Introduction

The Norwegian case study is centered on the Framework Programme 7 project *Science-Teacher Education Advanced Methods* (S-TEAM). The project was coordinated by the Department of Teacher Education (PLU[1]) at the Norwegian University of Science and Technology (NTNU).

S-TEAM had the purpose of disseminating inquiry-based science teaching methods (IBST) to the widest possible range of teachers and teacher educators across Europe and associated countries. The project ran from May 2009 until May 2012. S-TEAM comprised 26 institutions from 15 countries: Norway, Denmark, Sweden, Finland, Estonia, Lithuania, Czech Republic, Germany, England, Scotland, France, Spain, Turkey, Cyprus and Israel.

S-TEAM was preceded by the Mind the Gap project (April 2008-March 2010), which was coordinated by the University of Oslo. Mind the Gap comprised partner institutions from Norway, Denmark, Hungary, Germany, UK, France and Spain (Stadler & Jorde 2012).

Both projects aimed at promoting inquiry based teaching in science (IBST) and the projects concentrated on the role of teachers in the implementation of inquiry-based approaches to science teaching. Teacher professional development (TPD), therefore, became an important focus for both projects. Experiences from the German large-scale TPD project SINUS formed a starting point for the development of a common model for TPD for science teachers.

Mind the Gap and S-TEAM recognized four important elements in IBST:

- Authentic and problem-based learning activities
- Learning through experimental approaches and gathering information, in some cases (but not necessarily) involving hands-on activities
- Self-regulated learning, and a certain degree of autonomy for learners
- Talking science: argumentation and communication with peers

[1] PLU - Program for lærerutdanning, or Programme for teacher education

The impact of S-TEAM on the institution

The impact on NTNU's Department of Teacher Education can be described as follows:

1. Project experience

Working on an international project of this size has given our institution experience in terms of project management skills, in particular management of EU-funded projects. With a background in these experiences, it has become easier to develop new project proposals, in particular in the field of STEM education, but also in other fields and even in non-educational fields. S-TEAM seems to have had an impact not only on Teacher Education but also to a certain degree on other parts of the Faculty of Social Sciences.

2. Networks

Working with multiple partner institutions across many European countries has provided valuable contacts, which have led to further involvement in networks in STEM education. At individual level, NTNU staff members who were involved in S-TEAM have established new contacts with researchers in other countries and become members of informal and formal networks.

3. Knowledge, experiences, materials and other products as results from S-TEAM With a focus on IBST, S-TEAM has provided deeper insight in not only inquiry-based approaches to teaching science, but also in many issues of science education in general. Through studies and comparisons of the different national contexts in the project, we gained deeper insight into our own practices in teaching science and in our own national educational context, seen in a wider perspective. In S-TEAM, we actually found ourselves in a double loop, whereby we, and others, thought about how to change science education through inquiry and beyond that, about the change process itself (Stavik-Karlsen & Gray 2013). The deliverables we have produced at PLU/NTNU for S-TEAM and those produced by our partners, have contributed to a growing body of evidence based knowledge about effective ways of teaching science and how to change (or how *not* to change) teachers' thinking about teaching science. In particular, our institution has greatly benefited from the knowledge that was produced and exchanged in the project regarding teacher professional development.

This has formed an important base for the development of a nation-wide programme for schoolbased teacher professional development (the SUN-project).

4. Spin-off

Norway's involvement in S-TEAM and in its forerunner, Mind the Gap, created a well-timed incentive for a productive dialogue with the Norwegian educational authorities, which, at that time, had shown interest in the German SINUS-project. This resulted in funding for a national pilot project, *School Development in Science* (SUN). The SUN project started in 2011 and is still running. The success of the SUN-project is largely due to impulses from Mind the Gap and S-TEAM. An example is the Scottish PISCES project that originated from S-TEAM (Smith et al. 2013), which shares many common aspects with SUN, as both projects clearly acknowledge the central role of the teacher and recognize TPD as the top priority if a change in science education is to be made, rather than producing materials. In the next section, the contextual background of the SUN-project and the approaches used in the project will be described in more detail.

The impact of S-TEAM on the context

S-TEAM may have contributed to fostering more awareness of inquiry-based approaches in science teaching at several levels:

- At national level (The Ministry of Education and Research, the Norwegian Directorate for Education and Training),
- At school owner level (the provinces as owners of the upper secondary schools and the municipalities as owners of primary and lower secondary schools)
- At school level.

Although increased awareness at "higher" levels may be an important prescription for increased awareness of this field in schools, it is not enough. In other word, even if S-TEAM had contributed to increased awareness at national or school owner level, that alone would be no guarantee of implementation of inquiry-based approaches in schools and in STEM classrooms. S-TEAM, and other STEM-education projects, would only have had real impact if they had affected the way STEM teachers teach.

Therefore, special attention should be paid to teachers, and we should consider TPD is the most important vector for innovations in education. S-TEAM targeted teachers and their ways of thinking about teaching science and mathematics. How this was done at teacher level will be described here. As an introduction and background, some conceptual issues and important findings from current research in TPD will be presented.

In-service training and professional development

Borko, Jacobs & Koelner (2010) argue that we should make a distinction between in-service training and professional development. They describe traditional in-service staff development as a training model "where teachers are expected to learn a clearly defined body of skills through a well-specified process, often delivered in one-shot workshops or courses taught away from the school premises". Such approaches are described as "overly fragmented, not connected closely enough to classroom practice, and out of alignment with current theories of learning and school reform". Furthermore, they mention that these approaches are now being replaced by approaches that are grounded in classroom practice and aligned with situated learning and constructivist theories.

This view of a rather sharp contrast between traditional approaches, which seem to fail to meet the needs of science teachers, and newer approaches, is supported by several others authors, such as Bybee & Loucks-Horsley (2000) and Ostermeier, Prenzel & Duit (2010). Tyler (2007) distinguishes between a traditional "skills and knowledge approach" and professional development approaches, which are more sensitive to the context in which teachers work, and which are grounded in a coherent view of teacher learning and teacher professionalism. The perspective of a coherent view of teacher learning is also taken by Opfer & Pedder (2011), who, based on their comprehensive review of current literature in the field of teacher professional growth, describe teacher learning as a complex system, involving systems within systems.

Teacher collaboration

TALIS data show that there are surprisingly few differences between teacher categories when it comes to teaching practices and teachers' beliefs about teaching. There are no major differences between younger and older teachers, nor between teachers with a university

degree and those with a degree in teaching (primary teachers), nor between those with lower and those with higher university degrees (OECD 2014, Vibe, Aamodt & Carlsten, 2009). This may be explained by the assumption that teachers' practices are not primarily affected by their formal education but mainly by the challenges they meet in their daily work. One could assume that teacher collaboration would explain at least part of this convergence. But teachers report that most collaboration deals with practical matters and that they do not commonly take part in discussions about their own, or others', teaching.

New teachers seem to be more likely to adopt the culture of their schools and hence the "traditional" teaching approaches, then to introduce innovative teaching methods as learned in initial teacher training (S-TEAM, 2010). Many new teachers "struggle to survive" during their first years of practice, which makes it more difficult to challenge established structures and a culture where it may not be common to speak about one's own teaching. This demonstrates the importance of creating opportunities for communication and teacher collaboration.

Teacher Professional development: School-based and Situated in Practice

In their review of research on teacher professional development, Borko et al. (2010) show that two features stand out as content characteristics of high-quality professional development: the content is situated in teaching practice and it is focused, at least in part, on students' learning.

Closely associated with this, although not as a content characteristic, is that the professional development activity should be school-based (Borko, 2010; Galanouli, 2010). A school-based approach to professional development is usually associated with courses or workshops that take place at the teachers' school premises, rather than outside the school, although this does not always need to be the case. 'School-based' also frequently refers to the participants being from one school. When the group of participants comprises all or most of the school's staff, or the school's teaching staff in, for example, science, professional development activities normally become closely associated with school development.

As mentioned earlier, what seems to be important is that professional development is based on a perspective of situated learning (Putnam & Borko, 2000; Ostermeier et al., 2010). We speak about situated learning when the teachers' learning and professional development is situated in their own practice, as close as possible to their daily work, their own teaching, their own classes and their own students' learning.

Situated learning is learning that takes place in the context in which it is applied. Provided that enough time is available, a situated learning approach stimulates teachers to analyze their own practice, develop their understanding of the impact of their practice on students' learning, develop new ways of teaching, try them in their own classes, reflect, review and report. When the perspective is one of situated learning, the focus is always on teacher's own practice.

Another important aspect of a school-based approach to teacher professional development is that it engages teachers in the same school in collaborative inquiry; teachers work in partnerships and support and learn from each other. This may be a strong motive force for development at school level and lead to stronger commitment to adopt changes (Pickering, Daly & Pachler, 2007). But teacher collaboration is no guarantee of professional growth or change of practice. Guskey (2003) mentions that research on teachers has shown that individuals can collaborate to block change or inhibit progress just as easily as they can to enhance the process. Collaborative inquiry needs to be facilitated and directed carefully in order to be effective as an element of professional development that will lead to professional growth.

Professional Learning Communities

Teachers who work together with a focus on improved learning and teaching, and to generate new professional knowledge, may form what is called professional learning communities (Harris & Jones, 2010). They describe a professional learning community as a group of connected and engaged professionals who are responsible for driving change and improvement within, between and across schools that will directly benefit learners.

According to Vescio, Ross & Adams (2008), learning communities are grounded in two assumptions: First, it is assumed that knowledge is situated in the day-to-day experiences of teachers and best understood through critical reflection with others who share the same experience. Second, it is assumed that actively engaging teachers in professional learning communities will increase their professional knowledge and enhance student learning.

Bolam et al. (2005) describe professional learning communities as communities in which teachers in a school and its administrators continuously seek and share learning, and act on their learning.

They describe the following elements as key characteristics of effective professional learning communities: shared values and vision; collective responsibility; reflective professional inquiry; collaboration and inclusion. Furthermore, supportive leadership and school management is necessary for professional learning communities to be effective.

Although supportive leadership is important, it forms a part of the outer environment of the learning community. Leadership within professional learning communities is usually distributed. It is simply in the hands of the teachers working together on a shared area of enquiry. Distributed leadership provides the infrastructure that holds the community together (Harris & Jones, 2010, 174).

In many aspects, professional learning communities in schools may also be seen as what Wenger (1998) describes as communities of practice: "groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise by interacting on an ongoing basis".

Borko et al. (2010:548) argue that the new vision of professional learning communities as a structure for professional development is closely connected to a call for instructional reform.

The Norwegian SUN-project

In Norway, school-based approaches in teacher professional development are widely used. In particular, such approaches are used when focus is on generic pedagogic principles and methods or on teaching in general, regardless of the subject being taught. However, schoolbased professional development specifically for science teachers has so far not been widely used in Norway. Most commonly, professional development activities for science teachers focus on teachers' subject knowledge and skills, although teaching aspects (pedagogical subject knowledge, "didaktikk") are usually included in courses for science teachers.

The Resource Centre for Mathematics, Science and Technology Education is a unit at the Norwegian University of Science and Technology whose activities are, as its name suggests, mainly directed at professional development of schoolteachers in mathematics, science and technology. Initially, the activities of the Resource Centre have been more or less concentrated around university campus based courses for teachers and development of teaching materials.

More recently, there has been a growing awareness of the need for a wider range of approaches, which meet all the needs of science teachers, including subject knowledge, pedagogical subject knowledge and those forms of knowledge that are grounded in teaching practice and teacher professionalism. In response to this, the Resource Centre for Mathematics, Science and Technology Education at the Norwegian University of Science and Technology developed a school-based professional development programme for science teachers in secondary schools. Initially, the programme was piloted on a small scale (20082010), with the aim of exploring how the new model would work within different school contexts.

In 2010 the Resource Centre became involved in S-TEAM and in 2011 the Norwegian government provided funding for a three years national pilot project, School Development in Science (SUN). The pilot was run in four nodes in Norway: Oslo, Bergen, Trondheim and Tromsø. In the Trondheim node we drew on both the experiences from the pilot we ran from 2008 to 2010 and the impetus from S-TEAM. From 2014 there will be no more governmental funding for the project and The Resource Centre now runs SUN in Middle and Northern Norway with funding from regional school owners. In the following section, a presentation of SUN will be given, largely based on the work done in the Trondheim node of SUN.

SUN is premised upon five key principles, based on findings from international research on TPD and on a background of years of experience in working with science teachers.

The SUN key principles

The first principle is that professional growth is more likely to take place if teachers' learning is situated in their own school and their own teaching practice.

The second principle is that teachers' learning is more effective if they are challenged to further develop their expertise in teaching, rather than being told by external experts that they need to change their practice.

The third principle is that teachers' professional growth is more successful if it is grounded in collaborative inquiry.

The fourth principle is that successful TPD must take place over time.

The fifth principle is that TPD is more likely to be successful if it is internally generated and externally supported and guided.

The second principle is advocated by Harrison, Hofstein, Eylon & Simon (2008). In their work they also emphasize the importance of an evidence-based approach to teacher professional development. Following this idea, we require from the participating teachers that they provide evidence of innovations in their teaching practice.

When we approach the schools and invite them to participate in the project, we start with a meeting with the school leadership, in order to make sure that they will provide commitment and support. At the next meeting, we inform the science teachers on the SUNprogramme how they can benefit and what we will require of them. We clearly frame the focus and the aim of the project from the teachers' perspective: to develop expertise in teaching science.

In most cases the SUN programme runs at a school through one school year, including 5-6 half-day workshops with all the science[2] teachers at the school. The workshops always take place at the school's premises. Between workshops, the teachers work in small groups (2-4 persons), and staff members of the Resource Centre act as "consultants" for the teachers.

During the first workshop, we introduce some ideas about alternative approaches to science teaching, in particular more open-ended approaches. We present the 5E-modell (Bybee et al. 2006), and we ask the teachers to try to identify fields of inquiry in their own teaching practice. The teachers then form small groups with those who have chosen the same fields of inquiry. From there, the teachers are guided into a phase where they focus on plans for an innovation in their teaching. They spend the next months developing, testing and implementing these innovations in their own teaching practice. During each workshop, the teacher groups report on their innovations and the progress they have made, and they receive feedback from members of the other groups and the staff members from the Resource Centre. From the beginning, it is made clear to the teachers that each of the groups will be required to present their innovation at the end of the project. The format we have chosen for this is a poster presentation in the last workshop. The last workshop is common for all the SUNschools in the region and gives the teachers an opportunity to share the results of their innovations with teachers from other schools.

[2] Initially we only worked with science teachers. Currently the SUN-program is meant to include both science teachers and mathematics teachers at a school.

We based the model of the our program on a set of principles, which we chose on the background of years of experiences with work with science teachers and on the results from other TPD-programs, as described and discussed in the international literature on teacher professional development. In particular, our model has many principles in common with the model used in work with science teachers conducted by King's College, UK, and Weizmann Institute of Science, Israel, as described by Harrison et al. (2008) and Hanley, Maringe & Ratcliffe (2008). In these projects there is a similar notion of the goal: to promote expert or accomplished teaching. This is chosen explicitly as the goal of the project, rather than, for example, 'change of practice' or 'improving the way teachers teach'. We do not want to come to the schools and tell the teachers that they need to change their way of teaching. We have noted that the teachers responded positively to this, although they do not seem to consider themselves as experts. This reflects the nature of the needs of science teachers and the relationship between practicing teachers and teacher educators (or others who run the program and guide the teachers). On the one hand, most teachers strongly dislike it when so-called experts from outside the school come and tell them what to do. In fact, many would say that they know what to do and that the real experts on teaching are those who have their daily work in the classroom. But when the teachers were asked to bring examples of innovations in their own classroom practice and to present them in the workshops, we noticed that most of the teachers appreciated receiving support and feedback from experienced teacher educators; they realize that there are new things to learn and in such a setting they do not have to avoid the word expertise when speaking about their own teaching.

In some cases teachers may have some initial difficulties in understanding the aims of the program. This may have something to do with their being unfamiliar with the situated learning approach, where the teachers' own teaching practice is used as a starting point. Although we, and others, (Putnam & Borko, 2000; Ostermeier et al., 2010) have noticed that it is an approach usually appreciated by teachers, teachers are far more used to traditional approaches, where, usually, educational experts from outside school more or less "construct" and define a common understanding of the situation that needs to be changed.

Impact of SUN on the context

As mentioned, our work in S-TEAM resulted in valuable contacts and networks. We have gained deeper insight in effective ways of teaching science and materials have been produced. However, the most important impact of S-TEAM on teaching practice in Norwegian schools is through the SUN-project. A total of ca. 60 schools have already participated in SUN. School owners in two of the Norwegian provinces have adopted SUN in their long-term plan for TPD for teachers, which means that there will be another 15-18 upper-secondary schools signing up for SUN-based TPD for STEM teachers in the next few years.

In addition, there is a growing interest for a much wider use of the SUN-approach. A suggestion has been made by one of the school owners that the SUN-approach should be adopted as a model for TPD in a much wider sense than in science and mathematics and a program is in the planning stages for SUN-based TPD in classroom management.

The school owner for primary and lower secondary schools in Trondheim, Trondheim Municipality, has adopted the SUN-approach as the standard model for school-based TPD in science and mathematics in all the Municipality's forty schools, through a program that runs from 2012-2015.

Research on SUN

Svendsen, Bodil & Marion, Peter van (2014) A School-Based Professional Development Programme For Science Teachers: Participants' Reports On Perceived Impact Over Time, in: *Science Education Research For Evidence-based Teaching and Coherence in Learning (Proceedings of the ESERA 2013 Conference)*. Nicosia, Cyprus: ESERA 2014: ISBN 978-9963-700-77-6.

Bodil Svendsen is currently working on a Ph.D.-thesis, centered on development and testing of a model for TPD, based on experiences from work with SUN-schools.

S-TEAM and other projects

Norwegian institutions have been and are currently involved in other EU-funded projects on STEM education as well, such as MaSCiL, PRIMAS, TEMI, FasMed, M3EaL and ENGAGE. Those projects were presented at the Norwegian national workshop (*Building Bridges*) on 20th January 2014.

Participants in the workshop comprised researchers in science and mathematics education, teacher educators, school teachers, and persons representing school owners, the Norwegian Centre for Mathematics Education, the Norwegian Centre for Science Education, the Directorate for Education and Training and the Ministry of Education and Research. In the workshop, we discussed how the results of the various projects could and/or should be taken forward, in order to have widespread and long-lasting impact on what happens in mathematics and science classrooms in Norwegian schools. The points of view that were expressed are summarized and presented in the report of the Norwegian national workshop (http://instem.tibs.at/content/norwegian-national-instem-workshop)

Inquiry and entrepreneurship

NTNU's involvement in S-TEAM also has had implications for participation in other educational projects, such as ADEPTT, CGSE and E3 (see Table 1). All three projects focused on entrepreneurship in education. There has been a growing awareness of the close relationship between inquiry-based approaches and entrepreneurial approaches in education. Our experience is that there is potential in trying to bring together these approaches, although they may seem to be embedded in different cultures and traditions in schools, sometimes within the same school. Science teachers are usually not familiar with entrepreneurial approaches, while typical entrepreneurship teachers (commonly teaching business subjects in commercial studies) seem to know little about inquiry-based teaching. In April 2013 we organized a two-days-workshop in "Creativity" for science teachers, in particular science teachers who teach the school subject 'Technology and Research'. With creativity as a starting point, we managed to get the science teachers involved in entrepreneurial approaches. Feedback we received from the participating teachers indicated that such crossover was appreciated by the teachers and seen as a valuable input. When working with teachers and others in the entrepreneurship projects, we experienced that there are two rather different views on what entrepreneurial education is. The one vision is that entrepreneurial education is about teaching students how to think as an entrepreneur and how to start and run a business. On the other side is the view that entrepreneurship education is about how to learn, in other words a view were entrepreneurship is a pedagogical tool or approach to learning. It is the latter view that, in particular, seems to be a good starting point for more dialogue and closer collaboration between science teachers and entrepreneurship teachers.

NTNU is currently taking part in two Erasmus+ projects, both of which are following on from aspects of S-TEAM. STING (*STEM Teacher training INnovation for Gender balance*) will develop a teacher training package for increasing awareness of gender issues, using the principles that have been proven in the SUN project, together with gender principles from other EU-funded projects such as TWIST (*Towards Women In Science and Technology*). NTNU's Department of teacher education (PLU[3]) will build a theoretical framework for the package and will pilot it in Norwegian schools.

PLU is also coordinating the VISconti project, which connects vocational education student projects in STEM subjects to industrial advisers, building an entrepreneurial culture within and around STEM education. This has benefits in connecting STEM education to the real world, in involving students in thinking about social and economic aspects of STEM work, and in connecting schools to industry for mutual learning.

Table 1. EU-funded projects in which NTNU's Department of teacher education (PLU): Resource Centre for Mathematics, Science and Technology Education have been involved

Projects	**Yrs**	**Role**	**Funding**
ADEPTT Acknowledging and Developing Entrepreneurial Practice in Teacher Training - 2011-1-ES1- LEO05-36404	2011-2013	Partner	EU Leonardo da Vinci (Lifelong Learning Programme)
E3 Enhancing Entrepreneurship in Education 2011-COM-PV- REG-20-EU	2012-2014	Local partner	EU Comenius Regio Partnerships

[3] Program for lærerutdanning

Career Guidance Services for Entr. Ship (CGSE) 2010-NO1-LEO05-01967	2008-2011	Local Partner	EU Leonardo da Vinci (Lifelong Learning Programme)
S-TEAM Science Teacher Education Advanced Methods. FP7-CSASA. Project No: 234870.	2009-2012	Coordinator	EU FP7 Science in Society
INSTEM Innovative Networks for Science Technology Engineering & Mathematics education - 527333-LLP-2012-DE-COMENIUS-CNW	2012-2015	Partner, WPleader	EU Comenius Multilateral Networks
PRIMAS Promoting Inquiry in Mathematics and Science Education across Europe. Grant Agreement 244380	2011-2013	Member of National Advisory Panel	EU FP7 Science in Society
MASCIL	2013-2015	Member of	EU FP7 Science in Society
Mathematics and Science for Life		National Advisory Panel	
VISconti Viability Innovation Scientific Creativity oriented network for training and instruction	2014-2016	Coordinator	EU Erasmus Plus

STING STEM Teacher training INnovation for Gender balance	2014-2016	Partnertheoretical framework for teacher professional development	EU Erasmus Plus

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