

## **Can public knowledge be created through practitioner research? - learning studies and variation theory as mechanisms and strategies behind knowledge production in teachers' research**

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*In this paper, we address the question if teachers' collaborative research can produce practice-based knowledge relevant beyond the borders of the local school context. It has been argued that teachers' collaboration in professional learning communities (PLC) are aiming at practical innovations and change foremost in teacher learning, and thereby do not strive to create public practical knowledge beyond the borders of the local school. The purpose of this paper is to discuss a particular type practitioner research in schools, a type of theory-based lesson study, that have shown to have potential of creating knowledge products that enhance student learning that also are sharable between teachers.*

### **Introduction**

The purpose of this paper is to discuss the character of practitioner research in schools and the question asked is: *Can a specific form of teachers' research produce practice-based knowledge relevant beyond the borders of the local school context?* The possibilities for creating public knowledge through practitioners' research have been questioned by for example Enthoven and de Bruijn (2010) who in an extensive literature review, concerning professional learning communities (PLC) and communities of practice (CoP), focus the question of which mechanisms can be identified as enabling practice based knowledge products. They found that objectives and intended products are rarely clearly defined and operationalized in practitioner research conducted within professional communities. Instead, teachers' collaboration seemed to be aiming at practical innovations and change through teacher learning, and not through evaluation of the innovations, and that the practitioner's networks were not used to create public practical knowledge beyond the borders of the local school. In what way, the research contributes to students' learning was also found hard to assess. Enthoven and de Bruijn (2010) consider PLCs and CoPs as networks within and between schools with a common intention of collective learning and development of a professional community that share and critically interrogate its own practice. Two main aims of CoPs and PLCs are identified in Enthoven and de Bruijn's article; the first is learning in terms of professional development of its members, and the second is the creation and sharing of knowledge. However, through their review, they conclude that there was no clear collective understanding of the sort of knowledge intended to be created or of the strategies and mechanisms contributing to the creation of that knowledge, neither within nor beyond the borders of the local context.

In contrast to this, Morris and Hiebert (2011) have, by studying the quality movement in healthcare science and lesson studies in Japanese schools, found three characterizing features that enabled the construction of knowledge products in practitioner research: The first characterizing feature is shared ownership of problems across the system, problems that the products help to solve. Unless all participants are working together to find solutions for the same problems and if the solutions do not improve the situation at the working place, there is no reason for them to create problem-solving products. Moreover, when the progress in problem solving is evaluated, the participants' commitment to solving the problems is displayed more clearly. The second feature concerns the research methods that are commonly used to test and revise the shared products. Morris and Hiebert (2011) wish to highlight the value of "small tests of small changes", because it can be associated with the kind of knowledge products created by practitioner research and with research methods often ignored or dismissed in descriptions of scientific approaches. The third characteristic feature are knowledge products that are jointly created and harvested from participants with different kinds of knowledge and competence, thus contributing with multiple sources of innovation, that more effectively help to solve problems in the profession.

### **Educational research, basic, applied or both?**

The application of educational research in practice is indeed problematic and complex. Therefore, we want to propose, as well as Gibbons (1994) and Stoke (1997), that knowledge production would benefit from moving towards the context of application and that practitioner research might be both immediately useful and contribute with theoretical knowledge. Stoke (1997) uses Pasteur's quadrant (Fig. 1) as an illustration of how scientific findings can be valued in relation to their generalizability and practical outcome. Stoke takes Pasteur's discovery of microorganisms as an example of good science that has its origin in a practical problem, a discovery that contributes with both theoretical and practical outcomes and combine a high level of generalization with the production of practical applications. Stoke (1997) argued against the one-dimensional view of the relationship between basic and applied research and suggested that it instead should be represented in a two-dimensional space with both production of basic knowledge and useful applications in parallel. Research in the context of its applications might then be both immediately useful and contribute with new and basic knowledge.

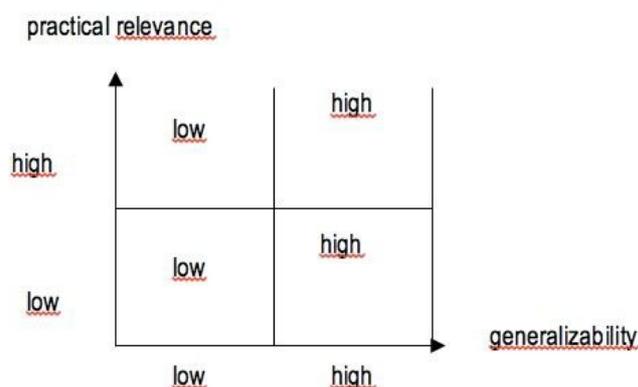


Fig. 1 Pasteur's quadrant (Stoke, 1997).

To find out whether practitioner research can be recognized as a legitimate knowledge source that produces knowledge relevant beyond the borders of the specific context, Enthoven and de Bruijn (2010) in their review searched for mechanisms that enable this kind of knowledge production. They found that mechanisms for producing knowledge relevant beyond the local school context lacked. We will argue that teachers' PLC can conduct research that is relevant for practice in a local context, as well as contribute with theoretical findings that might be useful for others. We illustrate our arguments with examples from learning studies where such knowledge products were produced and describe the process for creating them.

### **The role of theory and systematic inquiry in teachers' research**

The idea of researching classroom teaching and learning with teachers—not on teachers—was among the first recognized by Lawrence Stenhouse (1975). However, teacher research sometimes seems to be more concerned with teachers' professional development than with the generation of knowledge (Carlgren, 2012). Morris & Hiebert (2011) have, by studying lesson studies in Japanese schools, found those characterizing features that enabled the construction of knowledge products in practitioner research. However, the role of a theory in lesson study is mostly unclear or rarely made explicit (Elliott, 2012). We suggest that if the knowledge products of teachers' research are to combine practical relevance with some degree of generalizability, that systematic inquiry and theory is needed to investigate and improve the quality of teaching actions and how they affect students' learning (Elliot, 2012; Fernandez, 2005; Nuthall, 2004). The kind of teacher research we will report on here, the Learning study (Marton & Pang, 2003; Marton & Runesson, 2015), is underpinned by variation theory (Marton & Booth, 1997; Marton, 2015), which will be described in detail below. Our suggestion is that theory-informed teacher research, as learning studies, may offer more than just a reflective practice, but also a form of practice-based research where knowledge is produced within the process. Learning study, we suggest may have elements that provide the necessary mechanisms for practitioner research and offer the basis for producing knowledge that can be made public, shared and improved. From this follows that practical relevance of practitioners' research must not exclude some degree of generalizability, if the results can be used, tested and developed by other teachers and researchers in other contexts (Kullberg, 2012; Morris & Hiebert, 2011; Runesson & Gustafsson, 2012). In this paper, the character of such knowledge products will be discussed with concrete examples.

#### *The Learning study*

The overall aim for a learning study is to find out why certain objects of learning are difficult to learn, as well as the best ways to improve teaching and learning those objects. The resulting research product is a specification of what is critical for the development of a specific capability for a specific group of learners, together with a description of ways of presenting and sequencing the content (in e.g. tasks) in order to make it possible for students to discern those critical aspects and thus, make learning possible. The learning study shares many features with lesson study, and could be seen as a type of theory-informed lesson study. In the same way as a lesson study a

group of teachers (about three to five) work with an iterative design of planning, implementing, observing and revising one single lesson multiple times. In most cases, the variation theory of learning (Marton, 2015), is used to analyse and plan the lessons, although other theories have also been used. An important feature of a learning study is that students' knowledge before and after the lesson are explored by means of a test or interview in order to make conclusions about what could be critical aspects. A learning study is often conducted during one semester, have about six to ten meetings, and three to four video recorded research lessons.

Just as with lesson study, there are reports on the positive effects of Learning study on teachers' professional development (e.g. Kullberg et al. 2016; Lo, 2012; Lo, Chik & Pang, 2006; Nilsson & Vikström, 2015). Kennedy (2016) has in her review of professional development programs identified a problem with the fact that most PD programs typically meet with teachers outside of their classroom, yet they expect the program to alter teachers' behaviours inside the classroom. They are at risk for what Kennedy called the problem of enactment, a phenomenon in which teachers can learn and espouse one idea, yet continue enacting another without being aware of the contradiction. As a learning study is conducted within teachers' own practice this problem might have a better chance to be avoided. In a learning study, researchers and teachers work together as colleagues, something that Kennedy (2016) finds valuable, with a common interest of solving problems experienced by the teachers and thus improving practice. But, although teachers learn from learning study, the aim of the process is beyond teachers' professional development, since it is to produce knowledge that is shareable and can be utilized in other contexts. With this purpose, learning study is in line with Morris and Hiebert's (2011) claim that lesson study is a system that can create shared instructional products that guide classroom teaching. The instructional product generated in a learning study is a theoretical description of the object of learning; how it is constituted in terms of its critical aspects.

### **Variation theory: The object of learning and critical aspects**

In a learning study framed by variation theory, the object of learning is the focus. Basically, the object of learning is an answer to the question: "What is to be learned?", defined as the critical aspects that are necessary for the learners to discern to understand a certain content in a specific way. From a variation theory perspective, learning is seen as a change in ways of experiencing, and learning failures is explained in a specific way; when learners fail to learn, what was intended, they have not (yet) discerned aspects necessary to discern. So 'what is to be learned' are things that the students have not yet learned, but which are necessary for attaining particular educational objectives (Lo, 2012; Marton, 2015). Thus, the critical aspects must be empirically found for every group of learners.

To answer to the question "What is to be learned?", only regarding aspects of the concept from the point of view of the discipline it is not sufficient. Critical aspects cannot be derived from the subject matter only, but needs to be explored and identified in relation to the learners and tested in the classroom (Mårtensson, 2014; Pang & Ki, 2016). Furthermore, critical aspects are not identical to what students have problems with, although these give keys to what the critical aspects might be. Similarly, what has been found being problematic and reported in research literature is a valuable source for anticipating critical aspects. For example, the learning studies described in Vikström (2014) used results from science education research as resources when

identifying critical aspects and designing lessons. This can also be seen as an example of how the learning study framework can help bridge the gap between theory and practice. Sometimes unexpected results in a learning study can lead the team to identify aspects critical for students' learning, however initially taken-for-granted and thus, beyond teachers' awareness. When the learning study team iteratively test different ways of handling the content together with students' learning as a point of reference, the critical aspects emerge and become more and more specified (Mårtensson, 2015).

### *Variation theory as a design tool*

Besides providing theoretical concepts (like object of learning, critical aspects) that enables the team to have a common focus and common language to talk about teaching and learning, it can also be used for designing the lesson. The object of learning is central in variation theory. The object of learning concerns a specific way of understanding something, such as a particular content taught in school. To experience an object of learning in a certain way, the learner has to be able to discern certain aspects of that object at the same time. Any content has many aspects, but not all aspects are critical in regards to the specific object of learning. Learning is a function of discernment, and discernment is a function of variation. We cannot discern a critical aspect of an object of learning if we do not experience some kind of variation, or contrast, in relation to that aspect. Therefore, to make learning possible, certain patterns of variation must be manifested in the classroom, patterns that make simultaneous discernment of critical aspects possible (Marton, 2015; Marton & Booth, 1997; Marton & Tsui, 2004). When comparing two lessons arranged similarly and with the same topic taught, several studies have demonstrated that differences in the pattern of variation seems to have a significant role for student learning (e.g. Kullberg et al., 2014; Lo, 2012; Pang & Lo, 2012). Throughout a learning study, and with the object of learning as point of departure, variation is applied in three ways (Lo, 2012; Pang & Lo, 2012):

- Variation of students' ways of understanding the object of learning.
- Variation of teachers' understanding and ways of dealing with the object of learning.
- Variation as a guiding principle for pedagogical design; identifying critical aspects, creating patterns of variation in a systematic way to enable students to discern those aspects of the subject matter.

### **Learning study-both professional development and knowledge production?**

By collaboration in a learning study, teachers are able to learn about the relationship between teaching and learning, that is what was intended, what was enacted and what was learned of the object of learning. It is the how the content is handled and taught in the lesson and how that is reflected in students' learning that are analyzed throughout the process. A pre-test is used in an attempt to reveal students' prior knowledge, aspects that define different ways of understanding the object of learning and aspects that need to be pointed out in the lesson. When planning the lessons, patterns of variation that could be used and tested when teaching the lesson are agreed

upon. After the lessons, when the video recorded lessons are analyzed in relation to the results of the post-tests, the patterns of variation that improved students' learning are found. By this, teachers learn how to use variation theory in practice and translate their findings into teaching activities that are successful, thus by this avoiding Kennedy's (2016) *problem of enactment*, since they study and enact teaching in their own practice.

### *Identifying the critical aspects by means of learning study*

In general, a learning study involves teachers, often in collaboration with a researcher, in research lessons that are designed, observed, analyzed and modified in a cyclic way. Critical aspects are relative to the educational objectives, but they are also relative to the learners: they differ with the learners; "critical aspects are relational in nature in that they are related to the qualitatively different ways of experiencing the same phenomenon manifested by learners" (Pang & Ki, 2016, p. 6). Therefore, it is necessary to deeply study the different ways the students experience or understand the phenomenon (Marton, 2015). This is usually done by analyzing students' answers on diagnostic pre- and post-test, either as paper-and-pen test and/or in an interview. From the analysis, hypothetical critical aspects are identified. Based on these findings, the research lessons are planned to make the assumed critical aspects discernable. In this way, the classroom becomes a "laboratory" (Elliott, 2012; Dewey, 1910/1974) where hypotheses of conditions for learning can be tested. A careful analysis of data of the outcomes on the post-test (did the students respond differently to the tasks in the post-test compared with before they were taught?) and the video-recorded research lesson, give further insights into what is critical for learning and how the content must be handled to promote learning. This becomes the basis for the planning of the second lesson in the cycle, taught by a new teacher, and to new students, and again the observed/recorded lesson and the diagnostic post-test are analyzed. The iteration proceeds until all classes in the learning study are taught. The critical aspects that are found in the process are the knowledge product of a learning study. In short, learning study is a type of theory-based teacher research aiming to find and create the necessary conditions for learning of specific objects of learning, in other words: make learning possible. Carlgren (2012) suggests it is a type of "clinical research" for subject matter didactic research. In the following we will use Enthoven and de Bruijn's (2010) and Morris and Hiebert's (2011) conclusions as point of departure and argue that variation theory and Learning studies may offer the mechanism and strategy they searched for.

### *Defined and intended products as factors in teachers' research*

Enthoven and de Bruijn (2010) found that objectives and intended products were unclear in the PLC and CoP networks described. We want to argue that in a learning study this is not the case, on the contrary, there is a clear intended product that represents the objective of the research process. Teachers' professional object can be defined as teachers' ability to make learning possible for students. According to variation theory, this means that a teacher needs to be able to conduct certain patterns of variation when teaching, for example bring out contrasts that make it possible for students to discern the aspects that are found critical for a certain object of learning that is, what the students need to learn to 'see' (Marton, 2015). Therefore, we argue, the objective

of learning study is clear and the intended research products are well defined: To find the specific critical aspects for a specific object of learning and a group of learners, and create patterns of variation that make it possible for the students to discern those aspects is the aim of lesson study.

### *The contribution to students' learning*

According to Enthoven and de Bruijn (2010) it is hard to assess in what way PLCs and CoPs have the possibility to contribute to students' learning. Desimone (2009) suggests more work that links professional development and changes in teaching practice to student achievement is needed. As the objective for a learning study is to find ways to improve teaching and learning of certain objects of learning, the possibility to contribute to students' learning is obvious and by the student pre- and post-tests in the cyclic process students' learning is continuously assessed. According to Guskey (2002) teachers seldom change their practice until they have seen the benefits to students' learning. We suggest that studying this relationship between student learning (how they experience what is taught and what they need to learn) and teaching (what critical aspects need to come to the fore and how this can be taught) can generate knowledge about the learning of students, as well as knowledge about teaching the particular topic. In reported studies, students' results were usually better after the second or third research lesson developed than after the first lesson (Cheung & Wong, 2014; Marton, 2015; Kullberg, 2010). It has also been indicated that students with fewer of the prerequisites for learning usually learn the most and the difference between initially low- and high-achievers reduces (Runesson & Kullberg, 2010).

With the following three studies as an illustration, we want to suggest that learning studies are characterized by those features that Morris and Hiebert (2011) proposed; *shared problems that the participants want to solve*, and *innovations that are tested and revised* resulting in jointly created instructional products.

## **Knowledge products of learning studies**

We base our argument that practitioner research can produce knowledge relevant beyond the borders of the local school context on examples from three learning studies. One study (Vikström, 2014) exemplifies the character of an instructional product of a learning studies, in terms of specification of critical aspects for learning the concept of matter in natural science and how that could be taught to enhance student learning. Two studies (Kullberg, 2010; Runesson & Gustafsson, 2012), will illustrate how descriptions of identified critical aspects from a learning study in one context, and their effects on student learning, could be shared, implemented and developed in a new context when used by other teachers.

### *Critical aspects as knowledge products*

In a learning study project described by Vikström (2014) a group of secondary school science teacher, and their students grade 7 and 8, conducted three learning studies concerning three different science contents; atoms and molecules, photosynthesis and solution chemistry. At first, the teachers focused more on general teaching actions and less on the object of learning. As the process proceeded, the teachers' discussions and ways of offering the students the object of learning became more specific, a result supported by Holmqvist (2011) who also conducted three learning studies during three semesters. When variation theory was used as a tool during the process it helped the teachers to focus on finding the critical aspects of the objects of learning that were dealt with, and to try out patterns of variation that enhanced their students' learning. We believe that this was made possible by carefully studying the students learning before, and after, the lessons and how this was related to what was manifested, or not, in the lessons. Through the process of learning studies, a "science of teaching" (Elliot, 2012) was developed as the teachers were given an opportunity to pose critical questions about the subject matter taught, as well as about their own tacit and largely unexamined theories about the knowledge of learners and learning. Before the learning studies, the teachers were well aware of the students' difficulties concerning the content that were dealt with, but they were not able to express in any detail what those difficulties consisted of, or how to overcome them. By participating in learning studies, they became aware of things they had previously taken for granted; they became able to define critical aspects that they had not been aware of before and they became able to design their lessons based on their findings. Similar conclusions are drawn in Bergqvist (2017) where teachers through participating in a learning study became able to express their students' difficulties with the concept of chemical bonding in a much more detailed and explicit way.

The different contents that were dealt with in the three learning studies in Vikström's (2014) study, had one thing in common; to understand the phenomena as was intended, presupposed an understanding of the particulate character of matter. The teachers' ongoing exploration of teaching the concept throughout all three learning studies revealed what was required for the students to grasp concerning the concept, something that in turn supported their understanding of the different

phenomena that were dealt with. When summarizing the experiences from the three learning studies, the critical aspects and useful teaching strategies was formulated regarding teaching the concept of matter, aspects that seemed to be critical for understanding various phenomena in science. This, we suggest, represents knowledge products that might be useful for other teachers.

What concrete knowledge products, in terms of critical aspects and instructional strategies, were then produced in the three learning studies reported in Vikström (2014)? In the first learning study, it was found how important it was to point out that atoms build up everything material around us, as well as the importance of making a connection between the macroscopic and sub-microscopic level. The teachers were surprised by the fact that 95% of the students in the pre-test were unsure about this. Thus, the teachers concluded that this was a critical aspect, and a lesson plan was agreed upon. Groups of students were asked to divide well-known objects (air, water, chair, ear, flower, bicycle etc.) into smaller and smaller pieces, moving from the macroscopic level to a sub-microscopic level. The groups presented their results and the teachers took notes on the whiteboard. In the discussions about the variety of examples, and with the help of the teacher, they reached the atomic level and realised something invariant all the examples had in common; they all consisted of atoms.

Following variation theory, and in order to create a contrast, the second part of the research lessons in the first learning study concerned where atoms are *not*. New examples were given (sunlight, lamplight and heat). The task was the same as with the material examples. The students came up with more or less imaginative suggestions, but soon they realized that it was impossible to divide the new examples into smaller components or particles in the same way, and that sunlight and heat was something non-material that did not consist of particles at all and thereby they discerned the difference between matter and energy. This was something the teachers had never thought about, that the students understood the fundamental difference between matter and energy was something they had taken for granted. The teachers realised that this difference was made clear to their students by treating the two concepts simultaneously and thereby creating a contrast that made this critical aspect possible to discern. The importance of this critical aspect became even clearer in the second learning study about photosynthesis as it was found that one difficulty with understanding the complex process was to understand that plants are not build up with sunlight, but with atoms from carbon dioxide and water, and that sunlight is the source of energy in the process.

The importance of discerning the empty space between particles (atoms, ions and molecules) was revealed in the third learning study when the task was to explain dissolution processes at a sub-microscopic level. How come, for example, that a glass filled with water still can hold several spoons with salt? This phenomenon cannot be explained without understanding that it is still plenty of room between the water molecules even if the glass is filled all the way up. By demonstrating several examples of different substances and dissolving processes and by, for each example, talking about the invisible empty space between the different kinds of particles the teacher made the

students aware of something they had never noticed before and the particulate character of matter became even clearer.

At the same time, another critical aspect was found; How to connect observable phenomena in experiments at a macroscopic level and the corresponding explanations at the sub-microscopic level by dealing with both levels simultaneously. This connection also made it clear that a phenomenon, such as dissolving salt in water, can be described in qualitatively different ways by comparing how the same phenomenon can be talked about using everyday language as well as scientific language, something that also constitutes a critical aspect concerning language in science teaching.

Students' difficulties with understanding the particulate character of matter as well how important this is when teaching science has been well-known for decades (see for example Driver & Easley, 1978). What we want to suggest is that learning studies not only can help to bridge the gap between research theory and school practice (Nuthall, 2004), but also produce a type of knowledge that has different character, practical knowledge that might be produced when teachers are working together in their own practice trying to find solutions for shared problems, knowledge that also might be useful for other teachers with similar problems. As Morris & Hiebert (2001) suggests, we believe that learning studies, characterized by small tests of small changes, can reveal that kind of practical knowledge. Knowledge in terms of critical aspects and useful teaching strategies, such as the findings in Vikström (2014) represent examples of.

#### *Public practical knowledge beyond the borders of the local school context*

In order to prove the validity of the findings made in learning studies, it is necessary to conduct further research and evaluate whether the critical aspects identified can be used in novel situations, across different science topics and domains, and by teachers in different contexts. Is it possible to transfer findings from learning studies to other teachers and their students? On the one hand, Kullberg (2010), and Runesson and Gustafsson (2012), state that it is not possible to make lists of critical aspects and use them statically in new contexts since the critical aspects always are relative to the learners and thus, dynamic. On the other hand, studies have shown that the identified critical aspects can affect different groups of students in similar ways, hence to go beyond the borders of the local school context. Kullberg (2010) studied the effect of critical aspects when implemented with other teachers that had not participated in the learning study. Two quasi-experimental studies were conducted, one with critical aspects found for learning the density of rational numbers in grade 5 and 6, and one with critical aspects about addition and subtraction with negative numbers in grade 7. There were four teachers in each study conducting two lesson designs each with different number of critical aspects. Both studies showed that when the teachers succeeded to bring out all the critical aspects in the lesson as in the original learning study the effect on student learning was similar. When only some of the identified critical aspects from the previous study were enacted in lessons the learning outcomes were less. However, in one lesson in which the teacher only was

to implement two the four critical aspects, it was found that one student's questions opened up the possibility to experience the other two critical aspects as well. The student learning outcomes from this lesson was similar to other lessons in which all four aspects were enacted (Kullberg, 2012). Hence, it was argued that the critical aspects were transferrable to other learners within similar age in this study. However, critical aspects are relative to the learners and cannot be taken for granted to be similar for different groups of students, since there may be more aspects, or other aspects, that are critical (Kullberg, 2010). Runesson and Gustafsson (2012) studied how a group of teachers in Sweden made use of and improved an instructional product developed in a learning study in Hong Kong. In the learning study, four teachers and their classes (137 pupils in grade 3) participated. The object of learning was to enhance the pupils' creative writing. The findings of critical aspects, materials and tests used were well documented (Cheung, 2005). The researchers summed up the critical aspects of the object of learning and the dimensions of variation opened up in regards to them in different events in the lesson. For example, in the lesson six cards (invariant) were used to illustrate different possible sequences in a story (varied). The pupils discussed and performed (acting) different possible sequences for stories in front of the class. This made it possible for the pupils to experience different possible plots in a story.

Five teachers that were familiar with learning study and variation theory participated in the Swedish project to implement critical aspects from Hong Kong in their teaching. The teachers were from two schools and different parts of Sweden. The researchers met each team on two occasions. At the meetings, the researchers and the teachers discussed e.g. the critical aspect of sequence and the patterns of variation used in Hong Kong, which the researcher had documented on a single A4 paper. The Swedish pupils were asked to write a story (used as a pre-test) in order for the teachers to get information about their pupils' creative writing skills. The analysis of the writings showed that the Swedish pupils had similar problems with causal sequencing of the events as the Hong Kong pupils had. However, other possible critical aspects were identified as well. Some pupils did not have a main event in their texts, or no resolution. Furthermore, pupils rarely used dialogue. The teachers used the documentation from the learning study as a starting point in their collaborative planning of their teaching, and also took what they learned about their students' learning into account. In the analysis of the lessons it was found that the teachers added on dimensions of variation that was not present in the Hong Kong lessons;

1. casual sequences, identifying the component parts (in Hong Kong lesson)
2. plot structure of a narrative
3. modes of telling
4. appropriate and attractive title

The documentation of the learning study in terms of critical aspects and dimensions of variation was in the Hong Kong-Sweden study not used as a fixed product, it was tested, adapted and further developed. In this process variation theory was a means for the teachers that directed their attention to critical aspects and how to create patterns of variation and invariance. However, the theory does

not say specifically about teaching, e.g. *what* is to be varied. The teachers needed to determine this in regard to the development of creative writing skills and to their learners.

## Discussion

In this paper, we address the question if *practice-based knowledge can be produced by teachers through practitioner research, and be relevant and used beyond the local context of the participating teachers*. We argue that a certain type of teacher research conducted in PLC, indeed have the capacity to produce knowledge products that are useful even for teachers outside the local school conducting the research. Learning studies and variation theory (Marton & Pang, 2013), can offer teachers the external research resources and lead to the more directive research program that Enthoven & de Bruijn (2010) think needs to be mobilized in order to create public knowledge in teachers' professional networks. Variation theory helps teachers to focus on the object of learning in two ways, it provides theoretical concepts that guide the teachers in the investigation to identify *what* the necessary condition for learning are – the critical aspects, and it points out *how*, since variation is seen as essential in order to notice what is learned in the teaching situation. In the process of learning study teachers make connections between changes in teaching practice in terms of critical aspects enacted and opened up as dimensions of variation, to student achievement (cf., Desimone, 2009). “Small tests of small changes” are studied by carefully monitoring students' achievement in relation to critical aspects enacted (cf. Morris & Hiebert, 2011).

The knowledge products produced by teachers in a learning study –the critical aspects– are on a detailed level, and always in relation to a particular object of learning. For example, the critical aspect that students need to discern *the difference between matter and energy* in the science lesson about atoms was a new insight for the teachers, since they had never thought about that this could be a problem for the students (Vikström, 2014). By treating the concepts matter and energy simultaneously, it was made possible for the students to discern the difference between the two concepts. This problem is likely found in other classes as well thus, they are not clear about the difference between matter and energy, two basic and very important concepts in science education.

The critical aspects can be disseminated and tested by other teachers with their students and be further refined in practice (cf., Morris & Hiebert, 2011). In this sense, the research has the potential to develop teaching practice on a more general level than only on the particular school. Critical aspects identified in learning studies have also been used as a point of departure in other research (e.g. Marton & Pang, 2003). Learning studies framed by variation theory, we believe, can also be a fruitful way to overcome the “theory and practice gap” that Nuthall (2004) addressed, and be useful tools in teachers' professional development while at the same time aiming at enhancing students' learning. Results from learning study are developed inside the context where the problems have arised. Therefore, they cannot be directly applied in new context but they can be made accessible as hypotheses to other teachers to be tested, refined and developed.

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