Combining the inquiry-based learning and critical thinking frameworks for interpreting the processes of teachers' inquiry into teaching through lesson study

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We combine theories of inquiry-based learning and critical thinking to analyse planning meetings involving teachers and teacher educators as part of lesson study. Combination of the frameworks clarifies teachers' critical thinking related to teaching and learning and teachers' deep commitment to include all students in discussions and inquiry.

Keywords: Inquiry-based learning, critical thinking, teachers' inquiry, dialogic interactions, analytical framework of lesson study.

Introduction

The *CERME13* TWG28 call for papers to contribute to strengthen the connections of the theoretical and methodological issues of research on mathematics teachers learning and working in collaboration, in particular with practice in real-world settings. Recent research has highlighted an important issue of the large diversity of theories and research paradigms in the field. Examples include the various theoretical aspects of teachers' professional development, such as knowledge, beliefs, reflection of different mathematical content areas, together with the alternative values of instructional quality (e.g., Huang et al., 2023; Skott & Ding, 2022). It is thus necessary to develop networking strategies for connecting multiple theoretical approaches, particularly for better communicating and understanding the multi-faceted phenomenon of the field (Prediger et al., 2008). This paper presents our ongoing work on the development of networking strategies for building up a conceptual framework for analysing and interpreting the nuances of teachers' characteristics, occurring in the processes of teachers' inquiry into theory-research-oriented teaching in the collaborative settings of inquiry-based learning (IBL) lesson study (LS) in Norway (e.g., Grimeland & Sikko, 2019). We refer to the term 'combining' in the current stage of our work, because the two conceptual frameworks (IBL and critical thinking) are juxtaposed. Combining the two frameworks is necessary to enable us to analyse and interpret the dynamic processes of teachers and facilitators' interactions during lesson study involving IBL in primary mathematics classrooms. The research question in this paper is: What characteristics of teachers' critical thinking can be identified in the dynamic processes of teachers' inquiry into IBL-oriented lesson planning together with facilitators in a primary mathematics LS?

The need for networking theoretical framework for exploring teachers' learning through lesson study

In this section, we discuss the key research issues concerning the need for networking theoretical frameworks for research in LS settings. Huang et al. (2023) show that although the effects of LS, such as on teachers' learning and building of professional learning communities, have been widely documented, it is still an emerging field in which a diversity of theoretical approaches is needed for

understanding and guiding ways of professional learning and action. The diversity of theories can be viewed either as a problem or as a resource (Huang et al., 2023). Our intention in this paper is to contribute to the discussion of the combination of theories for understanding the empirical phenomenon and data in the LS collaborative settings addressed in CERME13 TWG28. We highlight some new efforts for the networking of theories made by researchers for research in LS in the European contexts. For instance, Clivaz et al. (2023) present the networking between a content analysis framework (Mathematical Knowledge for Teaching Problem-Solving) and a dialogic analysis framework (Lesson Study Dialogue Analysis). One significant point made in Clivaz et al. (2023) is about the development and use of the *Interthinking* framework to analyse how dialogic interactions contribute to constructing teachers' mathematical problem-solving knowledge.

> In this approach, spoken language is …, viewed as central, as it is directly linked to "collective thinking", which is seen as a dynamic and creative process. …, the focus is on language exchanges, as they are seen as crucial to understanding how ideas and knowledge are co-constructed during a conversation. (p. 24)

This is very much in line with our focus in this paper. We are concerned with the utilisation of an existing IBL framework of professional knowledge and learning that is taken as a premise in the LS, and also with the development of teachers' critical thinking on the value and ways of IBL-oriented teaching in the collaborative setting of LS. Jessen et al. (2023) investigate the use and potential of a theoretical combination of Realistic Mathematics Education and the Theory of Didactic Situations to support the LS and research teachers' learning in upper secondary mathematics in Denmark and the Netherlands. Noticeably, an important difference is highlighted regarding the role and the use of theory in LS in different cultural contexts (e.g., Japanese vs European contexts). In Japan, LS draws on and contributes to theoretical principles and methods of teaching (e.g., open-ended approaches) that enable teachers to communicate precisely about teaching designs, including key aspects of school mathematics. By contrast, theories in the European contexts are usually used and developed by and for researchers (e.g., the Theory of Didactic Situations in France). When LS is initiated and supported by university researchers, it is common that the researchers draw on theoretical perspectives from their scholarly work in order to make sense of – and in – the LS activity. Jessen et al.'s study particularly highlights the important role of university researchers in the development of new practical combinations of different, complementary theoretical tools, which aim to support LS in a European context.

Combining the conceptual framework of critical thinking with the IBL framework

We take the dynamic view of theories suggested by Prediger et al. (2008) in our empirical LS study. That is, we consider the two theories (critical thinking and IBL) as tools in use rooted in some kind of philosophical background in the mathematics education field. Yet they are not ready for use as they need to be connected to our empirical study and data. In this section, we briefly present how we combine the two frameworks for a networked understanding and interpretation of the empirical phenomenon and data of our LS. The concept of critical thinking has been introduced into the national curriculum in Norway as one of the overarching goals and is emphasized in varied situations of school

education (Kunnskapsdepartementet, 2017). As the term is new (in the curriculum) and misconceptions about critical thinking are common (Bailin et al., 1999), it is challenging for teachers and teacher educators to understand what critical thinking really means, and how to foster or implement it in schools across the different disciplines and different grades. In our IBL LS project, an effort has been made to implement a main idea with the IBL approach, viz. to get students to think, look for alternatives, and discuss with their peers (e.g., Artigue & Blomhøj, 2013). In this way IBL is closely connected to critical thinking: by engaging with IBL students develop their thinking and thus may be able to apply their thinking in critical ways. Nevertheless, it takes effort for teachers to engage themselves in inquiry into teaching mathematics with an inquiry-based approach (e.g., Kang & Keinonen, 2016). There is thus a need to negotiate the meanings of developing pupils' thinking in critical ways by the IBL approach between teachers and the curriculum goals via facilitators. Reviewing different philosophical positions, Mason (2007) extracts three aspects of critical thinking leading to five categories (pp. 343–344): (1) Skills of critical reasoning, which stems from a view that emphasizes critical thinking as a skill independent of discipline, emphasizing ability to apply critical thought to different disciplines. (2) Dispositions, which stresses the importance of being inclined to look for and make decisions based on rationales; including (2.1) critical attitude and (2.2) moral orientation towards critical thinking (3) Knowledge of content, including (3.1) knowledge of a particular discipline, which stresses that critical thinking is dependent on knowledge of a particular field and thus must be seen as particular to that field and not transferable to other disciplines, and (3.2) knowledge of concepts of critical thinking. It is for example difficult to think critically about mathematics without knowledge of mathematics. Accordingly, we use the three aspect and the related five categories to develop an analytical framework of critical thinking in the analysis of the data of the IBL LS project (see Table 1). The IBL conceptual framework developed in the EU PRIMAS project is summarised in five components as follows: (a) Valued outcomes (Inquiring minds, being critical and creative, Preparedness for uncertain future and lifelong learning, Understanding of nature of science and math); (b) Classroom culture (Shared sense of ownership and purpose, Contributions and mistakes are valued, Dialogic); (c) Learning environment (Open problems, multiple solution strategies, Access to tools and resources, From problems to explanations, not from explanations to practicing); (d) Teachers role (Foster and value student reasoning, Support and scaffold students, Connect to students' experiences); (e) Students role (Pose questions, Engage, explore, explain, extend, and evaluate, Collaborate) (Artigue & Blomhøj, 2013). For teachers to engage students in inquiry of mathematics, teachers themselves should engage in inquiry into the teaching of mathematics (e.g., Jaworski, 2006). It has been well documented that it is essential for teachers to develop their practices, cooperation with both colleagues from within school and knowledgeable others (facilitators) from outside school (e.g., Jessen et al., 2023). We are therefore interested in combining the IBL conceptual framework with the critical thinking framework for deeper understanding and interpretation of the characteristics of teachers' critical thinking when engaged in inquiry into the teaching of mathematics in the LS. Mason (2007, p. 344) points out that an integrated view of critical thinking should take all the five categories into consideration (see five codes in Table 1 below). This wholesome and integrated view of critical thinking thus fits in well in the analysis of the nuances of thinking processes occurring in the interactions among participants in the IBL LS cycle. The combination of the IBL framework and Mason's critical thinking framework provides a

good starting point for us to develop a more comprehensive analytical framework for interpreting in depth the nuances occurring in the processes of the teachers and facilitators' collaborative learning and working through the IBL LS project.

The context of the IBL LS project

The IBL LS reported in this paper was part of a larger project involving two primary schools in central Norway. The project has as its goal to enhance the use of IBL pedagogies in mathematics and science through engaging teachers in LS. Explicitly, the goals of IBL were being defined in the project as focusing on inquiring and explorative activities, student engagement, student wondering, reflection, critical thinking, asking questions; open tasks with multiple solutions (or solution strategies), use of professional language, cooperation, and communication. In the IBL LS reported in this paper, there were six participating teachers: TP (the school principal), TI and TR (grade 1 classroom teachers), TS and TT (grade 2 classroom teachers), TM (special education teacher who supports the classroom teachers). There were three participating facilitators (university teacher educators): DS (mathematics teacher educator), DR and DJ (science teacher educators). The school had previously participated, with the facilitators, in two projects focused on IBL, but of the teachers only TP had been actively involved in those previous projects. The lesson being planned was to be taught in two grade 1 classes (students 5–6 years old). The study follows the four stages of a cycle of LS (Lewis et al., 2019). Prior to the first meeting of planning the lesson, the teachers had agreed on a proposal for theme for the lesson study and communicated this to the facilitators via email. The facilitators also met to study and discuss the preliminary plan received from the teachers before the planning meeting with teachers. At the second stage, the teachers and facilitators met together in the school. The starting point for the discussion was the preliminary plan made by the teachers independently. The teachers explained their reasoning for the plan, and facilitators made comments according to the facilitators' independent study and plan meeting, bringing their suggestions for modifications into the discussion. Discussions focused on the openness of the tasks, the possibilities for inquiry and exploring for students to perform during the activities, and the relation to the mathematical goals. After agreeing on the theme and the activities to be used, the final lesson plan was outlined. The planning meetings are audio-recorded.

Data and data analysis procedure

Given the research question of this paper, we select the first lesson plan discussion meeting for constructing the analytical framework (see Table 1) and to build on our codes and categories for the research purpose. The planning meeting is around two hours long. Audio-recorded data is converted to written transcript for the analysis. Audio and transcripts are originally in Norwegian. In this paper the focus is on understanding the dynamic process of teachers' inquiry into the IBL-oriented teaching through the dialogic interactions in the LS meetings. We thus particularly seek to understand and interpret what characteristics of teachers' critical thinking can be identified by the codes, and what new subcodes are necessary to be set up towards the development of the analytical framework for studying the IBL LS project data, also in other countries. Some subcodes in Table 1 are developed for conceptualizing the different characteristics of critical thinking demonstrated in the process of

facilitators' and teachers' collaboration in the project. The subcodes developed, and to be reported in in more detail in a forthcoming paper, are presented in Table 1.

Table 1: Combining the IBL and critical thinking frameworks

Mason's (2007) five categories as the main codes of critical thinking and subcodes developed in IBL LS	Five components of the IBL conceptual framework (Maaß & Reitz-Koncebovski, 2013)
(1) Skills of critical reasoning Code 1. Ability to assess reasons properly. *(2) Dispositions* Code 2. Critical attitude, like scepticism, tendency to ask probing questions, commitment to express such attitude. Code 3. Moral orientation which motivates critical thinking. *(3) Knowledge of content* Code 4. A particular discipline. Code 5. Concepts of critical thinking.	(a) Valued outcomes (b) Classroom culture (c) Learning environment (d) Teachers' role (e) Students' role

Some challenging issues arose in the data analysis, for instance, what is to be coded as critical thinking regarding the use of IBL-oriented pedagogy, and what is not? As pointed out by Clivaz et al (2023), in the coding process researchers do not code an isolated statement, but a statement in the logic of a dialogue. In the process of coding and building up new codes it was necessary for the researchers to simultaneously address both the deductive thinking (from the combined conceptual framework to our data) and the inductive thinking (from our data to the conceptual framework) processes. The data analysis was shared and discussed between the researchers. In combining the two conceptual frameworks, we seek to build up sub-codes under each category and code, and if necessary, new categories and codes are added, from the inductive analysis of empirical data. In our initial data analysis, we have identified and developed subcodes of Mason's (2007) framework to further highlight the distinct characteristics of critical thinking. The combined frameworks form a skeleton to be used in the data analysis.

Findings

An important part of the teachers' role in IBL is to foster and value student reasoning (IBL code d), and to encourage students to collaborate and explore (IBL code e). Our first finding of the data analysis is that one characteristic of the teachers' critical thinking in their inquiry into IBL teaching can be identified by their concern in their dialogic interactions in the lesson plan meeting of the importance to let pupils discuss amongst themselves and explore the activity. The learning goal, that was to be the theme for the planned lesson, was "to converse about and explore structures and patterns". The teachers discussed the issue of how to best engage students, whether to ask them to make hypotheses before they started working, or not:

TI: I am thinking that the discussion is most important, if they are working with like open tasks, instead of them believing too much, as here they are supposed to make drawings and explore, so it is more about exploring than believing. Since there is no concrete answer. Hypothesis is for situations where there is one particular correct answer, isn't it?

DR: It doesn't have to be.

TI: A hypothesis is what they believe, isn't it? What do you think, then it is a thought process.

This also concerns the classroom culture (shared sense of ownership and purpose, dialogic: IBL code b) and learning environment (IBL code c). Subcode 2.2 (Commitment to engage students in discussions, with a commitment to express a critical attitude) is identified. Teachers are concerned that all students should have the opportunity to engage with the activity (Subcode 2.2) and discuss how to best steer students towards inquiry, with a commitment to develop students' thinking (Subcode 3.1)

TR: I believe that we kill creativity if we ask for a common hypothesis, since then they will all come to the same conclusion. But if we let them go to their seats and then tell us what they think, I believe we will get different answers.

TS: Yes, that is what I meant, that if we share too much at the beginning, it is easy to think that those who usually are correct have the conclusion, and then we don't let those who don't talk most loudly try.

The second finding from the data analysis is of teachers' moral orientation (critical thinking code 3) towards inclusivity, that is, to include all students (IBL codes d, e). Thus, a new subcode 3.2 Moral orientation to inclusivity in inquiry, might be helpful to understand the characteristics of the teachers' critical thinking. The next transcript points in the same direction:

TI: And it is a good point what you said about how do you think it continues, because then you are opening up for those who are not so strong, as well. They can continue colouring or as they believe it continues, since it doesn't stop.

TS: Or they can write that it increases, they don't have to write a number. But it is also a hypothesis that I think it is going to increase (...) they don't have to write a number if they are uncertain.

TI: If we set the limit somewhere that everybody has a chance to meet, I think, then we can motivate those that work further, so that everybody gets a sense of mastering. A bit boring to never be able to reach twenty.

Teacher TI wants to include students who don't feel mathematically strong, and teacher TS launches an idea how this can be done. The data analysis further shows that both teachers express awareness of the classroom culture and learning environment (IBL codes b, c) and a moral attitude for inclusivity (subcode 3.2). One can also consider it within critical thinking code 4, knowledge of a particular discipline (IBL code a) as knowledge of the discipline of teaching primary mathematics (new subcode 4.2).

Discussion and conclusion

In this paper we present our ongoing work of the development of networking two conceptual frameworks for analysing and interpreting the characteristics of teachers' critical thinking during their inquiry into the IBL-oriented teaching through the LS in Norway. Findings are presented in Table 2 to show the important characteristics of the teachers' critical thinking. One significance of the development of our analytical framework by combining both the IBL and the critical thinking

frameworks is of enabling researchers to highlight the teachers' voices and characteristics of their pedagogical thinking through the dialogic interactions between the teachers themselves and with facilitators throughout the LS meeting.

Table 2: Subcodes developed to interpret teachers' characteristics in the combined analytical framework of the IBL LS project

Subcode 2.2. *Commitment to engage students in discussion (talking to each other; letting students freely express and share their thinking) in inquiring about IBL codes b, c, d, e.*
Subcode 3.1. *Steering students towards inquiry, thus commitment to develop students' critical attitude; commitment to develop students' thinking in inquiring about IBL codes d, e.*
subcode 3.2 *Moral orientation to inclusivity in inquiry about IBL codes b, c, d, e.*
Subcode 4.2 *Knowledge of the discipline of teaching primary mathematics in inquiry about IBL code a.*

As pointed out by Clivaz et al. (2023), at the research methodological level of the networking theories, the analysis involves a "systematic coding" approach (in our study all participants' talks in the lesson plan meetings, classroom observation, post-lesson debriefing meetings, and teachers' interviews are coded) which is extremely time-consuming. Nevertheless, it allows for a very detailed analysis of the interactions in relation to the evolution of knowledge accumulated through participants' openness and collaborative inquiry into the LS-oriented practice (in our project both teachers and facilitators). At this initial stage of our data analysis, we carefully refer to Prediger et al.'s (2008) strategies of 'combining' the two frameworks (Critical thinking and IBL), in that combining theoretical approaches enable researchers to gain a multi-faceted insight into the empirical phenomenon of our LS project. Another significance of the development of the analytical framework that combines both IBL and critical thinking frameworks, is development of a deeper insight into the teachers' practical field for teachers' professional development. The function of theories in the practices of mathematics education research urges a wider notion of theory which not only keeps the idea of a structured building of knowledge, but also includes the function of theories as tools which help to produce knowledge about what, how and why addressed in our empirical LS (Prediger et al., 2008). Huang et al. (2023) suggest the use of the strategies of synthesizing and integrating locally on the development of theories into a new framework for research of LS. Such a development of theories must integrate some concepts or thoughts/views of the practitioners, regarding the questions raised in Jessen et al. (2023) of the role and use of theory to support teachers' practices in their real working context, and without the intensive involvement of university researchers in their lesson study at work.

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