Mediating Artifact in Teacher Professional Development

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Mediating Artifact in Teacher Professional Development

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This article focuses on teacher professional development (TPD) in natural science through the 5E model as mediating artifact. The study was conducted in an upper secondary school, grounded in a school-based intervention research project. My contribution to the field of research on TPD is founded on the hypothesis that teachers would be best facilitated to make their practice more inquiry based if they are provided with a mediating artifact. In this study the artifact is a model 5E, which is a conceptual way of thinking, to help teachers reflect on their practice. The aim is to encourage teachers to make changes themselves, by applying extended use of inquiry into their practice. This mediated artifact could thus be used across different national contexts. The main research question is; *how can the 5E model as a mediating artifact enhance TPD?* The article addresses the processes of the use of the 5E model and its influence on teachers' perception of the model. This is in order for teachers to conceptualize their goals related to inquiry and scientific thinking, and to solve the problems involved in achieving those goals in their own contexts.

The study concludes that, after the intervention, the teachers' approaches and strategies demonstrate greater emphasis on learning.

Keywords: CPD; TPD; IBST; The 5E model; Teacher collaboration

1. Introduction

This article seeks to address *how the 5E model can enhance* teacher professional development (*TPD*). Continuing professional development (CPD) may be used interchangeably with TPD. A definition of TPD is given by the Organisation for Economic Co-operation and Development (OECD, 2009) to be ongoing, which includes training, practice and feedback, and provides adequate time and follow-up support. Another definition of TPD is about the set of knowledge- and skill-building activities that enhance teachers' and administrators' ability to respond to external demands and to

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engage in the improvement of practice and performance (Elmore, 2002). Based on these definitions, this study of TPD concerns changes in practice, for which there is a theoretical argument to which the teachers are committed and from which they can drive, develop and refine through processes of collaborative reflection. Grounded on this understanding TPD concerns the professional development achieved by teachers, as a result of gaining increased experience and examining their teaching systematically.

The aim of the study is to explore inherent processes and implications of using the 5E model as a mediating artifact to enhance TPD. This is important because teachers support students in developing scientific thinking and learning how science works, as well as in refining their understanding of content.

Recently, there has been a perceived need for approaches to TPD that move beyond ordinary achievement of subject knowledge and skills (Darling-Hammond & McLaughlin, 1995; Hewson, 2007; Vescio, Ross, & Adams, 2008). This change is based on an extended view of teacher learning and practice. In addition, perspectives have changed from knowledge to teaching practice, from one-off training sessions to learning that takes place over time, and from individual to collaborative learning (Borko, 2004; Putnam & Borko, 2000; Watson & Manning, 2008). Based on their comprehensive review of current literature in the field of TPD, Opfer and Pedder (2011) distinguish the perspective of a coherent view of teacher learning and describe it as a complex system involving systems within systems.

The concept of mediating artifact (Vygotsky, 1978) is about interpreting the world through tools that are embedded in various social practices. This article describes the theoretical concept of a 'mediating artifact' and will introduce the 5E model as the mediating artifact for TPD in this study.

2. Theoretical Framework

The theoretical framework for the study is sociocultural perspectives on learning and knowledge (Vygotsky, 1978). The sociocultural understanding of learning is about the human ability to understand the world and the use of social experiences and collectively developed skills. In a sociocultural perspective, learning is understood as a content-dependent and situation-bound phenomenon, which concerns how people deal with cultural tools in situated practices and how they become competent actors in different contexts (Säljö, 2001). A situated learning approach might encourage teachers to analyze their own practice, develop their understanding of the impact of their practice on students' learning, and develop new ways of teaching by getting them to try to reflect, review and report on their own classes (Taitelbaum, Mamlok-Naaman, Carmeli, & Hofstein, 2008; Windschitl, 2003). From a sociocultural perspective psychological and physical tools act as structuring resources that make it possible for participants in social practices to interpret and act competently in new situations. When individuals learn, they gain the ability to deal with new intellectual and physical tools that make them enhance their competence (Säljö, 2001, p. 155).

A Vygotskian perspective includes a developmental aspect and aims to understand the functions of cognitive artifacts as a main element of learning, and for this reason

seems to offer an adequate theoretical framework for studying the use of artifacts in education.

Notably, the contribution of artifacts to education involves even the most basic tools such as books, which are widely used in schools. The concept of a mediating artifact (Vygotsky, 1978) concerns an interpretation of the world through tools that are embedded in different social practices. It is therefore incorrect to assume that we are in direct contact with the outside world. Human thinking cannot be studied in isolation, but must be understood in relation to the social activities that are part of it (Säljö, 2001). Mediation by artifacts is a central concept in Vygotsky's (1978) work. The idea of artifact is very general and includes several types of objects produced by humans such as sounds, gestures and oral and written forms of natural language; texts and books; musical instruments; scientific instruments; and tools related to information and communication technologies. Distinctions between tools as a means of learning about nature, and language as a means of social intercourse, are incorporated in the general concept of artifacts (Vygotsky, 1978, pp. 53–53).

2.1.   *5E Model as the Mediating Artifact*

The model has its origins in the Biological Sciences Curriculum Study (BSCS), in which American scholars developed educational programs and research on teaching and learning in science. The five Es are the initial letters in the words engage, explore, explain, elaborate and evaluate. The 5E model is a model for planning, implementation and evaluation of learning and teaching. Likewise, the 5E model (Bybee et al., 2006) can be used to support teachers in the planning, implementation and evaluation of teaching. The model can be helpful in order to make inquiry-based teaching explicit and targeted.
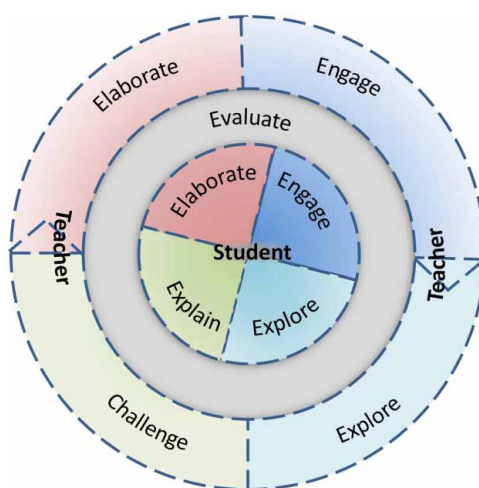

Figure 1.   Model of reflective learning and teaching. Based on 5E model (BSCS 5E Instructional Model 'Model 5E' (Bybee et al., 2006). The 5E model is further developed as a tool for reflective learning and teaching by Svendsen and Knutsen (in Bungum & Van Marion, 2014, p. 10)

Originally, the 5E model was an instructional model for implementing inquiry-based science teaching (IBST). At NTNU we have further developed this model as a tool for reflective learning and teaching, using an abductive process of reflection in the cognitive learning of both teachers and students. The learning process shuttles back and forth between the hatched areas as the cognitive process develops. The 5E model is shown as a model of reflective learning and teaching (Figure 1).

Table 1. Phases in model 5E, different roles (teacher/ student)

5E-phases	Teacher role	Student role	Assess/evaluate	
			Teacher	Student
Engage	Motivate, engage, and uncover prerequisites, context, and syllabus in focus	Enabling prerequisites, be engaged and motivated, formulate questions and make hypotheses	Assess/evaluate learner knowledge, and activity in relation to learning objectives and dividend	Assess/evaluate the knowledge and expertise and what is needed in order to achieve the learning objectives.
Explore	Suggest learning resources, varying methods, guiding	New experiences through exploration to find solutions, to communicate and discuss observations and new experiences develop new knowledge and perhaps relinquish old perceptions	Assess/evaluate the learning process in relation to the learning objectives, providing feedback to students on the exploratory activity	Assess/evaluate information and observations
Explain	Let students communicate their knowledge, introduce and use terminology, challenge students' explanations and summarize student' explanations	Observe and see connections, find and formulate an argument for their own explanations, and reflect on others explanations	Assess/evaluate students explanations give feedback on student academic argumentation, focus on student outcomes	Assess/evaluate information and scientific arguments, reflect on their own understanding by comparing and understanding different explanations
Elaborate	Summarize and transfer technical material, deepen and expand to other parts of the subject, asking open questions for further exploration	Develop a deeper and broader understanding, and use new knowledge in new contexts	Provide feedback on how the student can prepare and provide feedback on student learning	Assess/evaluate the learning process in relation to syllabus, and assess/evaluate the competence in relation to the learning objectives

By determining clear learning objectives for teaching, teachers can use the model as a reflection tool for designing, planning, implementing and evaluating their teaching sequences. Both teachers and students can determine learning objectives (see Table 1).

2.2. *Learning Communities*

Here, learning communities denote the mental structures between individuals in a community, and practice is to be found in communities of people and their relationships of mutual engagement (Wenger, 2008). Mentality in this context means how teachers' see themselves in their work, in their learning community, in their learning process and so forth. The concept of *empowerment* is therefore interesting in a learning community perspective. Empowerment is the ability to self-govern, participate actively, take initiative and turn change into opportunities. This cannot be taught, delivered or imported into communities or individuals (Svendsen & van Marion, 2014). Learning communities in schools are defined as communities of practice, which are at the science department in this study. A community of practice is a context for new insights to be transformed into knowledge (Wenger, 2008, p. 214). Through a process of empowerment, new structures of communication and collaboration might occur by the emerging changed mentalities (Svendsen & van Marion, 2014). In learning communities the main learner is the community itself; learning the mentality and practice of communication and collaboration, learning to take initiative, learning to take risks, learning to challenge old habits and learning to use available resources in new ways.

2.3. *IBST and Nature of Science (NOS) in National Curriculum*

A central goal of teaching science is to go beyond the facts and theories associated with particular sciences and to give students an understanding of the NOS in general. NOS has an essential part in the Norwegian national standards for science curriculum. In Norway, *Natural Science* consolidates biology, chemistry and physics into one subject. IBST is about producing knowledge, which includes making careful observations of phenomena and designing theories for making sense out of those observations. Newly acquired knowledge in the field of IBST may challenge dominant theories and previous knowledge.

IBST is a learning process driven by questions generated from the interests, curiosities and perspectives/experiences of the learner. Teaching strategies that actively engage students in the learning process through investigations are more likely to increase conceptual understanding (Minner, Levy, & Century, 2009). Inquiry is *the intentional process of diagnosing problems, critiquing experiments, distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models, debating with peers and forming coherent arguments* (Linn, Davis, & Bell, 2004).

IBST is not just about asking questions and discussing solutions; it is a way of converting data and information into useful knowledge. There can be variable amounts of direction from the teacher, in both open and guided inquiry (Minner et al., 2009).

This study investigates TPD in natural science through the use of the 5E model as a mediating artifact. Teachers can support students in a developing scientific thinking and learning how science works, as well as improving their understanding of content – there are several educational reasons for pursuing this objective. The model facilitates an understanding of the NOS; it meets the need to practice science as well as learn it, approaching 'authentic scientific activity' (McNally, 2010); it promotes active learning (Crick, 2009) and encourages creativity (Haigh, 2007).

The general objective of inquiry activities in Norwegian schools is to establish experiences that teachers and students can use later to introduce and discuss concepts, processes or skills, based on the national curriculum for *Natural Science*. This corresponds to the aim of this study, which is studying the process and implications of using the 5E model as a mediating artifact to enhance TPD. This concerns the nourishing of teachers' perception of the 5E model in order for teachers to conceptualize their objectives related to inquiry and scientific thinking, and further, to solve for themselves the problems involved in achieving those goals in their own contexts.

Later in this article, I will further discuss methods used in the study of the development process.

3. Studying the Development Process

3.1. *Methodological Approach*

This study is a formative intervention study. A formative intervention study is research that occurs before a program is designed and implemented, or while a program is being conducted, such as in this study. This article focuses on how the collaborative process of professional development practices works. The article addresses the interplay between teachers in a collective discussion of their teaching and the researcher´s perspective of the process over the timespan of one year. The intervention was based on teachers' need for professional development, and the main objective for the researcher was thus to investigate how TPD could be affected by the use of a mediating artifact.
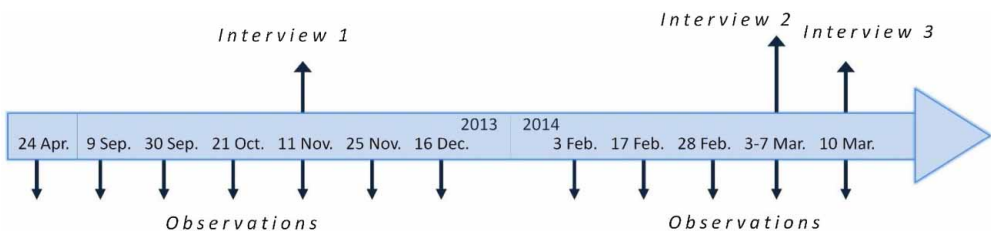

Figure 2. Timeline for data collections and samples

Teachers themselves defined their wishes and needs for the content of their professional development.

I used interviews and observations (see Figure 2) to study the processes in the intervention research project. As a researcher, I had to support the teachers, by giving both guidance and assistance when discussing teaching experiences in the reflection group. The teachers were introduced to the 5E model the previous school year when they participated in a school development program. The teachers adapted the 5E model which according to them yielded new meaning when used. This process is called *double stimulation*, originating from Vygotskýs idea of mediating artifacts (Vygotsky, 1978). Double stimulation aims at generating new, expansive forms of activity.

Below, I will specify the data collection methods, analytical framework and analysis. Finally, I will discuss the findings and end the article with some concluding comments.

3.2.   *Data Collection*

3.2.1.   *The intervention process and the role of the researcher.*   The intervention research project was a result of the teacher's experience in the previous school year while participating in a school-based development program with focus on using IBST. The initiative and project idea for this study came from the teachers themselves. They got permission to do this developmental project from the leadership of the school, and they also got time allocated for this. They wanted me to collaborate with them on this project since I worked together with them as a researcher in the previous year when they participated in the school development project. The teachers wanted to use the 5E model for their planning, and the model had already been introduced in the previous year. I asked for permission to do research on their developmental process, and the teachers and school leadership agreed on this. The intervention study was established with respect to teachers' need for professional development, and the focus for me as the researcher was to investigate how TPD was affected by the use of the 5E model. I was not involved in the process of planning the teaching, but instead challenged the teachers with questions regarding their teaching, and I was present at the teachers' reflection meetings when they planned their teaching. As a researcher I was available as support (in discussions) for the teachers through their process of reflecting on their experiences when planning their teaching. The processes of reflective discussions lead to a teacher–student project which was a new way of organizing the teachers teaching. The teachers organized teaching by crossing subject disciplines through using the principles of inquiry-based teaching by using the 5E model.

3.2.2.   *Participants.*   The teachers participating in this intervention study were from one upper secondary school in a suburban area. The science department consisted of 11 teachers (five women and six men), all of whom had master's degree in one of the science subjects. All participating teachers taught natural science. During the observations, all 11 teachers were observed as they planned their science teaching at the

team meetings. Two experienced teachers (one man – Teacher 1 – and one woman – Teacher 2) were selected for three in-depth dialogs in this intervention. The selection of these two teachers was settled in advance of the intervention, as part of the agreement between the school's administrators and the researcher. The reason for this was because both teachers had some administrative influence in the school's science department and could easily influence administrative decisions.

3.2.3. *Design.* Within the interventional framework of one school year, there were 11 observations of teacher meetings where they planned their teaching and discussed science-teaching issues in the science department. The time period for the intervention is illustrated in Figure 2.

The first meeting was in April 2013, and this meeting was with the school's administrators to agree on conditions for the intervention study. The agreement was that the teachers should have 1 hour available every 2 weeks to be used for planning and reflection with colleagues. This was a defined period of time and included in the teachers' work.

3.2.4. *Observations.* I took field notes in order to collect data from observations. I did this as a researcher at every meeting in the science department while teachers were planning their teaching (see Figure 1). The observation notes became the basis for the key questions in the interviews with the two teachers, and observation was subsequently used to validate the perception of TPD through the intervention. Thus, the quality of the data from the study is strengthened by frequent observations combined with close collaboration and discussions with the involved teachers. The design is based on one school year from September 2013 to March 2014 (see Figure 2). I did both observation notes and audio recordings of the discussions. The notes and recordings were transcribed by me and subsequently member checked (Lincoln & Guba, 1985).

3.2.5. *Interviews.* This qualitative study was carried out as a communication process in which I directed the conversation as little as possible, despite the fact that it was based on prepared key questions. The purpose of the interviews was to gather information from the teachers' experiences, not to get a measure of theoretical variables. I ensured the respondents before they participated that the outcome of the interviews would be open.

The aim of the interviews was to reflect critically on the teachers' didactic practice and their perception of IBST.

3.2.5.1. *Organization of the interviews.* I had three individual interviews with Teachers 1 and 2. The focus of the interviews is listed in Table 2.

I aimed to end the interview with a summary of the conversation. The interviews with the two teachers were audio recorded and transcribed. All the interviews are translated from Norwegian to English.

Table 2.   Focus of the interviews

Interview	Focus of the interviews
First	How is the intervention process perceived?
	How is the experience of using IBST?
Second	Describe challenges and solutions in this process
Third	Teacher reflection on their experiences Self- development?

3.2.6.   *Triangulation of observations and interviews.*   The opportunity to triangulate my observations with the teacher provided an insight into the learning process of the teachers. It also gave me an insight into how the teachers planned and evaluated their teaching.

3.2.7.   *Ethical Concerns.*   Confidentiality of the teachers' discussions of their own practice and any references to specific classes or students that could arise was ensured, and permission from the school leadership to carry out the study was obtained. In the beginning of the study, the teachers were informed that their participation was voluntary, and that they could leave the project whenever they wanted. I emphasized that the teachers would remain anonymous throughout the project as well as after it ended, and that all the collected material would be handled in such a way that the teachers' identities would be concealed.

4.   Data Analysis

The constant comparative method was used for the data analysis (Strauss & Corbin, 1998), where the emphasis was on the abductive aspect in order to answer the research question: *How can 5E model as a mediating artifact enhance TPD*. To discern the meaning of the text, I gave the data tags, placed the encoded material into categories and then conducted the analysis. This process of coding and categorization was inspired by Strauss and Corbin (1998) and generated three main categories; (1) 'Teachers acting and talking together', (2) 'Teachers' experiences from using IBST' and (3) 'Teachers' reflection on their use of the 5E model', with a core category 'Teacher Professional Development' (see Figure 3). It is essential to note that the data analysis had two purposes; first, to organize the data into categories, and second, to analyze and interpret the data. In this intervention, the data are partly presented as segments from observation notes and interviews.

As a researcher, I was in constant motion between theory and the data, and between the field of practice and the processes of gathering or analyzing data. This also challenged me, in that I was both close to and removed from the processes being studied. As I conducted the analysis, each incident in the data was compared with other incidents for similarities and differences. Incidents found to be conceptually similar were grouped together under a higher-level descriptive concept, such as reflection, which led to further development of the main categories (see Figure 3). This type of comparison was essential to all the analyses because it allowed me to differentiate
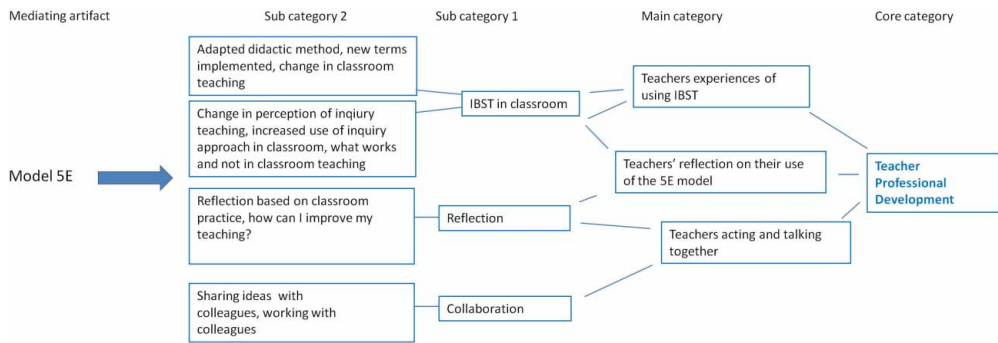
Figure 3. Coding chart

one category or theme from another and to identify properties and dimensions specific to that category. The purpose was to contribute to knowledge concerning professional development, with the intention of highlighting similarities, differences and variations to create a nuanced theory (Strauss & Corbin, 1998). For measuring changes, the intervention depends on informants' *perceptions* of changes. Figure 3 shows the coding process for the main categories.

Member checking (Lincoln & Guba, 1985; Merriam, 1994; Stake, 2005) was used to ensure the quality of the research project. This means that the teachers involved checked the text for correctness. The statements from observations and interviews have been chosen to give a picture of the content of these categories. Thus, they are representative of the interviews.

In the following section, I will present the findings from the study, using the developed categories to structure the presentation.

4.1. *Teachers Acting and Talking Together*

This category includes illustrations showing how the teachers exchanged knowledge and interpreted the 5E model during their meetings. The illustrations presented below have been chosen from reflections and collaborative meetings in the science department, and from observation notes on November 11, 2013:

> T1: I talk a lot about my teaching with you (addressing his colleagues), but maybe not in an introspective way, I think I become more critical of my practice when I share my experiences regularly with you.

> T2: To be academically challenged by my colleagues is affecting me, and it is not only positive, it may be at the expense of my self-confidence, but nevertheless I think it actually makes my teaching better because I have been very critical in my arguments for why I do this and that.

> T3: It is challenging to discuss and analyze my own teaching with colleagues, but it gives me a greater understanding of how I can change small things and actually improve my teaching.

> T4: After working with 5E model and IBST, I have begun to think more about how I can challenge students and make them more curious about the topic we are working on, instead of

working with the theoretical issues first in my classroom teaching, I present them with a chal-
lenge. Students like the approach.

The teachers state that they sometimes find it hard to be confronted with their teach-
ing, but also realize the importance of this process. The introduction of the 5E model is
making the teachers question their teaching approach and the purpose of their teach-
ing, and they are being very critical of their own practice. The importance of teachers
reflecting on their practice has been emphasized in earlier studies, and Dewey (1933,
1938/2004) also draws attention to the need for reflection and learning from
experiences.

Note the following statements from a discussion (observation notes November 11,
2013) between two teachers regarding the 5E model and IBST.

T1: What I experience is that it is easier to agree on something when we do have a shared under-
standing of what we want to achieve. Since all the teachers at the science department agreed to
work with IBST, it was easier to focus on this.

T2: Our aim was to use an IBST approach, and all teachers agreed on this. I think it made it
easier to focus on our goal when supported by 5E model. I get new ideas to what the
content of the IBST should be when talking and discussing with my colleagues, we had to col-
laborate on our ideas. Actually, I sensed a positive attitude for the work on this. I don't always
agree on how to relate to 5E model with the others, but that was quite motivating itself, and it
was also a lot of fun to discuss ideas with my colleagues, and to experience that my ideas gave
nurture to someone else's ideas. That makes me feel good.

T1: Of course, we have a tradition of collaboration at our department, but we usually talk about
learning resources, not examining our own teaching critically. So, having a focus on the 5E
model and IBST sure has affected the way we share ideas and thoughts with each other.

T2: I think, sharing ideas with colleagues is nothing new, but discussing teaching, what works
for us and not, is really something which made the cohesion in the science department better.
And of course, having time to do so together is good.

T1: I usually do my science teaching by introducing conceptual definitions and then introdu-
cing some practical tasks for my students. I think this is pretty much how we do our teaching in
this department. 5E mode turned this practice the other way around, for me at least.

T2: Teaching in our department may be very traditional, but somehow it seems like the stu-
dents prefer it this way. Still, I am open to other teaching approaches. I suppose my colleagues
are open for a challenge too. However, if I do not sense the meaning of the developmental work,
and I can't relate this to my practice, then it is a waste of my time. Don't waste my time! I think
my colleagues will agree totally on this.

T1: In our science department, I sense a shift towards thinking more about how we might
encourage and challenge our students in scientific issues. I look at my colleagues in a more pro-
fessional way now, compared to earlier.

T2: The support from other teachers is very valuable. We are open to each other's successes
and failures, and it sure is easier to share experiences when we have the same focus, such as
Model 5E.

In this conversation, the teachers discuss their perception and use of the 5E model and its influence on their inquiry teaching in the classroom. This conversation shows that the teachers give each other support based on their own teaching experiences when practicing IBST. They share their aim of keeping a focus by implementing the 5E model into their teaching. They also state that their colleagues are helpful in their thinking about new ideas. Mediation is the basis of collective activity in sociocultural theory, and it occurs when people use symbolic tools to regulate their activity, such as the 5E model. Vygotsky (1978) explains that, as people engage in mutual activity in pursuit of a goal, the ways in which they think and act accommodate themselves to the purpose and limits of the tools in use.

Their experiences of using IBST in the classroom, when shared with other teachers, might contribute toward generating new ideas. The teachers also state that they do not always agree on how to use the 5E model, and they can detect a change in practice because the teachers reconsider their teaching practice. According to Leontev (1978), tools are not just physical artifacts, but they also include a social operation system. This refers to the complexity of social practices that are associated with the tool, in the sense that this is how the tool is perceived within the culture in which it is used (Lammont & Boreham, 2002). The teachers consider themselves as open to changes if the changes are considered useful in their practice. At the same time one teacher states that if he cannot find any meaning in the developmental work directly related to his practice, then it is a waste of his time.

4.2. *Teachers' Reflection on their Use of the 5E Model*

The teachers approached the 5E model differently. This is articulated by Teacher 2 (interview February 17, 2014):

> I think it is important to find our own way to approach and use the 5E model, and I think it would be impossible for all teachers to approach it the same way. The reason for this is simply because classes have different students and different needs. As an example I can mention how my students worked with the model at its different phases, while a colleague of mine worked with one phase at a time before moving on to the next phase in the 5E model. I do not think this is very crucial for the teaching, but it is important for the teacher to find his own approach to 5E model in order to teach inquiry based science.

The teacher states that it is not crucial that teachers approach the 5E model in different ways, because this is just the teacher's way of fitting the model to their own individual classroom environments and to their own needs. It is a fact that artifacts have recognizable histories of interpretation and is a resource to be used in the production of new meanings (Wenger, 2008, p. 83). Another relevant example concerns e-learning, and states that no matter how many e-learning platforms teachers are offered, they will still meet those platforms with very individual mentalities. This is supported with the following statement from Teacher 1 (interview February 17, 2014):

> This is how the 5E model works for me: I engage students by showing a phenomenon or present an issue that creates curiosity of the student. It is me who activates the student to

do his own inquiry. The student is challenged by me to come up with his own expla-nations, and often he needs to be challenged again. I deepen the science content, and expand it to become more general throughout discussions, to be used in other situations and new problems. This makes the student gain knowledge of his own and establish scien-tific concepts. If my teaching is inquiry based or not depends on my own approach to 5E model, and for me it makes sense if I work from one phase to the other. Not all my col-leagues approach the model like this, but perhaps that is not so important at all?

The teachers created their own meanings when using the 5E model. Professional development is the set of knowledge- and skill-building activities that raise the capacity of teachers to respond to external demands and to engage in the improvement of prac-tice and performance (Elmore, 2002, p. 13).

4.3. *Teachers' Experiences in Using IBST*

This category includes illustrations showing how the teachers experienced IBST in their classrooms. The discussion below comes from two teachers (observation notes December 16, 2013), and concerns IBST and their perception of the concept.

> T3: I think we have a common understanding of what IBST is, because we participated on a course on this last year. Still, it was necessary to discuss our definition of what we think is important when using an IBST approach.

> T4: Since we attended a course last year, we did agree on what IBST is, but still it was necessary to discuss how and why we want to work on this. It was also important to discuss how extensive the IBST should be. And when we discussed that, it was clear that we needed to refresh our common understanding of the teaching method.

> T3: I feel more comfortable with using IBST and I think I have a good approach to 5E model, and I am quite confident with what I am doing in my classes. It feels good, and I think I am in control at any time guided by model 5E. In the beginning, I felt like I lost a bit of the control in my classroom.

> T4: I am very confident about this teaching method. Besides, I am not afraid of taking an initiat-ive to my colleagues if I have an idea about something to do in the classroom. I do practice IBST as often as I can, and even though I use the model slightly different from T3, it gives my teach-ing a new meaning when guided by the model. It helps me with the structure.

To implement inquiry teaching in their classrooms, teachers need to challenge their own practice (Windschitl, 2003). This is expressed through further statements from Teacher 1 (interview February 17, 2014):

> You see, in our daily work as a teacher, there is never any time for discussions and plan-ning like we do now. It is essential to discuss teaching with colleagues, to experience how they practice, and to get constructive comments on my own practice. For me it is essential to know what the other teachers experience in the classroom. It is stimulating to discuss my teaching and thoughts with other colleagues and this is something my colleagues and I value as important; we want to implement inquiry in our teaching. I sure feel more confident with IBST, and I also see that the method does not require more than other teaching methods. Besides, 5E model helps me to focus on my IBST. My students

have worked well and they express the joy of a change, and last but not least, the classroom does not end up in chaos (laughs). Still, I cannot see this professional development happening if we don't have the time and motivation for this work. The motivation comes from us teachers, who defined our needs and got you (researcher) to work and discuss with and stress our effort in IBST and challenge us when we needed that.

From this statement, it seems clear that time provided for talk and collaborative work in the science department is essential. Several studies show the importance of TPD programs supporting teachers with time to reflect, and to collaborate with other teachers (e.g. Harrison, Hofstein, Eylon, & Simon, 2008; Villegas-Reimers, 2003). The teacher confronts his prior assumptions about IBST, and how these assumptions are changed. The teacher also says that it is more motivating to have defined his needs and ways of working with this method. He points out the importance of having someone from outside the school to attend the teachers' meetings and challenge their ideas. The teacher's improved confidence in IBST indicates that he has also improved his competence in IBST. The reflections before and after the intervention showed that, in general, the teachers gained more knowledge about IBST and how to use it. Developing competence is a continuing process of the achievement and consolidation of a set of skills needed for performance in one or more domains (Elliot & Dweck, 2007, p. 18).

5. Discussion

5.1. *TPD through Formative Intervention*

The constant comparative analysis method revealed that categories from the discussions and dialogs all aimed at TPD. TPD includes both formal and informal experiences (Ganser, 2000). This is an issue central to the encoding process and it affects all three categories in this study. The perceived need for change of practice acts as a catalyst for the TPD process leading to professional development and learning. Another important element for the TPD process is time allocated to work with reflection and planning in the science department at the school. According to the teachers, the time assigned for investing in TPD provided the essential basis for developing teacher collaboration, examining their teaching practice, developing a common understanding of IBST and, finally, providing opportunities to reflect on all of these.

As a researcher, I discussed the 5E model with the teachers in order to support them through their TPD process. However, the model is a tool that must be adapted and further developed by the teachers themselves. Discussing 5E model with the teachers involved working *with* teachers, not *on* them, in order to develop the attitudes, skills and knowledge compatible with this development process. I as the researcher, along with the teachers, experienced changes in attitudes, skills and knowledge. Best practice is not an issue here, and the focus is instead on suitable practice for achieving the teachers' goal of implementing the 5E model as a tool to approach IBST in order to enhance TPD. The teachers stated that they used the 5E Model in different ways. Teachers fitted the 5E model to their own individual classroom environments and needs.

According to Boreham and Morgan (2004), teachers' professionalism expresses objectives and actions learned from official guidelines, academic knowledge from education and knowledge that teachers as actors have extracted from their practice, individually and collectively. In this intervention study, teachers learned to make changes for themselves and to develop their own practices aimed at achieving goals appropriate to their own contexts, and to share them as collaborative learning. Teachers did not fully agree on how to approach the 5E model. When going through the process of double stimulation, the aim is not that the teachers approach the model in the same way as other teachers, but rather that they create their own practices regarding IBST when using the mediating artifact. The aim is to trigger new, expansive forms of activity related to IBST and TPD. It does not really matter how the teachers use the model, but it is more interesting to look at how they implement the model as part of their teaching practice. Teachers did as a fact tailor the model to fit their own individual classroom environments. Based on this, change is more likely to be qualitatively authentic and inventive, leading to genuine TPD.

The need for change in this particular intervention came from the teachers themselves and was not forced on them from outside the science department. This is important, as it lays the foundation for further developing the teaching profession. According to Engeström (2001), it is easier to get the organization itself to address development needs, rather than others outside the organization pressuring them to do something. In this study, the developmental process was a bottom-up expansion development for school-based TPD as the teachers defined their needs to be the focus of this intervention. This was particularly true after the school's leadership had agreed with the teachers that they could focus on their professional development.

TPD could be generated from the bottom-up expansion model for professional development, it should for instance aim at generating professional development of the individual teacher (Svendsen & van Marion, 2014). Through a process of empowerment, new structures of communication and collaboration seem to arise as a result of evolving mindsets, which indicate possible changes in teaching practice. In this intervention, this was accomplished through a bottom-up approach, with support from the leadership of the school. The teachers themselves found the developmental aim, and they used the researcher as support in this process. The importance of a successful learning community is that it enhances collaborative teacher learning and empowers the teachers even further in a positive feedback loop (Svendsen & van Marion, 2014). This type of learning is about empowerment based on experiences of failure and success. The teachers need to see the relevance of the artifact in their practice for developmental processes to happen. According to Fielding et al. (2005), the content and method of transfer must engage the teachers first, if TPD is to profit the students. This point is illustrated in Figure 3. TPD courses and training are often designed with the aim of impacting students' performance. This might lead to a highly instrumentalist view of CPD (Pickering, 2007, pp. 197–198). Teachers' learning is complicated and does not fit without difficulty into a hierarchical and linear typology like Guskey's (2002) measurable features of TPD, which also positions teachers' learning fairly low down the hierarchy (Pickering, 2007, p. 198).

Although teachers at the school had a common need to develop their practice, this does not mean that they all had a common understanding of the perspectives that they had to work with, and there was no pronounced understanding of what was most important to comprehend in the science department. Teachers' experience is based on their practical training, learning of skills, personal experience and learning community. According to the teachers in this study, their competence and organization of their teaching can become habits and routines if they do not reflect on the methods, goals and means within their learning community. Teachers have limited access to professional resources explicitly designed to support their professional practice. Lack of cooperation and involvement in the planning of teaching and joint work with development are factors that may be at risk in a mutual initiative (Wenger, 2008). Enhanced understanding of IBST and the 5E model should be seen as a result of a collective process. The motive for the collective activity of the project was to develop TPD through the use of 5E model as an artifact. In order to achieve an understanding of the mediating artifact, the teachers realized that it was necessary to achieve a better understanding of IBST in general. The focus on the 5E model was thus the result of their focusing on IBST.

5.2.   *The Developmental Process*

Experiences from a previous activity can thus be used in a new activity. This bridge building generates new learning processes. Without this bridge-building process, new knowledge can be fragmented and disjointed. When the teachers and I reflected on their practice, the teachers functioned as a second stimulus to each other. After reflecting on their own teaching, teachers started the process of developing their practice collectively, to act in the zone of proximal development in teaching practice concerning IBST (Vygotsky, 1978, p. 86). In this study, the teachers began to construct a new solution regarding IBST, by implementing the 5E model, and continued the process throughout their professional development. Teachers developed new routines when it came to IBST, and they also developed their learning and collaboration. The artifact was intended to help the teachers to reconceptualize goals related to inquiry and scientific thinking, and to solve for themselves the problems involved in achieving those goals in their own contexts.

The teachers agreed that they would focus on IBST to a greater extent than they had done earlier. They discussed how this could be possible in their practice, concluding that there could be a need for a new mindset in teaching, as a substitute for traditional lessons. There was a desire for change, which came from the teachers themselves. They asked how this could be done in collaboration with other teachers. Furthermore, they asked how do we teach when using inquiry-based methods? What do we know about IBST? The teachers in this intervention have a common understanding of how they want their science teaching to be; however, they want student work to be more inquiry based. Their teaching practice is characterized by traditional classroom teaching, but they are nevertheless open to new approaches. The teachers participated in a TPD program during the previous school year, with the intention of increasing

IBST skills. The teachers teach inquiry science with a shared understanding of IBST, and critical examination of this new teaching practice is the basis for implementation. Continuing reflection is necessary while trying out IBST in practice, since these experiences create the basis for assessing whether the ideas work well in practice or not. The teachers evaluated their implementation of IBST and they found it challenging, but educational in terms of their professional development.

5.3.   *Enhanced Teacher Learning and Teacher Development*

By participating in an inquiry-teaching project, teachers have the opportunity to expand their own insights through reflection. Their dialog may be linked to a reflection perspective (Søndenå, 2007). The dialog represents a shift from an individualized reflection concept to a more collective and interactive phenomenon. This means that more people join in the conversation and that it encourages an exchange of views. Collective reflection can grow from dialogs that occur in a variety of situations, as the teachers in this intervention pointed out. The teachers are very aware that they need to deepen their knowledge and improve their competence during the course of their careers. Using enhanced, innovative teaching methods as a means of development and learning requires teachers to demonstrate commitment and confidence. Their perceptions of changes in practice should guide the plans made for teaching.

It might seem difficult to establish a standard method for handling professional development in the teaching profession, since establishing new forms of practice involves cognitive and physical costs for the teacher (Klette, 1998). Teachers in the study corroborated exactly this: that it entails costs for teachers to adopt inquiry-based teaching methods, but that the 5E model helps them to structure their teaching. It creates new experiences and provides opportunities for reflection around them. As teachers engage in mutual activity in reaching a goal, the ways in which they think and act demonstrate the usefulness and limitations of the 5E model. If this experience is perceived as positive, teachers seem to be further motivated by their mastery of this new method, but teachers must be given time for the transition. This resource is essential for professional development, as teachers emphasize.

The teachers state very clearly that working together with the researcher was a valuable resource for their developmental progression. According to them this was because my presence made it easier to stay focused during the reflection and planning meetings. In learning to teach using inquiry, the teachers experienced a sense of achievement when their own students mastered the given task. Positive experiences of mastery help to raise confidence about handling similar tasks in the future. Teachers process and learn from experience through reflection. According to the teachers, teaching actions are based on habits and routines, and when these are disturbed, critical thinking, and therefore valuable learning, is activated through the uncertainty of the situation.

Learning is predicted to occur when knowledge seems relevant to something experienced, and when the experiences can be drawn into the learning process (Dewey,

1916). The teachers experienced how the 5E model, as the mediating artifact, was perceived in their teaching. This experience would not have been the same if they did not personally experience it. Teachers think, feel and act all the time. It is difficult to determine when learning actually takes place. In particular, it is difficult to state conclusively that the use of the 5E model is causing the teachers to think more inquiry based, as there could be other factors outside the intervention influencing their view. However, I cannot control such factors and I can only relate to what I actually observe and what the teachers tell me.

Teaching practice is based on assumptions that evolve and becomes part of the teachers' consciousness and subconsciousness. Once a teaching practice is established, it can be difficult to change it over the short term: such changes take time. Nevertheless, the teachers reported that after the intervention, they collaborate more actively and more autonomously within the science department at their school. Teachers' growing confidence and reflective skills form the basis of the development of the school's science department as a professional learning community, from which, in turn, teachers are stimulated and empowered to develop their teaching practice in an even more reflective way. Stoll, Bolam, McMahon, Wallace, and Thomas (2006) have identified various characteristics relating to the development of cultures of teacher collaboration, and among these characteristics are shared trust, respect and collegial support. Teachers clearly state that they are now more collaborative in their learning community and this is experienced as important for their professional development. I consider the ultimate objective of professional development to produce competent teachers who have at their disposal a range of methods they can use, based on a comprehensive understanding of what will work and professional instinct that has been developed over time. As a response to a change in the science department's teaching practice, teachers claim that they have gained a more professional attitude to their colleague's teaching.

6. Concluding Comments

The purpose of this study was to address the question: *how can the 5E model as a mediating artifact enhance TPD*? The 5E model as the mediating artifact was shown to help the teachers enhance and structure their teaching. Furthermore, the facilitating organizational structure provided support and stimulated teacher collaboration and teacher development, thus preventing the individualization of practice. The teachers addressed their own development rather than becoming stressed from pressure originating outside the school. Teachers' discussion of issues concerning the use of the 5E model was, in this study, something that triggered new teaching ideas and motivated them to rethink and change their teaching practice.

Professional development is more likely to be voluntary and successful when the starting point is teachers' own needs, and the subsequent learning is personal, properly formed and absorbed by each individual, and shared in collaboration with colleagues. The school's science department emerged as a professional learning community

through the teachers' growing confidence and reflective skills. Moreover, teachers were supported to develop their teaching practice in an even more reflective way.

Teachers who call for change in a bottom-up way should expect structural and administrative support in making informal and formal collaboration possible, such as time for reflection with colleagues, and the use of external resources (e.g. researchers) supporting and guiding the teachers. Post-intervention reflection revealed that the teachers gained knowledge through using the 5E model, and learned how to use IBST in their classrooms, with greater emphasis on learning. Teachers do not need to perceive the use of the model in the same way as their colleagues, as long they develop their own practice and find the model useful in their practice in science teaching.

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