and journal entries (teachers' and the researcher-facilitator's) was carried out; this guided the researcher-facilitator's interpretations of the events that occurred and allowed her to check her own interpretations against that of the participating teachers. In other words, the data set was triangulated to construct the narrative descriptions. Whenever necessary, relevant excerpts from the interview transcripts and journal entries were presented to anchor and enrich our descriptions and interpretations of the significant events during the meetings.

The subsequent thematic analysis (for details, see Miles and Huberman 1994; Tan and Nashon 2013) included the following:

> Selection and reduction of data, with the constructed description and data set read reiteratively and alongside each other, and relevant parts that depicted the teachers' experiences of problem finding were marked.
>
> Construction of themes through a search for recurring regularities in words, phrases, meanings, relationships, and patterns from the marked parts of the data.
>
> Verification of themes by checking them against other data sources, and adjustments were made whenever necessary.

Results and Discussion

A narrative description, organized in terms of four consecutive meetings, is presented to provide details of the problem finding process the teachers have experienced. This includes the challenge teachers faced in finding the problem, exploration of strategies to overcome the challenge (through the application of theory of variation and determination of curricular flow), and the subsequent identification of the problem. The thematic analysis also surfaced two aspects of teachers' experiences that supported the problem finding process, namely, a meaningful engagement with the curriculum and teacher ownership and empowerment. The former underscores the need for teachers to develop collaboratively a more holistic approach to the curriculum in order for shared meanings to emerge. The latter emphasizes the importance for teachers to take ownership of their own problem finding process.

Experiencing Problem Finding Process via Learning Study

Meeting 1: Challenge in Finding the Problem

At the beginning of the session, teachers were introduced to the notion of a learning object and were shown examples of learning objects from different research studies (e.g., Pang and Marton 2003, 2005). In order to help teachers reflect on teaching genetics, they were given a short questionnaire to fill up. The questionnaire was intended to help teachers explore their views on student learning genetics and their teaching of the topic. For example, it probed for what teachers thought were important outcomes of teaching and learning genetics – "are the outcomes of teaching genetics expressed in terms of students learning *more* or different content?" The questions were adapted and modified from studies of Koballa et al. (2005), Samuelowicz and Bain (1992), and Trigwell and Prosser (2004). In order to further engage the teachers, they were also provided short notes of previous research studies that highlighted the challenges of teaching and learning genetics (based on Duncan and Reiser 2007).

Although the teachers were provided the genetics questionnaire and research literature to guide their exploration of the challenges in teaching genetics and thus to facilitate the problem finding process, it appeared that they were having difficulties coming to a decision on what problem they wanted to work on. In the interviews, the teachers described this difficulty as a frustration (Kate's interview transcript), where they felt like they were "going around in circles" (Pam's interview transcript). According to the teachers, as expressed through the interviews and reflective journal entries, they faced two challenges in trying to determine the learning object. Firstly, the teachers highlighted the difficulty in teasing out the pedagogical and curricular problems embedded within the genetics unit: the teachers

indicated that "genetics was a huge topic" – "spanning across six chapters" in their textbooks (Pam's interview transcript). It is also our belief that the teaching and learning of genetics is fraught with other challenges (Duncan and Reiser 2007), such as students' confusion and the concomitant need to approach genetics at different levels (macro- and microlevels; chromosomal, DNA, and gene levels), and the time gaps in teaching different genetic subtopics. We believe that these exacerbated the lack of clarity in identifying a problem.

The new experiences in the learning study constituted the second challenge. During the interviews, the teachers constantly mentioned about how they were unsure of the scope and depth of the details to include (Amy's interview), especially since they were teaching the new genetics content for the first or second time. Moreover, the idea of determining a learning object runs counter to how "we often focused on curricular content instead" (Kate's interview transcript). In other words, the teachers attributed the challenge of finding a problem to their unfamiliarity with what a capability was. As described by Pam in the interview:

> "… I know we were quite stuck initially… at the end of the first session or something like that, I still wasn't very clear on what we were going to focus on". Similarly, Kate described the experience as follows: "I thought it was a bit of a stalemate sitting there and don't know what was going on", resulting in them feeling "a lot more frustrated" (Kate's interview transcript).

Meeting 2: Strategies to Overcome the Challenge – Introducing Theory of Variation

With the intent to encourage new ways of thinking about teaching practices and student learning, the *theory of variation* (for details, see Pang and Marton 2003, 2005) was introduced in this meeting. In accordance to the learning perspectives provided by the theory of variation, what was emphasized to the teachers was that learning can be seen as increasing one's capability to experience a learning object in more advanced or complex ways than before (see also Marton and Booth 1997). The increasing complexity can be appreciated as the learner discerning and simultaneously holding in his/her focal attention more critical aspects of the learning object or phenomenon studied than before; these critical aspects are identified as aspects that are crucial to mastering the learning object or understanding the phenomenon, and may be constituted by what the learner could focus on or the meanings ascribed to a particular way of experiencing the learning object. It was also highlighted to the teachers how the theory serves as a pedagogical theory and tool (Elliott 2012; Pang and Lo 2012) to support the problem-solving process. Patterns of variation and invariance could be designed with the view that critical aspects that are varied will come to the attention of the learner while other aspects are kept invariant. These patterns draw the learner to aspects that he/she is unaware of previously, and the consequent discernment of these aspects may promote learning. Examples of *patterns of variation and invariance* employed in different learning

studies were provided, such as those that focused on promoting students learning in economics (Pang and Marton 2003, 2005) and physics (Linder et al. 2006). It is worth noting that a genetics example was not included as it was not available then; thus, the teachers were provided other examples.

The introduction of the theory of variation was intended to help explore possible critical aspects and clarify a learning object the teachers might have in mind, but were not able to fully articulate and describe. In this case, rather than focusing solely on the variation, it was hoped for that teachers could develop an understanding of what critical aspects were in relation to how they constitute the learning object, prior to how these aspects may be varied. The hour-long meeting provided enough time only for the introduction of and discussion about the theory. Thus, an in-depth discussion concerning the learning object did not take place. Rather, the teachers were provided with readings (e.g., Pang and Marton 2003, 2005) that could help them further clarify the relationships between critical aspects and learning object.

Meeting 3: Strategies to Overcome the Challenge – Determination of Curricular Flow

With the intent to provide teachers with additional resources and to facilitate the problem finding process, teachers were provided with examples of how their own teaching experiences and knowledge, coupled with the use of research literature and theory of variation, can be drawn upon to help determine the critical aspects of the learning object. A case illustrating how the exploration of the "parts" of a problem (critical aspects) could be used to construct the "whole" (learning object) was presented to the teachers. Although the time gap between Meetings 2 and 3 is short (a week), this activity in the meeting was designed with the intent of giving teachers more time to explore the theory. However, it was not the expectation of the researcher-facilitator for teachers to fully grasp the theory at this point. Rather, they may begin thinking about the challenges in teaching genetics in terms of critical aspects and object of learning.

The teachers were then encouraged to employ this "new strategy" of using the critical aspects to help determine the learning object. Contrary to the intention of the researcher-facilitator, it appears that trying to get the teachers to explore possible critical aspects could have confused them further, rather than to help clarify the problem; it was observed through the audio-video recordings and documented in the researcher's notes that the teachers seemed to have problems discussing in terms of "critical aspects." Recognizing that this could be attributed in part to the "newness of thinking in terms of critical aspects" (Kate's interview transcript), the teachers' interview transcripts also suggest that the difficulty lies in how they were facing difficulties navigating through the "parts" because they have not grasped a sense of the "whole." In other words, the teachers faced the challenge of making sense of the whole-part relationships embedded within a problem they could work on. This suggestion also draws its support from the event that followed.

Emerging from the sense of "frustration" (Kate's interview transcript) was another strategy the teachers proposed to try. In abandoning the intent to determine the learning object then, the teachers suggested exploring the whole genetics unit instead. The teachers started to write on Post-it® notes the different key topics spanning across the six genetics chapters and proceeded to stick them onto a large piece of paper. The teachers began to link different subtopics in the textbooks, e.g., linking the topic of hereditary with mutation, genetic engineering as a "stand-alone" chapter, and linking mitosis and meiosis with cell division. The links were articulated verbally (captured in the audio-video recording). Moving the pieces around, the teachers started to situate new genetics content onto their maps and proposed linking structure of genetic entities (chromosomes, DNA, and genes) with the processes of transcription and translation (new genetics content). The mapping process (Åhlberg et al. 2005), as a way to determine the sequence of the subtopics, thus seems to have directed the teachers' conversations to the relationships between the different subtopics. As described by Chris in the interviews, he felt that the activity prompted the determination of the flow of subtopics based on these relationships rather than the order presented in the textbook.

The teachers anticipated pedagogical and learning challenges associated with the different subtopics through the mapping process. They also discussed different curricular problems even as they explored different possibilities to sequencing the subtopics, such as potential gaps in understandings or difficulties in rearranging the predetermined scheme of work. In rearranging and re-sequencing genetic subtopics differently from the prescribed curricular materials, the mapping process also granted teachers opportunities to discuss and defend their suggestions. What emerged appears to be a new way in which the teachers could approach the problem finding process, which they termed the "determination of curricular flow." The teachers pooled their resources and teaching experiences (manifested in how they drew from these experiences to anticipate challenges and establish links between the subtopics) and quickly established consensus without much tension as to what they would tentatively like to focus on in terms of the object of learning. As observed in the video, all the teachers contributed to the discussion without clear directions from any one member of the team. In fact, when prompted to share about their experiences of determining the curricular flow, the teachers expressed appreciation that the process constituted a good and "new" experience (Kate's interview transcript) to help organize student learning experiences – "the mapping was good" in helping to explore "other possibilities" (Chris' interview transcript). Similarly, the teachers all expressed appreciation for the opportunities to collaborate in this way and to "see another person's point of view" (Pam's interview transcript).

Meeting 4: Problem Found

The teachers proposed to further their discussion on the curricular flow, rather than proceeding to define the learning object; in differing from the researcher-facilitator's suggestion, this was documented as a "critical incident" where the

researcher-facilitator felt that the teachers were beginning to take greater ownership as to what they wanted to do in the allocated time. Jointly, the teachers identified students' potential difficulties in understanding the structural relationships between genetic entities (e.g., genes, DNA, and chromosomes), as well as the relationships between the structural and functional aspects of these entities; these were subsequently documented in the meeting notes. How these difficulties may be further amplified in their students' struggle to link the structure of genes to genetic processes of transcription and translation and to real-life genetic phenomenon (e.g., mutation) was also discussed.

After the prolonged discussion that comprised active contribution of perspectives from all members of the team, the teachers decided to work on what they felt was a fundamental aspect of learning genetics, in other words, the development of a "fundamental capability" that would eventually help the student better understand the different genetic subtopics (Kate's interview transcript). The teachers identified the process of gene expression (including the processes of transcription and translation) as the topic of interest and began crafting the learning object around it. They decided that the learning object would be the development of students' capability to understand and apply the principles of the genetic processes of transcription and translation (new curricular content) to real-life contexts, such as mutation. What is worth mentioning is that the newly identified link between the genetic processes and mutation was established through the application of the theory of variation. As highlighted by the teachers when they were prompted to share about the usefulness of the theory of variation, the teachers made mention of how the theory helped them link the genetic processes of transcription and translation to mutation, a "missing link" (Kate's interview transcript) they would otherwise have failed to pay attention to especially since the two subtopics were taught at different grade levels. According to the theory of variation, varying the genetic processes results in cascading changes (varying gene structure and thus the products of these processes) that may eventually lead to mutation. With this pattern of variation crafted, the teachers (preliminarily) identified the critical aspects of the learning object as the structural and functional relationships between genes, DNA, and chromosomes.

In this context, the teachers applied the variation theory to help organize curricular content, rather than as a learning theory or a pedagogical tool (as reviewed earlier). In addition, the identification of this "missing link" that the teachers focused on subsequently led to the determination of the learning object: in wanting to help students develop the link between the genetic processes and mutation, they articulated the importance of students applying the principles of the genetic processes to help understand genetic phenomenon such as mutation. What is also noteworthy is that the collective identification of this missing link, which the teachers also termed as a "fundamental capability," allowed them to reach an agreement on what the learning object would be. This was observed in the audio-video recording and has been supported by the interview transcripts, where all the teachers mentioned about the importance of this capability to help students learn genetics. The teachers expressed this idea in terms of "stones" and "foundation" necessary for students to "fill in the gaps" in genetics (Kate's interview transcript). During the meeting, the

teachers also expressed their readiness to proceed with the next phase of the learning study when they began discussing how the lessons could possibly be structured. As a result, other possible problems teachers could have worked on were not further explored, thus differing from typical problem finding processes.

Using CPS terminologies, the aspects of the problem that were identified by the teachers when they participated in the learning study can be described as follows. The initial state corresponds to the condition when students experience conceptual difficulties in relation to the genetic processes of transcription and translation, with a particular focus on their nature and real-life applications. The goal state (i.e., the learning object) refers to the development of students' capability to understand the genetic processes described, along with their practical applications. The elements of the problem space that were highlighted include the linkage among and sequencing of curriculum topics, knowledge of students' difficulties, gaps in students' understanding, literature on genetics, and theory of variation.

Facilitating Problem Finding

Drawing from the narrative descriptions above, two themes that emerged from the authors' analysis further explicate the problem finding process and underscore possible modes of action to facilitate teachers' problem finding process: meaningful engagement with the curriculum as a strategy to attain clarity of the problem and teachers taking ownership of their own problem finding process.

Meaningful engagement with the curriculum during the problem finding process. What was evident in the teachers' experiences of the problem finding process was that the opportunity to determine the curricular flow was pertinent in enabling the teachers to clarify the problem they wanted to work on. As demonstrated in the teacher interviews and reflective journal entries, the teachers identified three ways whereby the curricular flow contributed to the determination of the learning object:

1. The discussions enabled the teachers to gain a "more holistic picture" (Amy's reflective journal entry) of the genetics curriculum and the associated challenges.
2. The teachers valued the opportunities to identify the key topics and the links between them and thus articulate often tacit links – "looking at big picture and looking for links between sub-topics was important" (Kate's reflective journal entry). In addition, the teachers appreciated how the discussion allowed for the identification of links that they themselves did not make.
3. The teachers appreciated the opportunities to discuss student learning difficulties and the difficulties in teaching various aspects of genetics, such as helping students link the structural and functional aspects of genes.

As seen from the above, it appears that the opportunity for meaningful engagement with the curriculum (Clandinin and Connelly 1992) supported the problem finding process by allowing teachers to gain a better understanding of the problem. For one, the determination of curricular flow encouraged teachers to carefully study the

genetics curriculum. Moreover, pedagogical challenges, such as students' difficulties in learning genetics and the difficulties in teaching aspects of it, were situated within the larger frame of the entire genetics unit that was mapped. In other words, the teachers identified possible gaps in students' existing knowledge and competencies in relation to specific genetic concepts and capabilities that teachers intended to develop among students; the cause of this gap, or the "cause of imbalance in functional operations" (Ramirez 2002, p. 19), was students' difficulties in dealing with structural and functional aspects of genetic concepts.

Furthermore, mapping of the curriculum could have served as a "common ground" (see Schwartz 1995) for the teachers to situate their subsequent discussion of the problem. The construction of the links between the subtopics embodies what Schwartz described as "shared representation" (1995, p. 349), which acted as a catapult that allowed the problem finding process to take off. By focusing on the links between the subtopics and by engaging in a discourse that require them to explore, suggest, and defend their suggestions of how to sequence the topics, the teachers also began situating difficulties in students' learning in the prescribed arrangement of topics in the curriculum. For example, the teachers highlighted that teaching mutation together with the topic of inheritance may result in students lacking the ability to understand the phenomenon of mutation in terms of its processes. Reordering the prescribed sequence in the textbook, they decided to link mutation with gene expression instead. Examining the interconnection among topics was also emphasized by Ramirez (2002) as an important step in the problem finding process of teacher teams. What has been observed in this study, but was not detailed by Ramirez's, is the importance of going beyond commonly known links which may be found in textbooks to identifying "nonexistent" and yet essential links.

Thus, the "more holistic picture" that the teachers frequently mentioned may be understood as the opportunity to situate pedagogical and curricular challenges into (1) the context of teaching particular topics, (2) the larger context of the genetics curriculum, and (3) the context of their own classrooms, where their prior experiences and knowledge of their students serve to further clarify the challenges in teaching. Seen in this light, the teachers' experiences are a manifestation of how they have meaningfully engaged with the genetics curriculum. Phrased differently, what is suggested is that the process of problem finding is not merely the identification of a problem, but that it requires a process of meaning-making, to be able to tease out the pedagogical and curricular problems embedded within and to situate it in multiple contexts that affect the complex process of learning (see Clarke and Hollingsworth 2002). Consequently, this process of collaborative meaning-making promotes building of a common knowledge base that could potentially enhance the "synergistic benefits" (Nemeth and Chiles 1988, p. 53) from the collaborative problem finding process, a knowledge base situated within the teachers' own classroom contexts.

Although the narrative descriptions are presented in a linear fashion, the teachers' need to revisit the curricular flow in two sessions – including the need to revisit various discussions reiteratively in order to gain a "more holistic picture" – suggests the *complexity* of the problem finding process. Furthermore, as demonstrated above, teachers are required to simultaneously hold multiple aspects of an approach to

curriculum in their focal attention when engaging in problem finding: these include establishing links of explicit (as suggested in prescribed curriculum materials) and implicit (new and often unarticulated links) nature, situating different subtopics within the larger curricular unit, identifying student learning challenges within the topics, as well as negotiating a discourse where varied views can be examined. Following up on the latter, the learning study discourse has allowed for the diverse views of the teachers to be discussed and negotiated – as was noted by Reiter-Palmon and Robinson (2009) – which promoted further sharing of the views among the team (as was also noted by Nemeth and Chiles 1988) and the development of a deeper understanding of the possible problem to address (see also review of Chiu 2008). For example, the participating teachers had varied opinions on what was a problem worth tackling. Some of the teachers wanted to work on gene expression, while others on the newly introduced topic of cell division (including the processes of mitosis and meiosis); the teachers had different assumptions as to what students struggled with in learning genetics. As the teachers mapped the curricular flow and continued to engage in discourse, the integration of varied conceptualizations of the possible problems "provided us [them] with a holistic view of the problem" (Kate's reflective journal entry). As illustrated, the teachers' efforts to create a point of convergence in their diverse ideas about the problem to be tackled by the team widened the common ground among the team members, an aspect crucial in the success of a collaborative process (Nokes-Malach et al. 2012; Roschelle and Teasley 1995). The foregoing points also resonate with Jonassen's (1997) view that identifying problems in ill-defined real-world situations requires consideration of alternative views and analysis of the broad range of knowledge situating the problem.

Teacher Ownership and Empowerment

It is interesting to note how the teachers overcame the challenges of defining the learning object and took charge of the problem finding process, that is, by suggesting the alternative strategy of approaching the genetics curriculum as a whole. The demonstration of teacher ownership and empowerment in the problem finding process situated in the present study resonated with Kincheloe and Steinberg's (1998) assertion of the importance for teachers to engage in the development of their own knowledge. We have seen how the teachers developed their own knowledge through a meaningful approach to the curriculum (discussed above). Similarly, teacher empowerment is also manifested in how a meaningful approach to curriculum also frees the teachers from being "disempowered in their role as information delivers, servants of knowledge and curricula produced elsewhere" (Kincheloe and Steinberg 1998, p. 13). In developing their own knowledge, it appears that the collective interpretations of the curriculum and its associated challenges that emerged allowed for an internalization of the curriculum. This manifested in how the teachers were able to subsequently explain the rationale for choosing the learning object and for the final sequence of the genetic topics. In other words, the teachers were better able to defend their decisions rather than basing it on decisions made by someone else.

Conclusions and Implications

The findings of this study serve as an exemplar of how teachers engage in collaborative problem finding (which is a key part of CPS process) in an authentic setting. We have found that problem finding implemented within PLC initiatives and via the learning study approach is a challenging process that can be streamlined by meaningful engagement with the curriculum and by developing conditions that favor teachers' sense of empowerment.

Teachers' meaningful engagement with the curriculum may be a pertinent aspect of a productive problem finding process within PLCs. In teasing out the pedagogical and curricular challenges associated with teaching a particular unit and then re-situating these key barriers in developing targeted capabilities back into the contexts of the larger curriculum, as well as into the contexts of the teachers' own classrooms, teachers can develop their abilities to negotiate meanings and commit to a learning object. The mapping of the curricular flow also afforded the construction of a common knowledge base through a negotiation and amalgamation of the differences in varied assumptions. This common knowledge base was augmented by the researcher-facilitator's presentation of the theory of variation. Noting that the employment of a theoretical framework is a hallmark of learning study, it can be surmised from the results of this study that elements of learning study can be blended with CPS structures in order to promote efficient problem finding and, perhaps, the entire CPS process. This assertion is in consonance with Laughlin et al. (2003) that underscores the importance of having common knowledge resource to enhance the probability of good team performance in carrying out CPS.

In promoting greater teacher autonomy and empowerment (Carr and Kemmis 1996; Kincheloe and Steinberg 1998) in the context of problem finding, a meaningful discourse around the curriculum may well be an effective platform for teachers to explore their beliefs pertaining to the problem to be addressed. In concurring with the view that teachers must be convinced of the importance of new aspects of teaching (e.g., a problem-solving strategy) to their daily teaching practices in order for them to take an interest in acquiring a knowledge or skill (Abd-El-Khalick and Akerson 2004; Martín-Díaz 2006; Schwartz and Lederman 2002), we make our proposition: the opportunities for teachers to make sense of the problem through mapping (1) *their* own assumptions, (2) *their* collective understandings, (3) *their* own knowledge derived from research literature, (4) *their* situated knowledge about their own students and classroom contexts, and (5) *their* understandings of the pedagogical and curricular challenges onto a learning object may well serve as the necessary motivation for teachers to be engaged in CPS in more empowering ways.

The results presented in this article offer microlevel insights into the process of collaborative problem finding in authentic contexts. We acknowledge, however, that these results, which are based on a single case study, have limited generalizability and applicability. Noting the complexity and challenges faced by a team of teachers during problem finding as part of a learning study and in view of the lack of extant literature explicating this aspect, more studies detailing how teachers craft

the learning object and the challenges faced are certainly worthy of pursuit. In the same vein, more empirical studies need to be carried out to further understand how the formidable process of problem finding in collaborative teams can be facilitated and how different aspects of this process influence the quality of solutions generated during CPS. Another potentially fruitful research direction that would serve as a good follow-up to this study is the determination of ways and creation of environments that foster teacher empowerment, in such a way that teachers become more equipped and prepared to take control of the trajectories of their own PD and make it responsive and relevant to the needs of twenty-first-century learners.

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