A scientific approach to teaching
– to reach innovative pedagogical approaches nationwide

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Keywords: SoTL, Engineering Education

INTRODUCTION

This paper is about interdisciplinary common national initiatives to enhance and encourage quality of engineering education. STEM, referring to the academic disciplines of science, technology, engineering, and mathematics is in Norway an important field addressed by education policy to improve competitiveness and technology development. Recruitment for STEM education, to reduce dropout and to increase throughput within these study programs is an area of priority. Many different initiatives and activities to enhance quality of STEM education has in Norway been initiated on a national level, as well as on institutional level.

The paper will give an overall introduction to the national work to enhance quality of education, the national collaboration parties, motivation, objectives and activities, and particularly present and reflect on the scholarly approach to planning and carrying out the 1st Norwegian STEM conference on teaching and learning. This has been an important activity within the national projects on enhancing quality of STEM education by promoting a scholarly approach to teaching and learning within the STEM area.

1 ENHANCING QUALITY OF EDUCATION THROUGH NATIONAL PROJECTS

The Norwegian Association of Higher Education Institutions (UHR) is a national cooperative body for Norwegian universities and colleges, whose purpose is to

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develop Norway as a knowledge-based nation of high international standard. The academic strategic work of UHR within the STEM fields consists of the National Faculty meeting of Natural Sciences (NFmR) and the National Council for Technological Education (NRT), where all Deans within these areas are members. NRT and NFmR have received funding for national projects to enhance quality and relevance of STEM education from the Ministry of Education and Research (KD).

The KD also established “Centres of Excellence in Higher Education” (SFU’s) in 2010, as a prestige arrangement for educational activities in higher education. The SFU programme, managed by the Norwegian Agency for Quality Assurance in Education (NOKUT), implies a long-term commitment to stimulate the development of teaching and learning methods at both the bachelor and master levels [1]. Within the STEM area there are so far two SFUs established; *MatRIC*, Centre for Research, Innovation and Coordination of Mathematics Teaching and *bioCeed*, Center of Excellence in Biology Education.

At the same time, in 2010, KD started a process to revise the national curriculum framework for engineering education. “The Engineer – community committed, creative and empowered, with the ability to actively contribute to the challenges of the future!” – is the vision for the future engineer used to express the challenge to make this education attractive through meeting the expectations of young people and show them how they can realize themselves through engineering and that they through the engineering profession can contribute to sustainable future changes. A competence based framework for Norwegian engineering education on the Bachelor level were adopted by the KD in February 2011, and full implementation started the academic year 2012/2013 [2]. The framework consists of mandatory regulations and guidelines anchored in the regulations but expected to be in a process of continuous improvement. NRT has been responsible for developing the national guidelines and a national common implementing process, involving academic staff in all subjects. The competences described as learning outcomes, divided into knowledge, skills and general competences, are in accordance with the requirements of FEANI, European Engineers Federation [3]. The regulations define competences equal for all engineering candidates regardless of engineering area, and the guidelines define competences specific for different engineering areas. The Master level of Norwegian engineering education is also described by national characteristics and learning outcomes. As a result of this work, the European Monitoring Committee (EMC) of FEANI, agreed October 2014 to automatically accept all programmes following the regulations and submitted by the Norwegian National Monitoring Committee (NO NMC) for the next five years.

The National Center for Science Recruitment is working to increase recruitment to science education and careers. The center is a national organisation – created by and positioned directly under the KD.

All these initiatives from the different bodies have a common overall objective to strengthen the STEM area in Norway and NRT/NFmR has, through the projects they as a national body received funding for, started a common work to facilitate cooperation, collaboration and knowledge sharing between these (and other) national and institutional initiatives to contribute to even better results, compared to results from the separate initiatives.

2 DEVELOPING A CULTURE FOR A SCIENTIFIC APPROACH TO TEACHING

Based on experience from the different national and institutional initiatives, as well as other activities, NRT/NFmR has chosen a common goal for the initiatives and

activities. As a top-down initiative the goal is to facilitate a bottom up initiative for a scholarly approach to planning, carrying out, evaluating, assessing and reviewing teaching. In other words fostering a Scholarship of Teaching and Learning (SoTL) [4] culture. To reach innovative pedagogical approaches it is seen as important to stimulate collaboration and knowledge sharing across engineering disciplines, across STEM disciplines and interdisciplinary approaches in a broader perspective.

To encourage and give credibility to a SoTL approach among higher education teachers it has also been used for the development of these national initiatives. Experiences from LTH, the Faculty of Engineering at Lund University in Sweden, which is very active within the area of teaching and student learning, and from DTU, the Technical University of Denmark as well as from Norwegian Centres of Excellence in Higher Education (SFUs), have been considered and incorporated during the process. More about the cooperation, SoTL objectives and other national activities are presented in the following sections.

2.1 Cooperation

NRT and NFmR have developed close strategic cooperation because of the projects. Earlier, academic strategic work of these national bodies was on the technology and engineering (NRT) and science and mathematics (NFmR) respectively. For technology education dropout and throughput problems are often related to mathematics (see section 2.4). When the ministry encouraged NRT to work with national activities to reduce dropout and increase throughput within engineering education they responded with a need to work in close cooperation with NFmR as well as The National Center for Science Recruitment. Also the SFU MatRIC (Centre for Research, Innovation and Coordination of Mathematics Teaching) was involved as a cooperative partner in the project.

LTH, the Faculty of Engineering at Lund University in Sweden has a strong tradition of strategic educational development and is very active within the area of developing teaching and student learning and it has its own academic development unit, closely associated with the teachers in the faculty. The Academic Development Unit (ADU) at LTH bases its activities on the theories of Scholarship of Teaching and Learning [4]. These activities include pedagogical courses, consulting, evaluations, research on teaching and learning, and arenas promoting pedagogical discussions such as seminars, newsletters, a biannual campus conference about teaching and learning and a pedagogical reward-system "The Pedagogical Academy" [5, 6]. The experience from Lund has been used as the starting point for a similar development in Norway. The working groups of NRT and NFmR have visited the biannual conference in Lund. The ADU at LTH has shared their experiences at different Norwegian higher education institutions, is cooperating with Norwegian SFUs and has also a member in the review committee for the first Norwegian STEM conference about teaching and learning, named the MNT-conference (see section 3).

The Journal Uniped – Journal on Science of Education [7], has since 1978 published scientific articles on quality education. A meeting with the editor-in-chief and the editorial board resulted in an agreement to work towards a special issue on STEM education winter 2015. This was important as articles in the journal results in publication points, which again counts in research based funding for higher education institutions. The cooperation with Uniped has been of vital importance as their experience from other areas of education has been very useful in the work. For Uniped the cooperation makes it possible to increase focus on STEM education. Traditionally these areas of higher education have had few articles in the journal.

2.2 SoTL Objectives

Development of the STEM conference has been one of several activities within the national work to enhance quality of STEM education. The STEM field is special in the sense it is a fast moving field. For instance as mentioned in one of the conference articles “A regular laptop - which most students have - is as powerful as a supercomputer was ten years ago; This has to change the way we are teaching STEM-subjects” [8]. The STEM conference shall contribute to produce new knowledge and deepen the understanding of teaching and learning STEM subjects. It is expected that a scientific approach to teaching and learning will:

- increase quality of education
- increase reputation for teaching among colleagues
- stimulate development of a variety of and innovative pedagogical approaches by collaboration and knowledge sharing across STEM disciplines, across engineering disciplines and interdisciplinary approaches in a broader perspective
- increase recruitment to STEM education
- reduce dropout and increase throughput of these study programs

It is assumed that increased educational focus nationally will increase institutional educational focus and also develop a culture for teaching and learning within universities where a strong research focus exists.

2.3 Other national activities

Examples of further conducted activities on a national cooperative basis:

- An engineering didactics course owned by and developed for NRT by PLU – the Programme for Teacher Education at NTNU, the Norwegian university of science and technology. This course has been executed two times, each for approximately 25 participants from different Norwegian higher education institutions. Evaluation has been conducted.
- A national survey on mathematics – from high school to university. Some results are presented in section 2.4.
- Pedagogical inspiration seminars. Both international and national speakers have shared their knowledge. Seminars have also been streamed to make them available for a broad audience.
- Meetings within different subjects and across disciplines. Goals have been to share experiences and discuss subject matters, subject didactics and cross-disciplinary challenges.

A national cooperation to obtain national robust and innovative high quality education has been an overall goal for these activities. The experience and results from the different activities has been used for developing the STEM conference. As the survey on mathematics gave broad and valuable information for the further work, a few of these results are presented in the next section.

2.4 A national survey on mathematics

A national survey on mathematics with focus on transition from high school to university was conducted autumn 2013 [9]. 81 teachers and 2994 students responded to the survey. Percentages on failure on passing exams in introductory courses in mathematics are high. It was assumed that teaching and learning could be approved. To increase the number of students who complete these courses, the study's goal was to highlight different aspects of teaching and learning mathematics from the perspective of both the institution and the students. In addition the survey should give information to strengthen science of education within this area. Of the 81

teachers 48.7% teach at a university, 52.3% teach at a university college. Of the 2994 students who responded to the survey 62% are studying at a university, the rest at a university college. There are 35.9% female students and 64.1% male students among the respondents. The assumption was confirmed. Ordinary lectures and exercises were main activities. Both lecturers and students found the level and size of curriculum in respect to credits to be appropriate or slightly too big. On a scale 1 - totally disagree to 6 - totally agree, 85.2% answered 5 or 6 on the question if they found the lecturer academically clever, but only 49.2% found the lecturer pedagogical, 33.5% found that the lecturer activated the students and 43.6% found that the lecturer motivated the students, all referring to the answer 5 or 6 at the same scale. The survey showed the same tendency when the answers are related to students' grades and sex. From the results of the survey the teaching and learning activities seems to be of higher importance to failure than the curriculum itself, but teaching provides low reputation among colleagues. On the question "What do you think provides the highest reputation among colleagues" 20.5 % of the university college teachers selected teaching as answer. None of the university teachers selected teaching, and only 11.4% selected research and teaching are equal. Research/teaching/research and teaching are equal/ do not know/ was the different answers to select. Research is for both groups what provides the highest reputation among colleagues. Development of teaching and learning as well as increased reputation of the teaching activity are expected to contribute to better results in the introductory courses in mathematics.

3 THE STEM CONFERENCE – TEACHING FOR QUALITY LEARNING

For the STEM areas the Norwegian Ministry of education and research has supported four conferences to address different challenges within these areas. Different universities and The National Center for Science Recruitment have been organizers. As an activity within the national projects it was decided to convert one of the existing conferences from a regular meeting and cooperation area, mainly attracting administrative staff, to a scientific conference on teaching and learning. An organizing committee and a review committee was established. Four themes for the conference, developed based on the experiences from earlier activities, and experiences from cooperative parties, were addressed in the call for papers June 2014 [10]:

- Education goals and contents:
  - Implementation of academic profile and learning outcomes at the institutional level, the program level and course level.
  - Integration of professional skill in educations - teamwork, systems thinking, ethics, environmental and sustainable development and communication and language skills.
  - Alternative pathways towards the same learning outcomes.
- Education management:
  - Development and management of study programs.
  - Culture for pedagogical and didactic development.
  - Learning that promotes quality and relevance, student effort and study mastery.
- Education – execution:
  - Effective, interesting, active and good teaching methods.
  - Strategies to handle different or weak knowledge.
  - Interdisciplinarity, innovation and entrepreneurship.
- Education – cooperation; school, work and internationally:
  - Profession enclosed learning activities.
  - Profession expertise and practical knowledge
  - International orientation and competence.

Important goals of this conference are both to support and encourage teachers to do research about their own teaching practice, and to spread good examples of educational development. The conference is established to perform an essential arena for teachers to meet, discuss and share knowledge of teaching and learning across institutions. An important role of scholarship of teaching and learning is bridging boundaries in higher education. It is expected that increased focus on quality of education and a scientific approach to teaching and learning is important to increase recruitment for STEM education, to reduce dropout and to increase throughput within these study programs. Innovative pedagogical approaches is expected to develop when collaboration and knowledge sharing across engineering disciplines, across STEM disciplines and interdisciplinary approaches in a broader perspective is stimulated.

3.1 Results

The STEM conference was held on 18 - 19 March 2015. The conference reached the limit of 180 participants. 39 articles were presented, addressing all different themes and with education execution as most frequent theme. 8 institutions had 2 or more articles, 3 had 1 article, 4 had no article but participants at the conference and just 3 of 21 relevant institutions had neither article nor participants. 4 institutions had 10 or more participants. Institutions with few participants have asked for increased limit.

A goal was to increase participation from academic staff compared to earlier conferences, where administrative staff have been in majority. More than 105 of the participants were academic staff or head of departments. Among these, 19 professors, 30 associate professors and 24 assistant professors were represented, as well as 8 deans. Furthermore, there were 15 students at the conference, also playing an important role in organising the conference as they chaired the parallel sessions. KD was represented by 2 participants, NOKUT and the research Council of Norway was each represented by one participant. The rest of the participants were administrative staff or from other organisations, profession and high school.

During the two days in total 40 parallels were given; the first day five parallel sessions, each with 5 presentations, and the second day five parallel sessions each with 3 presentations. Included were two workshops. In addition there were two keynotes from international speakers, motivating speeches for SoTL and examples of good cooperation between high school and higher education, also involving pupils. A round table discussion session ended the conference. All these were for the full audience. In the parallel sessions, the members of the review committee each attended different parallels. Students chaired the sessions. The participation within the different parallels varied from a minimum of about 15 to a maximum of about 50 people on different presentations. As it was a good possibility to alternate between different parallel sessions, the participants used this opportunity to listen to and discuss the presentations among the several different themes that was of most interest to the individual. The time for common discussion of articles was valuable.

3.2 Evaluation

After the conference an evaluation questionnaire was sent to all participants. Questions were related to the goals of the conference. 75 respondents, almost 50%, have answered. Some interesting findings, where the answers are on a scale 1 (low/totally disagree) to 6 (high degree/totally agree):

- To what degree was articles/presentations inspiring for you in your everyday work? – 5.15
- To what degree did you get references to work that you can take advantage of in your future work? – 4.59.

- Were you inspired to work with a scientific approach to teaching? – 5.08
- Did you get useful feedback on your own work? – 3.71

Especially valuable is that the conference seems to have inspired the participants to work further with a scientific approach to teaching, and that they were inspired by the presentations from colleagues. Comparing results from the evaluation with assumptions and objectives as defined above, as well as based on additional oral and written feedback to the organising committee and review committee it can be concluded that the MNT-conference has worked according to its intention. The answers below, according to the scale 1 (low/totally disagree) to 6 (high degree/totally agree) underpins this:

- A venue as the STEM conference is important for improving quality of education – 5.37
- Scientific approach to teaching will raise teaching status – 5.32
- Sharing experiences with various teaching methods contributes to greater variety and more innovative teaching methods – 5.28

3.3 Comparing with results from Lund

The *Pedagogical Inspirations Conference* at LTH, the Faculty of Engineering at Lund University has been used as a model for the STEM conference [11]. The *Pedagogical Inspirations Conference* has been organized 8 times since the start in 2003. But if we compare the quality of the contributions for the first *Pedagogical Inspirations Conference* and the first Norwegian STEM conference we can see a higher quality for the Norwegian contributions. On the other hand they are not up to the level of the 8th *Pedagogical Inspirations Conference*. This gives credibility to our idea that building something using experiences from other with a scholarly approach will increase the quality.

3.4 Comparing with characteristics of quality engineering education

Characteristics and indicators for quality engineering education were defined within the development of the revised framework for engineering education [2,12]:

- Integrated and holistic education
- In front by means of professional updating
- Updated and varied learning- and evaluation methods
- Research and development orientation
- Professional competence and practical skills
- International expertise
- Interdisciplinarity, innovation and entrepreneurship
- Study effort and coping
- Engineering formation

These characteristics may also be suitable for other study programmes within the STEM area, and may be supported by a SoTL approach. Several papers on the STEM conference gave examples that indicate that the implementation process has resulted in increased quality of engineering education, and that quality of STEM-education has equal characteristics. Papers presented activities, experiences, knowledge and results related to different indicators relevant to a SoTL practice:

- Cooperation on learning methods with other disciplines, including pedagogy.
- Variation in learning and evaluation methods.
- Teaching methods to activate critical, reflective and conscious thinking.
- Teaching methods and evaluation methods to stimulate collaboration across engineering disciplines and interdisciplinary approaches.
- Teaching that stimulates enthusiasm, creativity and innovation.

4 CONCLUSION

The main focus of this paper has been to present national initiatives to enhance quality of education, with a special focus on the activity of developing and executing a STEM conference to encourage a scientific approach to teaching and hence to contribute to development of improved and innovative pedagogical approaches nationwide. The conference evaluation shows that the conference has been a success. As much as 55.4% totally agreed on the assertion that a scientific approach to teaching will raise teaching status. The question "Would you attend a new STEM Conference in 2017?" resulted in 90.7% answered yes, 8 % maybe. The evaluation also resulted in many positive written comments, and as expressed by one of the deans "This approach makes it possible for us to conduct research on our core business". To develop a culture for a scientific approach to teaching through a SoTL approach, the STEM conference and the national common initiative has, based on evaluation and results, proved to be effective for enhancing quality of education. Project funds have resulted in valuable coordination and cooperation between various national instruments and activities. A new conference with its own journal is, based on these results, planned in 2017. The organizing committee is established.

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