Mechanisms enabling knowledge production in learning study

Angelika Kullberg
Department of Pedagogical, Curricular and Professional Studies,
University of Gothenburg, Gothenburg, Sweden

Anna Vikström
Department of Arts, Communication and Education,
Luleå University of Technology, Luleå, Sweden, and

Ulla Runesson
School of Education and Communication,
University of Jönköping, Jönköping, Sweden

Abstract

Purpose – The purpose of this paper is to add to the discussion about practitioner research in schools – by addressing mechanisms and systematic strategies based on theory in a research model, which enables the creation of knowledge products that enhance student learning and are sharable between teachers.

Design/methodology/approach – The research question is the following: Can a specific form of teachers’ research produce practice-based knowledge relevant beyond the borders of the local school context? This question is addressed through empirical examples from previously published papers on learning studies in natural sciences, mathematics and language.

Findings – This paper promotes the view that teachers in learning studies can create practical public knowledge relevant beyond their local context. The authors suggest that learning studies and variation theory can offer teachers mechanisms to create such public knowledge.

Originality/value – The paper proposes that teachers’ collaboration in professional learning communities, as in a learning study, not only has the capacity to increase students’ and teachers’ learning, but it can also be used to create practical public knowledge.

Keywords Learning study, Variation theory, Professional learning communities, Mathematics

Paper type Conceptual paper

Introduction

To overcome the frequently discussed research-practice gap in education, several researchers (e.g. Cai et al., 2017; Kieran et al., 2013) have proposed as a solution communities where teachers and researchers work together and address problems raised in teachers’ practice. It has been argued that such collaborations can create a sustainable and sharable knowledge base that can assist teachers and researchers in implementing learning opportunities in classrooms (Cai et al., 2017). This paper aims to add to this discussion by presenting a particular form of teacher–researcher collaboration – learning study – which is a theoretically framed version of lesson study (Huang and Shimizu, 2016). We suggest how learning study has the potential to create that which Cai and colleagues envision: a legitimate knowledge source for professionals, relevant outside the local school context. We take our point of departure in previously reported studies (Kullberg, 2010; Runesson and Gustafsson, 2012; Vikström, 2014) to illustrate what this knowledge source would look like and how it can be used and developed beyond the borders of the local context. We further elaborate on the mechanisms and systematic strategies that enable production of such knowledge sources.

Although there are extensive reports on the positive effects of teacher learning from teacher–researcher collaboration (e.g. Cheung and Wong, 2014), the possibility of creating public knowledge through this form of communities has been questioned. For instance, Enthoven and de Bruijn (2010), in an extensive literature review concerning professional
learning communities (PLC) and communities of practice (CoP), asked 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 research conducted within professional communities. Instead, the collaborations seemed to focus on practical innovations and change through teacher learning, not through evaluation of the innovations, and the practitioners’ networks were not used to create practical public knowledge with reach beyond the borders of the local school. Enthoven and de Bruijn (2010) considered PLC and CoP as networks within and between schools that share a common intention of collective learning and development of a professional community and critically interrogate their own practices. Two main aims of CoP and PLC were identified in their article: the professional development of the networks’ members and the creation and sharing of knowledge. However, through their review, Enthoven and de Bruijn concluded 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, either in or beyond the local context. Morris and Hiebert (2011), by contrast, studied the quality movement in healthcare science and lesson studies in Japanese schools and found three characteristic features that enabled the development of knowledge products in practitioner research: The first, they argue, is shared ownership of problems across the system – problems that the products help to solve. If all participants are not working together to find solutions to the same problems, and if the solutions do not improve the situation in the workplace, then there is no reason to create problem-solving products. Moreover, when participants evaluate the progress of the problem-solving, their commitment to solving the problems is made more evident. The second characteristic feature, according to Morris and Hiebert, concerns the research methods that are commonly used to test and revise the shared products. Morris and Hiebert (2011) highlighted the value of “small tests of small changes” (p. 6), because they can be associated with the kind of knowledge products created by practitioner research using research methods often ignored or dismissed in descriptions of scientific approaches. The third characteristic feature is knowledge products that are jointly created by participants with different competences and kinds of knowledge, which thus contribute with multiple sources of innovation and more effectively help to solve problems in the profession.

To uncover whether practitioner research can be recognized as a legitimate knowledge source that produces knowledge relevant beyond a specific context, in their review, Enthoven and de Bruijn (2010) searched for mechanisms that enable this kind of knowledge, which schools lacked. This paper argues that research featuring a genuine collaboration (i.e. teachers take an active part in the process, their competence is seen as a valuable resource, and the researcher and teachers have a shared and common object of research) can be relevant to practice in a local context, and it can contribute findings that might be useful for others. Our arguments are supported by examples from learning studies in which such knowledge products were produced, and the process of creating them is described.

The practice-research dichotomy
The application of educational research in practice is indeed problematic and complex. One argument suggests that the gap between research and practice reflects two sharply contrasting types of knowledge: research-based knowledge that is published in scientific journals, and pedagogical knowledge, which is used by teachers in their classrooms (e.g. McIntyre, 2005). Bates (2002) argued that a tension exists between researchers and practitioners; practitioners want solutions to their teaching problems, while researchers seek new knowledge. Vanderlinde and van Braak (2010), who found that teachers were skeptical about the value of educational research, argued that educational researchers do not ask questions of practical relevance. They concluded that more cooperation between researchers
and practitioners is something that teachers, school leaders and researchers can all agree is necessary. This paper therefore proposes, as, for instance, Gibbons et al. (1994) and Stoke (1997) did, that knowledge production would benefit from a greater focus on applicability and that practitioner research might be immediately useful and contribute a professional knowledge base for teaching. Furthermore, this paper argues that teachers’ PLCs can conduct research that is relevant to practice in a local context and that they can contribute theoretical findings that might be useful for others.

The role of theory and systematic inquiry

Stenhouse (1975) was among the first to propose the idea of researching classroom teaching and learning with teachers, rather than conducting research on teachers. However, what is called teacher research (cf. Cochran-Smith and Lytle, 1999) sometimes seems to be more concerned with teachers’ professional development than with the generation of knowledge (Carlgren, 2012). Morris and Hiebert (2011) have, by studying lesson studies in Japanese schools, identified the characteristic features that enable the development of knowledge products in practitioner research. However, the role of theory in lesson study is generally unclear and is rarely made explicit (Elliott, 2012). In this paper, we propose that a systematic enquiry, as in a lesson study, combined with a theory is beneficial in order to create knowledge products with practical relevance that could enhance student learning (cf. Elliott, 2012; Fernandez, 2005; Nuthall, 2004). The type of teacher research we propose and elaborate on here, the learning study (Marton and Pang, 2003; Marton and Runesson, 2015), is underpinned by theory; with some exceptions (e.g. Martin and Towers, 2016), it is the variation theory of learning (Marton and Booth, 1997), which will be described in detail below, that serves as this underpinning theory. In this paper we suggest that the theory-informed learning study may offer not just a reflective practice, but also a form of practice-based research that produces knowledge that is useful for practice. Learning studies may provide the necessary mechanisms for collaborative research and the basis for producing pedagogically relevant knowledge about how to enhance learning – gains that can be made public, shared, and improved upon. Thus, such research must be transferable to some degree so that the results can be used, tested, and developed by other teachers and researchers in other contexts (Kullberg, 2012; Morris and Hiebert, 2011; Runesson and Gustafsson, 2012; Runesson et al., 2018). In this paper, the character of knowledge products from learning study will be illustrated with concrete examples.

Learning study

The overall aim of a learning study is to find out why certain objects of learning are difficult to grasp and to explore the best ways to improve teaching and learning these objects. In this sense, the participating teachers and researchers share the same object of research. The resulting research findings show what is critical for a specific group of learners to develop a specific capability, together with a description of ways to present and sequence the content (e.g. in tasks) in order to enable students to discern the critical aspects, thus making learning possible. The learning study shares many features with the lesson study and could be seen as a type of theory-informed lesson study. As in a lesson study, in a learning study, a group of teachers (about three to five) works with an iterative design of planning, implementing, observing and revising a single lesson multiple times. In most cases, the variation theory of learning (Marton, 2015) is used to analyze and plan the lessons, although other theories have also been used. An important feature of a learning study is that in order to determine which aspects may be critical, students’ knowledge before and after the lesson is explored by means of a test or interview. A learning study commonly consists of between six and ten meetings and three to four video-recorded research lessons.
Just as with lesson studies, in learning studies, positive effects on teachers’ professional development are reported (e.g. Kullberg et al., 2016; Lo, 2012; Lo et al., 2006; Nilsson and Vikström, 2015). In her review of professional development programs, Kennedy (2016) identified the problem that, in most such programs, teachers typically meet outside their classrooms, yet the expectation is that the programs will alter teachers’ behavior inside the classroom. They are at risk of what Kennedy called the problem of enactment, a phenomenon in which teachers can learn and espouse one idea, yet they continue to act based on another, without being aware of the contradiction. As a learning study is conducted within teachers’ own practice, it may be more likely that this problem is avoided. In a learning study, researchers and teachers work together as colleagues, with the common goal of solving problems experienced by the teachers and thus improving practice. This is something that Kennedy (2016) found valuable. However, although teachers learn from a learning study, the goal of the process is not just teachers’ professional development; it is to produce knowledge that is shareable and can be utilized in other contexts. This goal is something learning studies share with lesson studies, which Morris and Hiebert (2011) claimed 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
One central idea in variation theory is that what is being learned must be taken into consideration prior to how it is learned (e.g. arrangement of the classroom, group work vs individual work, teaching materials). What is being learned is referred to as “the object of learning.” Thus, a learning study framed within variation theory focuses on what the learners learn. Hence, focusing on a particular object of learning and exploring its character are specific features of the variation theory-informed version of lesson study.

The focus of the variation theory of learning is the content that is to be learnt. It has its roots in phenomenography, a research approach for studying differences in individuals’ ways of experiencing, e.g. a concept, a problem or a situation (Marton and Booth, 1997). Differences in ways of experiencing the same thing are explained in terms of differences in discernment. In order to experience, for instance, a linear function in the way the teacher intends, it is necessary to discern and focus on all its critical aspects, for example that in a graph representing a linear function, the x-axis is the point of reference (since some students experience that it is the opposite (y-axis)) (Mårtensson, 2015). Consequently, one reason why students fail to learn, from a variation theory perspective, is that they might not have discerned that which is necessary to discern. Identifying what these critical aspects of the object of learning might be and how to handle the content in a way that makes the critical aspects possible to discern is the main aim of a variation-theory-informed learning study.

In order to identify what is critical to discern, it is not sufficient to only consider critical aspects of the concept from the point of view of the discipline. Critical aspects cannot be derived solely from the subject matter, but they need to be explored and identified in relation to the learners and to be tested in the classroom (Mårtensson, 2015; Pang and 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 reported in the research literature as problematic is a valuable resource for anticipating critical aspects. For example, the learning studies described in Vikström (2014) used results from science education research as a resource 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 academic theory and practice. Sometimes unexpected results in a learning study can lead the team to identify aspects critical for students’ learning, even if these aspects were initially taken for granted and the teachers were thus unaware of them. When the learning study team
iteratively tests different ways of handling the content, using students’ learning as a point of reference, the critical aspects are identified. What such critical aspects might be in relation to different objects of learning will be described in detail in the following sections. In this sense, variation theory is what Kvernbekk (2012) calls a “strong theory” that is useful for asking critical questions about the practice.

Variation theory as a design tool
Besides providing theoretical concepts (such as objects of learning and critical aspects) that enable the team to have a common focus and common language to talk about teaching and learning, variation theory can also be used to design lessons. The object of learning is central in variation theory. It concerns a specific way of understanding something, such as 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 given content has many aspects, but not all aspects are critical 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. For example, in order to experience the tallness of a person, you need to experience a variation of people with different heights. If all people had the same height, one would not understand tallness, or if everything in our environment had the same color, we would not know what color is. In order to discern an aspect, it must be experienced as something that can vary. 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 and Booth, 1997; Marton and Tsui, 2004). When comparing two similarly arranged lessons on the same topic, several studies have demonstrated that differences in the pattern of variation seem to have a significant effect on student learning (e.g. Kullberg et al., 2014; Lo, 2012; Pang and Lo, 2012). Variation is applied in three ways: in students’ and teachers’ ways of understanding the object of learning and as a guiding principle for pedagogical design (Lo, 2012; Pang and Lo, 2012).

Learning study – both professional development and knowledge production
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 about the object of learning. Throughout the process, how the content is handled and taught in the lesson and how this is reflected in students’ learning is analyzed. A pretest 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, teachers and researchers agree on the patterns of variation that could be used and tested when teaching the lesson. By analyzing the video-recorded lessons in relation to the results of the posttests (with the same items as in the pretest), the patterns of variation that improved students’ learning are found. In this way, teachers learn how to use variation theory in practice and how to translate their findings into successful teaching activities. For example, in a study about learning that there are an infinite number of decimal numbers between any two numbers, it was found necessary to represent the same rational number in various ways e.g., as decimal numbers, as fractions and as percentages, i.e. keeping the number invariant and varying the representation.

Identifying the critical aspects by means of a 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 defined as such 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 and Ki, 2016, p. 328). 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 pretests and posttests, which take the form of paper-and-pen tests and/or interviews. From this analysis, hypothetical critical aspects are identified. Based on these findings, the research lessons are planned so as to make the proposed 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. Careful analysis of data from the posttests (looking, for example, at whether students responded to the tasks differently before they were taught and in the posttest) and from the video-recorded research lessons gives further insight 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 to new students, and again the observed/recorded lesson and the diagnostic posttest are analyzed. The iteration proceeds until all classes in the learning study are taught. The critical aspects, that is, what the learners need to discern in order to understand, for instance, a linear equation in the targeted way, are the knowledge product of a learning study. In short, a learning study is a type of theory-based teacher research that aims to find, and create, the necessary conditions to enhance learning for specific objects of learning. In this paper, Enthoven and de Bruijn (2010) and Morris and Hiebert’s (2011) conclusions will be used as points of departure, and variation theory and learning studies will be proposed as 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 they described. We argue that this is not the case in a learning study; on the contrary, there is a clear intended product that represents the objective of the research process. The teachers’ professional objective can be defined as making 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 highlighting contrasts that make it possible for students to discern the aspects that are considered critical for a certain object of learning; that is, what the students need to learn to see (Marton, 2015). Therefore, the objective of a learning study is clear and its intended research products are well defined: its aim is to find the specific critical aspects for a specific object of learning and group of learners and to create patterns of variation that make it possible for the students to discern those aspects.

**The contribution to students’ learning**

Enthoven and de Bruijn (2010) argued that it is hard to assess in what way PLC and CoP can contribute to students’ learning. Desimone (2009) suggested that more work linking professional development and changes in teaching practice to student achievement is needed. As the objective of a learning study is to find ways to improve teaching and learning of certain objects of learning, the potential to contribute to students’ learning is obvious, and students’ learning is repeatedly assessed through the student pre- and posttests in the cyclic process. According to Guskey (2002), teachers seldom change their practice until they have seen the benefits to students’ learning. This paper suggests that studying this relationship between student learning (how students experience what is taught and what they need to learn) and teaching (which critical aspects need to come the fore, and how they can be taught) can generate knowledge about the students’ learning and about teaching the particular topic. In a number of learning studies, students’ results were
better after the second or third research lesson than after the first lesson (Cheung and Wong, 2014; Marton, 2015; Kullberg, 2010). Using the following learning studies as examples, this paper suggests that learning studies are characterized by the 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**

Our suggestion that researcher-practitioner collaborative research can produce pedagogical knowledge relevant beyond the local school context is based on examples from previously published learning studies. The first example (Vikström, 2014) illustrates the character of an instructional product (cf. Morris and Hiebert, 2011) of learning studies, specifying critical aspects for learning the concept of matter in natural science and how they could be taught so as to enhance student learning. The other examples (Kullberg, 2010; Runesson and Gustafsson, 2012) illustrate how descriptions of critical aspects identified from a learning study in one school context (and their effects on student learning) could be shared, implemented, and developed in a new context when used by other teachers.

**Critical aspects and instructional strategies as knowledge products**

In a learning study project (Vikström, 2014), a group of secondary school science teachers and their seventh- and eighth-grade students conducted three learning studies concerning science content on atoms and molecules, photosynthesis, and solution chemistry. The different types of content that were addressed in the study had one thing in common: to understand the phenomena as intended presupposed an understanding of the particulate character of matter.

Students’ difficulties with understanding that character, as well how important this is when teaching science, have been well known for decades (see for example Driver and Easley, 1978). Before the learning studies, the teachers were well aware of students’ difficulties with the content, but they were not able to express in any detail what those difficulties consisted of or how to overcome them. Knowledge of students’ difficulties with understanding certain content is important, but our point is that it is even more important to gain knowledge about how to overcome those difficulties. By using the variation theory of learning, the teachers started to ask questions such as What does it mean to understand the object of learning in the way we are aiming for? and How can we make it possible for our students to become aware of the aspects of the object of learning that they are not yet aware of? In other words, the teachers wanted to find out how they could enable their students to “see” what they had not yet seen.

When searching for the answers to the questions above, concrete knowledge products, in terms of critical aspects and instructional strategies, were produced in the three learning studies (Vikström, 2014). The first learning study revealed the importance of pointing out that atoms build up everything material around us and of making a connection between the macroscopic and submicroscopic level (meaning the connection between what is and what is not possible to see). The teachers were very surprised by the fact that 95 percent of the students in the pretest were unsure about what are composed by atoms. The students gave answers like “Pasta is not made of atoms, it is made of wheat flour.” Thus, the teachers concluded that this was a critical aspect, and a lesson plan that could make it possible to discern this aspect was agreed upon. In Lesson 1, 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 submicroscopic level. For example, a chair is made of wood, wood is made of cellulose, and cellulose is a molecule made of carbon, hydrogen and oxygen atoms. The groups presented their results, and the teachers took notes on the whiteboard. In the discussions about the variety of everyday examples, and with the help of the teacher, the students reached the atomic level in all the examples and realized something invariant: all of them 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, representing energy (sunlight, lamplight and heat) were presented to the students. 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 were something non-material that did not consist of particles at all, thereby discerning the difference between matter and energy. This also 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. When analyzing the posttests from the first and second lesson in Learning Study 1, the importance of treating the two concepts matter and energy simultaneously became clearer to the teachers. Therefore, in the third research lesson, the two concepts and the examples were written side by side on the whiteboard, enabling the students to compare them. Thus, a contrast was manifested that made this critical aspect possible to discern. In the posttest after the third research lesson, 88 percent of the students were able to differentiate between matter and energy and to point out what was built up of atoms and what was not. This critical aspect became even clearer in the second learning study about photosynthesis, as it was found that one difficulty with understanding this complex process was understanding that plants are not built by sunlight but by atoms from carbon dioxide and water, and that sunlight is the source of energy in the process.

Another critical aspect, the importance of discerning the empty space between particles (atoms, ions and molecules) was revealed in Learning Study 3, when the task was to explain dissolution processes at a submicroscopic level. How can a glass filled with water still hold several spoons of salt? This phenomenon cannot be explained without understanding that there is still plenty of room between the water molecules even if the glass is filled all the way up. In the pretest, only 6 percent of the students were able to explain this phenomenon in a scientific way. The majority of the students described it on a macroscopic level without any notion of the particles and the empty space between them. 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, as well as an instructional strategy, was found: How to connect observable phenomena in experiments at a macroscopic level and the corresponding explanations at the submicroscopic 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. In the posttest after Learning Study 3, about 45 percent of the students were able to describe the dissolution process of salt in water at a submicroscopic level with the use of scientific language and awareness of how the empty space between atoms made it possible for the ions to have room.

In summary, the critical aspects that were found – the importance of understanding that everything material around us is built of atoms; connecting the submicroscopic level with the macroscopic level; understanding the difference between matter and energy; awareness of the empty space between atoms; and noticing the difference between describing a phenomenon with scientific and everyday language – represent concrete knowledge products that can be useful for teaching science in general. How these aspects were made possible for students to discern represents knowledge products concerning instructional strategies. Variation theory guided the teachers to plan the lessons where different examples were shown in a well-thought-out way, and necessary patterns of variation that can be used by other teachers were manifested.
This paper argues that a careful study, guided by variation theory, of the students’ learning before and after the lessons, along with analysis of how their learning was related to what was (or was not) manifested in the lessons enabled the production of the knowledge products.

What we want to suggest is that learning studies can help not only to bridge the gap between research theory and school practice (Nuthall, 2004), but also to produce a type of knowledge that has a 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 and Hiebert (2011) suggest, we also believe that learning studies, characterized by small tests of small changes, can reveal that kind of practical knowledge. We also want to argue that knowledge, in terms of critical aspects and useful teaching strategies, such as those exemplified in Vikström’s (2014) study, might be useful when science teachers try to overcome the difficulties – described more than 40 years ago by Driver and Easley (1978) – with understanding the particulate character of matter.

Public practical knowledge beyond the local school context

Although learning study as a collaborative research approach is idiosyncratic, there are similarities and patterns of problems, across different contexts, that teachers encounter every day. So, it can be assumed that knowledge from a learning study can be beneficial outside the original context. Stigler and Hiebert (2016, p. 584) propose that having the lesson as the unit of analysis, the close analysis of teaching, and the very specific focus, all substantiate the validity of learning study. To test the usefulness and the ecological validity of learning study findings, it is necessary to conduct further research and to evaluate whether the critical aspects identified can be used in novel situations, across different science topics and domains, and by teachers in varied contexts.

Is it possible to transfer the findings from learning studies to other teachers and their students? On the one hand, Kullberg (2010) and Runesson and Gustafsson (2012) stated that it is not possible to make lists of critical aspects and use them statically in new contexts, since the critical aspects are always relative to the learners and thus are dynamic. On the other hand, studies have shown that the identified critical aspects can affect different groups of students in similar ways, hence they reach beyond the local school context. Kullberg (2010) studied the effect of critical aspects being implemented by teachers who had not participated in the learning study in which those critical aspects were identified. Two quasi-experimental studies were conducted, one that identified critical aspects for learning the density of rational numbers in Grades 5 and 6, and one that identified critical aspects about addition and subtraction with negative numbers in Grade 7. Each study had four teachers, each of whom conducted two lesson designs containing a different number of critical aspects. Both studies showed that when the teachers succeeded in bringing out all the critical aspects in the lesson, as had been done in the original learning study, the effect on student learning was similar to the effect found in the original learning study. For example, in the learning study with the three cycles about the density of rational numbers four critical aspects were identified (decimal numbers as points on a line, the interchangeable representation of rational numbers, a rational number as part of a whole, and the divisibility of rational numbers). When one identified critical aspect was enacted in Lesson 1, in the posttest, only 3 of 19 students (16 percent, effect size 0.35, Cohen’s $d$) could explain why there were an infinite number of decimal numbers in an interval of two decimal numbers (e.g. 0.97 and 0.98), compared to one student on the pretest. When the four critical aspects were identified after Lesson 1 and enacted in the second cycle (in another class), on the posttest almost all the students (16 of 17, 94 percent, effect size 1.98) could do so, compared to four students (24 percent) on the pretest. When the same critical aspects were enacted in the third cycle (in the third class), the effect size (1.98) was the same as for the second cycle.
The quasi-experimental study showed that when the four critical aspects (Design 2) were enacted in a lesson, the learning outcomes were greater than when only one critical aspect was enacted (Design 1). The effect size was large (1.55 for Design 2 compared to 0.59 for Design 1). In two classes (Design 3) that were supposed to enact four critical aspects, only three were enacted. In these cases, the learning outcomes and the effect size were also smaller than with Design 2 (see Table I).

In conclusion, when only some of the identified critical aspects from the learning studies were taught in the new lessons, the learning outcomes were poorer. However, in one lesson in which the teacher was only to implement two of the four critical aspects in the study about negative numbers, it was found that a student’s questions opened up the possibility to experience the other two critical aspects as well. The students’ learning outcomes from this lesson were similar to those of the other lessons in which all four aspects were taught (Kullberg, 2012). Hence, it was argued that the critical aspects were transferrable to other learners of similar ages in this study.

However, critical aspects are relative to the learners and cannot be assumed to be similar for different groups of students, since there may be more or other aspects that are critical (Kullberg, 2010). Runesson and Gustafsson (2012) report on how a group of teachers in Sweden made use of and improved an instructional product developed in a learning study in Hong Kong. In this 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 from this study were documented in terms of the critical aspects the Hong Kong research group had identified, that is, that which was critical for pupils’ learning, but materials and tests used were also well documented (Cheung, 2005). When working with the Swedish teachers in the follow-up study, the researchers summarized the critical aspects of the object of learning and the dimensions of variation opened up relative to them in different events in the Hong Kong lessons. For example, in the lesson, six cards (invariant) had been used to illustrate different possible sequences in a story (varied). The pupils had discussed and acted out different potential sequences for stories in front of the class. This had made it possible for the pupils to experience different possible story plots.

The five teachers who participated in the Swedish project were from two schools in different parts of Sweden and were familiar with learning studies and variation theory. The researchers met each team on two occasions. At the meetings, the researchers and the teachers discussed, for example, the critical aspect of sequence and the patterns of variation used in Hong Kong, which the researcher had documented on a single A4-sized paper. In order for the teachers to get information about their pupils’ creative writing skills, the Swedish pupils were asked to write a story (used as a pretest). The analysis of the writings showed that the Swedish pupils had problems with causal sequencing of the events similar to those the Hong Kong pupils had. However, other possible critical aspects were also identified. Some pupils were missing a main event or a resolution in their texts. Furthermore, pupils rarely used dialogue. The teachers used the documentation from the Hong Kong learning study as a starting point in the collaborative planning of their teaching, and they also took into account what they had learned about their students’ learning from the pretest. In the analysis of the lessons, it was found that in some cases the aspects implemented in the Swedish classrooms were the same as...
in the Hong Kong classrooms. For instance, the aspect “causal sequence” of a story was taught, and just as in the original learning study, this aspect was made possible to learn by means of variation. So, just as in the original learning study, when the pupils ordered the sequence of the pictures differently, an opportunity to tell/act different stories was afforded. In this way, the causal sequence of a story aspect varied, or in other words, was opened up as a dimension of variation, while the instances of the story remained invariant. Moreover, Runesson and Gustafsson (2012) found that the teachers did not just make use of what had been found effective for learning in the learning study, but they also improved and developed the results for their own context. It was found that the teachers added on dimensions of variation that were not present in the Hong Kong lessons, namely:

1. plot structure of a narrative;
2. modes of telling; and
3. appropriate and attractive title.

These aspects were found to be critical for the Swedish pupils, and thus necessary to learn. The documentation of the learning study in terms of critical aspects and dimensions of variation was not used as a fixed product in the Hong Kong-Sweden study; rather it was tested, adapted, and further developed. In this process, variation theory was a means for the teachers to direct their attention to the object of learning and its critical aspects and to create patterns of variation and invariance. However, the theory does not specify what in the teaching is to be varied. The teachers needed to determine this in regard to the development of creative writing skills and in relation to their learners. Runesson and Gustafsson conclude:

We would suggest that the knowledge product, created in the Learning Study and framed and described in theoretical terms related to a particular object of learning, was possible to communicate to Swedish teachers. They could make sense of the specific theoretically grounded description of the lesson, adapt and adjust it to the specific context. The analysis of the lessons also demonstrated how they applied the theoretical framework in the enactment of the object of learning (Runesson and Gustafsson, 2012, p. 257).

Final comments
This paper takes as its point of departure the discussion about practitioner research and particularly the discourse about whether such research can generate practice-based knowledge that has relevance and can be used beyond the local context of the participating teachers’ schools. The argument endorsed in this paper is that a certain type of teacher research conducted in PLC can indeed produce pedagogical knowledge and knowledge products that are useful even for teachers outside the local school conducting the research. Learning studies and variation theory (Marton and Pang, 2013) can offer external research resources and lead to the more directive research program that Enthoven and de Bruijn (2010) argued needs to be mobilized in order to create public knowledge in teachers’ professional networks. This paper has demonstrated how variation theory, through both its clear focus on the object of learning and the common language it provides for teachers, is a mechanism and provides a strategy for producing knowledge. In the process of a learning study, connections between changes in teaching practice and student achievement, in terms of critical aspects enacted and opened up as dimensions of variation, are central (cf., Desimone, 2009). In a learning study, “small tests of small changes” are studied by carefully monitoring students’ achievement in relation to the critical aspects enacted (cf., Morris and Hiebert, 2011).

The knowledge products produced by teachers in a learning study – the critical aspects – are detailed and always in relation to a particular object of learning. For example, the critical aspect that students needed 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 considered that this could be a problem for the students (Vikström, 2014). By treating the concepts of matter and energy simultaneously, the teachers enabled the students to discern the difference between the two concepts. This problem – confusion about the difference between matter and energy, two basic and very important concepts in science education – is likely to be found in other classes as well.

The critical aspects can be disseminated and tested by other teachers with their students and be further refined in practice (cf., Morris and Hiebert, 2011). In this sense, the research has the potential to develop teaching practice on a more general level, beyond the particular school (Cai et al., 2017, p. 345). Critical aspects identified in learning studies have also been used as a point of departure in other research (e.g. Marton and Pang, 2003). Learning studies are a useful tool in teachers’ professional development, and they also aim to enhance students’ learning. Results from learning studies are developed within the context where the problems have arisen. Therefore, they cannot be directly applied in new contexts, rather they can be made accessible as hypotheses to other teachers to be tested, refined, and developed. Finally, this paper suggests that this type of teacher research and collaboration provides possibilities for generating knowledge about learning and teaching, which contribute to teachers’ collective professional knowledge base.

References


Mechanisms enabling knowledge production


Further reading


Corresponding author

Angelika Kullberg can be contacted at: Angelika.Kullberg@gu.se