First Evolution of the Introduction to Engineering course

– Case Study from the University of Turku

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ABSTRACT

Engineering education in the department of Information Technology at the University of Turku, Finland, follows the CDIO framework. In this paper, we examine the first evolution of the Introduction to Engineering course. The course is based on the CDIO standard no. 4, and it is the very first course for the engineering students when they commence their studies. The background and structure for the course as well as its intended learning outcomes will be presented.
Key research questions are how the students and the teaching team have understood the course's learning outcomes, and how the teaching team has been able to adopt the learning outcomes into the course structure. The research material has been gathered from the two consecutive courses during December 2012 – December 2013. The research material comprises of study journals and feedback that was collected after the course. The questions used in both surveys and study journals were based on intended learning outcomes and partly on CDIO standard no. 4.
The results from this longitudinal research shows that the evolution of the course is going to the right direction. The most promising results arise from the group work, which was changed from big groups into smaller ones: from 8 to 9 students per group to 4 students per group. According to the research results, it is important that also in the following Introduction to Engineering courses the substance and knowledge of embedded electronics and software (i.e., programming) is kept and further developed. The key issue for future courses is to further integrate the disciplinary knowledge with other learning areas such as design thinking, problem solving, communication skills, group work and societal understanding of the importance of engineering.

Keywords: Freshmen course, hands-on learning, intended learning outcomes, problem solving

INTRODUCTION AND RATIONALE FOR THE COURSE

Engineering education in the department of Information Technology at the University of Turku (UTU), Finland, follows the CDIO framework (Crawley et al., 2007). This study examines the first evolution of the Introduction to Engineering –course (ITE). The course is based on the CDIO standard no. 4, and it is the very first course for the first year students in the very first morning of their studies.

> *Introduction to Engineering: An introductory course that provides the framework for engineering practice in product, process, and system building, and introduces essential personal and interpersonal skills. Standard 4 (Crawley et al., 2007)*

Engineering students come to the university from different socioeconomic status, gender and racial backgrounds. All of them have a different viewpoint and perception of what engineering is. At the same time, students seek to understand both cultural and philosophical questions through different levels of exploration (Cheville, 2012). Question is does the first, second or any year's curriculum answer these needs? What is the responsibility of the university in all this? Whether these questions are relevant or not, the university faculty have a big role to play in enhancing the students learning and answering the questions (Atman et al., 2010). According to a recent research, the engineering faculty in US report that despite their research responsibilities, they perceive that their teaching is relevant and they are committed to communicate with the students (Atman et al., 2010). Froyd et al. (2012) has also pointed out that, at least in US, the emphasis on mathematics and science in general went too far in the 1960´s and 1970´s, which led to the need of implementing freshmen design courses to the engineering curriculum. In 1980´s, the growing need for IT skills replaced the first year design course in many occasions. It was in the 1990´s when the design courses made their way back to the engineering curriculums (Froyd et al., 2012). This trend can still be seen in global engineering education development.

Each engineering student is a different kind of learner (Felder et al., 1988), and hence there is no one perfect way to teach. This means that teaching is about finding the right balance and combination among the heterogonous group of learners (Cheville, 2012). In addition to above mentioned reasons concerning learning there are at least two other reasons for having a hands-on design course during the freshmen year. Firstly, it is showed that design course has a positive influence on the retention rate for engineering students. Secondly, the intellectual development of the students taking the design course, compared to those not taking it, is increased (Knight et al., 2007, Marra et al., 2000). Student retention is an important issue since experiences during the first year are decisive when looking at student attrition (Knight et al., 2007). It is already acknowledged that the majority of student losses happen during the first year. Student losses can range from 50% up to 84% (Moller-Wong et al., 1997, Budny et al., 1998).

In UTU, the degree reform started during 2011 with the decision to do a total re-engineering to the whole engineering degree structure and teaching methods. Major influencing issues were the above mentioned: facilitating increased student retention and student intellectual capital and by also acknowledging the change of paradigm in engineering education in general. UTU engineering education is discussed in more detail in previous research (Taajamaa et al., 2013, Taajamaa et al., 2012).

CONNECTIONS WITH OTHER CDIO STANDARDS

An introductory course as the Standard 4 is connected to other CDIO Standards. As a framework for engineering practice, it provides, reflects and paves the main learning outcomes in CDIO Standard 2, e.g., improving personal and interpersonal skills, product, process and system building skills as well as disciplinary knowledge (Crawley et al., 2007, Joyce et al., 2011, Crawley et al., 2002). Meanwhile, as a fundamental course, it is usually introduced to students at an early stage in a program and plays as a basic but central role in the Integrated Curriculum which is highlighted in CDIO Standard 3. Design-implement experiences as CDIO Standard 5 requires a curriculum that includes two or more design-implement experiences, including one at a basic level and one at an advanced level. Doing a project in a team is an essential part of an introductory course. The ITE course in UTU is at the bachelor level and complies with the Standard 5. Latest in master´s level students are expected to do more advanced projects after getting more professional knowledge (Joyce et al., 2011). Starting hands-on projects at an early stage facilitates this and also helps students to quickly adapt to engineering workspaces and laboratories, which is illustrated in CDIO Standard 6. (Crawley et al., 2007, Lindsay et al., 2008, Joyce et al., 2011, Crawley et al. 2002). Majority of the teaching methods follow active learning methods from Standard 8: problem solving in small multidisciplinary (IT and Biotech) groups, active CDI – cycles in a competition mode, role chances in a team, active joint discussion inside and between teams and reflective study journals about lessons learned (Crawley et al. 2007).

AN INTRODUCTORY COURSE TO ENGINEERS – ITE

In the traditional engineering education structures, students learn disciplinary knowledge separately without systematically understanding what engineering is all about. Many encounter difficulties to link theories with practice (Atman et al., 2010). The ITE course in UTU is designed to stimulate students' passion and strengthen their motivation for further engineering studies as well as enhancing their disciplinary knowledge and relevant working life skills (see next chapter for intended learning results). To enhance aforementioned, it is important that the whole teaching team is responsible for the course design in order to commit to the learning objectives of the course as well (Taajamaa et al., 2013).

The idea of the course is to show for the students that, as engineers, they have the chance and obligation to be constructive and they are able to build things, hands-on. From the very beginning, the doing process increases students' interests, and, at the same time, describes a general image of what engineering is all about. In addition to this, if the students are having fun, their learning is enhanced as well. Feeling of having fun engages the student to the learning process even without a student noticing that he or she is learning while doing and having fun (Giles et al., 2010, Bisson et al., 1996).

> *"The characteristics of fun are that it is relative, situational, voluntary, and natural. Fun can have a positive effect on the learning process by inviting intrinsic motivation, suspending one's social inhibitions, reducing stress, and creating a state of relaxed alertness."* [citate from Bisson et al., 1996]

It is the responsibility of the university, in practice the responsibility of the teaching team, to provide this experience so that students can adapt the true picture of what engineering can be.

EVOLUTION OF THE COURSE

When completing the introductory course, students should understand that engineering is about team–based problem solving (Moti et al., 2003, Lehmann et al., 2008). Many times in an undefined environment full of ambiguity, and with expectations from the customer and the whole society that the solutions are communicated in an understandable and context-driven way. These main learning outcomes were challenged and analysed thoroughly after the first year and before the first evolution, that is, before starting the second cohort. No radical changes were seen necessary, which lead to an implementation of a set of minor adjustments.

The Introduction to Engineering course is the first year bachelor level course. The course is 5 ECTS and runs for the whole fall semester. As mentioned above, the main ITE course's intended learning outcomes (ILO) have stayed the same from year 2012 to 2013 as listed below in List 1 and List 2. The main reason for this is the fact that ILO´s were found to be up to date and the feedback from the first year was also encouraging. This said, a set of minor practical changes were made to the way the course is run: size of groups, different emphasis in the examination, change of programming language and a change on what is taught and when. Below are the three main points for why the ILO´s were not changed.

a) the course structure and intended learning outcomes were created in align with the CDIO standards,
b) the teaching team has stayed the same for both courses and
c) two years is a short time for a course and curriculum development.

During the first year, the intended learning outcomes were reduced significantly by number in result from the experience coaching the course and were also more focused content wise. The main difference for the year 2013 content wise was the change of programming language from Python to Java because the latter is more suitable for Lego robots and is better aligned with the other courses that students have at the same time. Also the order of the lectures was changed: there was more focus on group work, team dynamics such as team roles and different kind of personalities, and front–end project management. This affected the exam that was held in the mid-point of the course. In year 2012, the Python programming test had more weight and there was also a controlled pragmatic part in the exam testing each student's capability to use the Lego software for the robots. In year 2013, the emphasis was in team and individual roles and understanding of the importance of communication and problem solving in different situations because the whole programming part of the course was moved into the second period. Basic lego-programming questions were also asked but with less emphasis. The embedded electronics part of examination was with the same emphasis as during the first year but with new question sets.
In addition to the exam, the ITE course had seven (7) study journals from different subjects and an obligatory feedback survey during the first year (year 2012). In year 2013, there were only two (2) study journals and the feedback survey.

During the second year, no oral presentations were given because the experience from the first year showed that there was not enough time for systematic presentations. Group sizes were considerably smaller in the second year. In the first year, each group had from 7 to 9 students, and in year 2013 there were typically from 4 to 5 students per group. Also the number of second and third year students was reduced from nearly 30 % to about 20%. This was a natural decrement because old students do not need to take the course anymore to switch to the new curriculum. In forthcoming years, the expected amounts of old students in ITE will be even fewer. Concerning the personal and interpersonal learning results, the main **personal skills** that were emphasized during the course were: *problem solving, time scheduling, tolerance for ambiguity and the capability to apply theory in practice*. For **interpersonal skills** the respective skills were: *teamwork, project planning and communication and the capability to apply theory in practice.*

1. *During the course the students will learn how to analyse, create possible solutions and implement them in multifaceted engineering problems.*
2. *After the course the student will have preliminary readiness for small group work in a project environment.*
3. *Project work will include understanding of planning phase and project management, communicating the achieved results both literally and orally.*
4. *The student will also learn how to manage and prioritize time planning.*
5. *During the course the students will have the opportunity to recognize and develop their substance learning and personalities.*
6. *During the course the students will learn about learning and will learn to trust her/his abilities to solve problems*

7. *The assignments and themes will change on a weekly basis and they will contain tasks and competitions that will develop the ability to conceive problems settings, designing and executing solutions.*
8. *Course will contain individual student assessments, self-assessments, building personal portfolios; for example personal strengths, work capabilities etc.*
9. *During the course the students will apply to different roles.*
10. *To pass the course student must pass a written exam and weekly assignments.*

List 1. The Intended Learning Outcomes for IEC-course in 2012 (named ITE in 2013). The intended learning outcomes were from CDIO standard 4 and were further developed by the faculty curriculum development team (Taajamaa et al., 2013)

- *understand the engineering process*
- *get motivated about engineering*
- *to obtain comprehensive capability to solve problems*
- *being a part of a team (three musketeers)*
- *ability to tolerate uncertainty and failures*
- *creating time tables and prioritizing*
- *learning by doing*

List 2. Learning outcomes that were developed from the CDIO standard 4 intended learning outcomes by the teaching team already in 2012 (Taajamaa et al., 2013). They were approved also for the year 2013 as such.

METHODS

Empirical data for this paper is gathered from questionnaires and study journals in 2012 and 2013. The questionnaires encompassed open and multiple–choice questions on the areas such as interdisciplinary work environment, teamwork setting, problem solving capabilities and communication. Notwithstanding quantitative data included in the questionnaires, this paper concentrates to qualitative data using comparative analysis research method. In the comparative research, we use both qualitative (Myers 1997) and quantitative data. The aim is to find emerging trends and themes to analyze the success of the evolution. Results for 2012 are also presented separately in an earlier research (Taajamaa et al., 2013). The changes in the survey questions have been kept minimal in order to increase the uniformity of data

The answering rate was 100% among those who passed the course giving us 52 and 70 respondent for the years 2012 and 2013, respectively. The reason for high answering rate is that it is part of course. Totally there were 58 and 75 students enrolled in the course, and thus the pass rate for the ITE course is for 2012 course 90% and for 2013 93%.

RESULTS

The main result from the “Introduction to Engineering” course was that the students learned about teamwork, problem solving and coping with ambiguity. In terms of student retention, the fact that 87% of the course participants were motivated or really motivated to continue their engineering studies was a very important result. Previous year the result was 80%. One explaining factor can be that during the second year the percentage of first-year students is greater. This trend can be expected to continue as the degree level implementation process of CDIO structure continues.

Usage on problem-based learning with hands-on approach was received well by the students: 79% of the students found using robots useful or very useful (63% year 2012) in linking theory to practice. Majority of their first year classes are still in classroom lecturing format where the knowledge is transmitted instead of constructing knowledge together (Biggs et al., 1996). This was also the main working method and coaching philosophy among the teaching team. Next we will discuss the research findings to understand how the evolution of the ITE course have affected students' perception of the course.

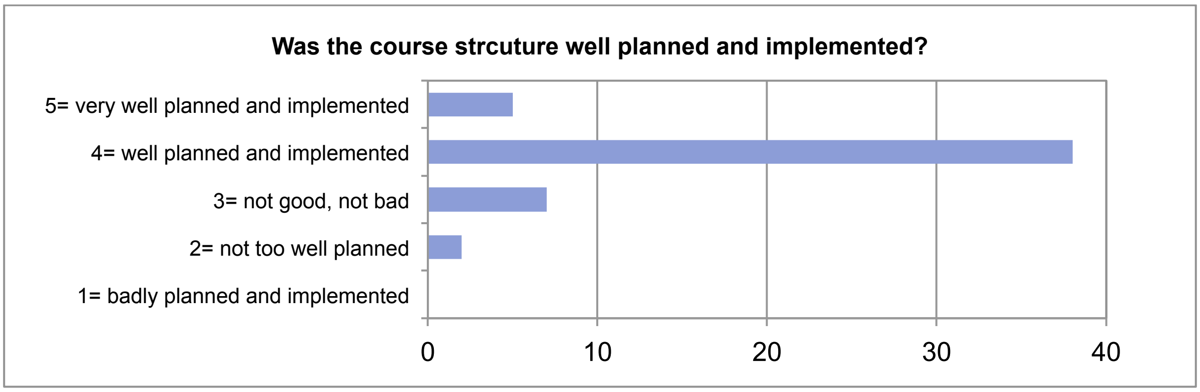

Figure 1 [Year 2013]. Structure of the course: 83% of the respondents rated the course structure to be well or very well planned and implemented. In year 2012, the similar percentage was 78%. In year 2013, the course was in two distinctive parts. First, teamwork, communication, embedded solutions. Second, Java and its applications in robots. For more details see the "Evolution of the Course" Section.

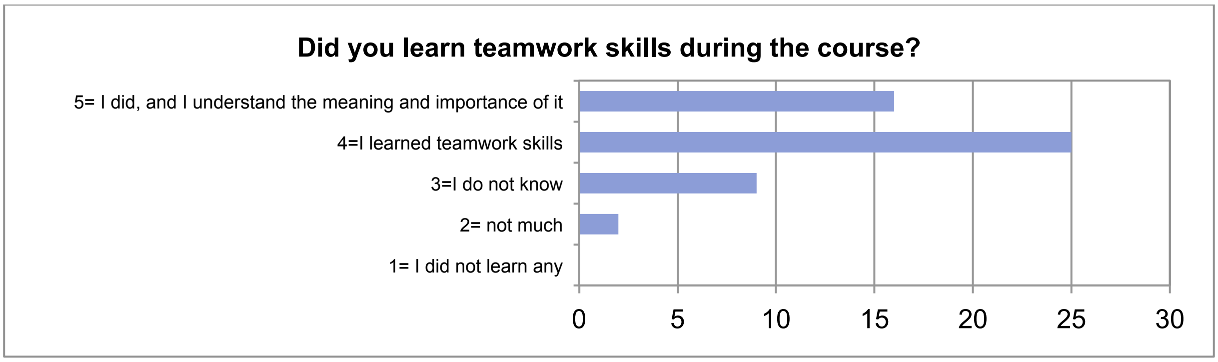

Figure 2 [Year 2013]. In year 2012, the result for student claiming to have learned teamwork was 69%. In year 2013, the result was 78%. What is interesting is that during the first year only 14% gave the best possible grade for teamwork. Second year 30% gave the best grade. One explaining factor is the team sizes which were considerably smaller in year 2013 which meant that it was easier for the students to integrate to the team and influence how the team behaved. During both years, the teams stayed the same for the whole course. For year 2014 the teams should be changed at some point of the course in order to make the team formation process happen more than once.

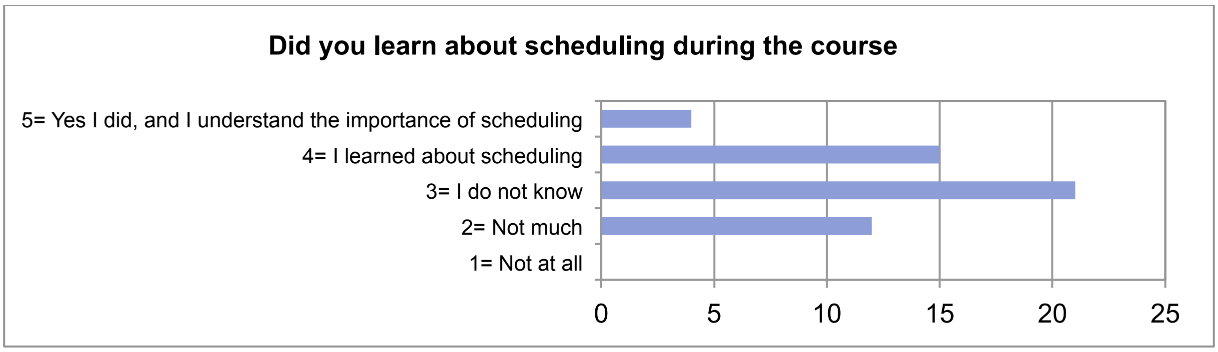

Figure 3 [Year 2013]. A striking result with the same tendency for two consecutive year. The students do not learn time management! First year 0% gave the best grade and only 47% claimed that they learned time management. Second year less than 37% gave the best or second best grade meaning that 63% claimed that they did not learn time management at all, little or couldn´t say.

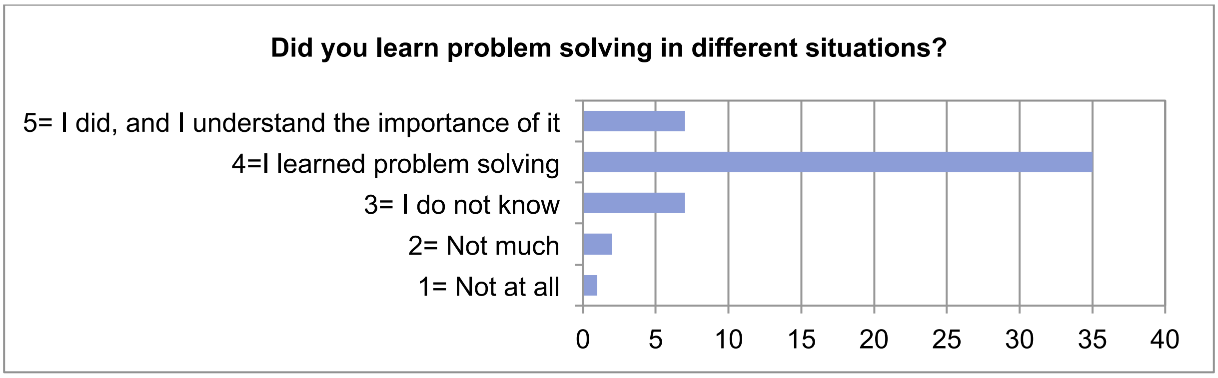

Figure 4 [Year 2013]. The main and most important learning result from the course is the capability to solve problems. Almost 15% of the students claimed that they “learned problem solving and understand the importance of it”. More than 81% claimed that they learned problem solving. This is the crucial factor deciding whether the course is a success or not. First year the same result was 72%. Interestingly, In thethe first year 53% gave the best grade, whereas in the second year the result was only 15%. From the open feedback answers it can be stated that first year was all about problem solving, second year the importance of teamwork was emphasized more.

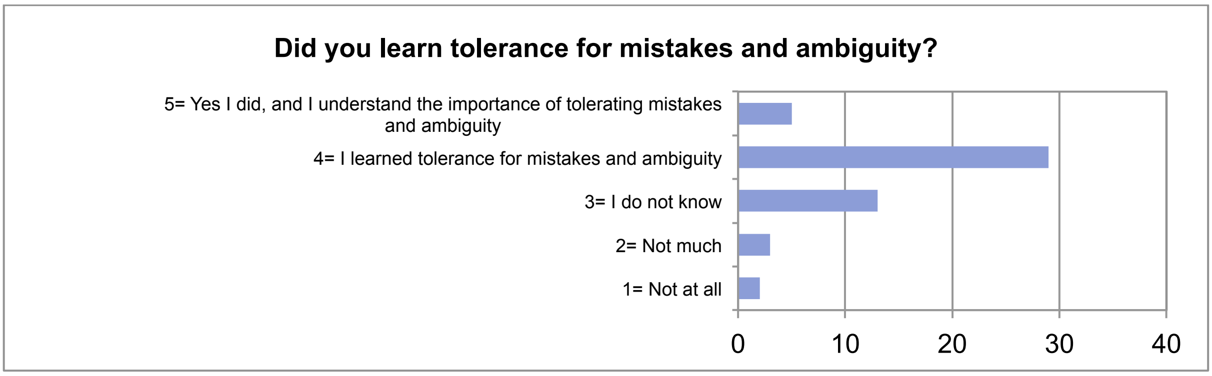

Figure 5 [Year 2013]. Ambiguity tolerance in problem solving situation and in a teamwork context is of paramount importance to engineers (Taajamaa et al., 2013). In the first year 57% answered that they learned tolerance towards mistakes and ambiguity. In the second year the same result was 65%. This is a positive trend. A thought-provoking result is that 25% could not say have they learned or have not learnt ambiguity tolerance. Then again, in the first year this number was 35%. One plausible explanation is that young engineering students are not yet capable of deep self-reflection.

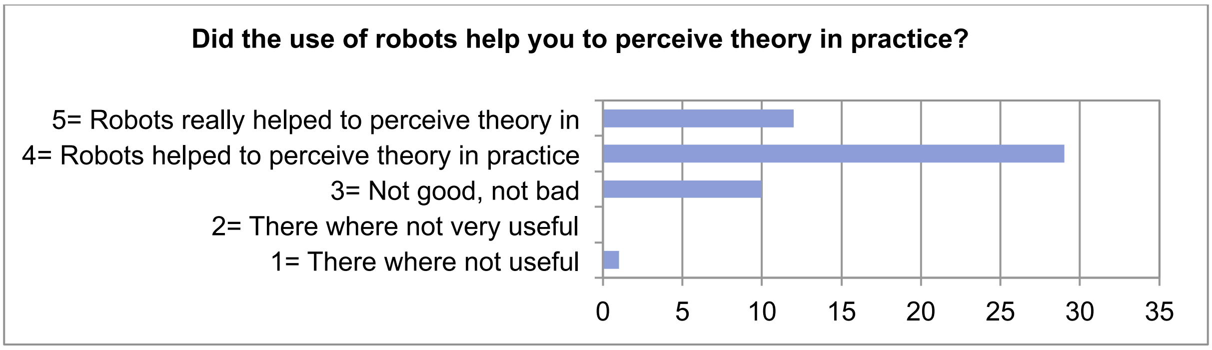

Figure 6 [Year 2013]. In the first year 63% and in the second year 79% found robots helpful or very helpful in linking theory with practice. What is good to acknowledge is that almost every fourth student, more than 23%, gave the best possible grade for usage of robots during the second year.

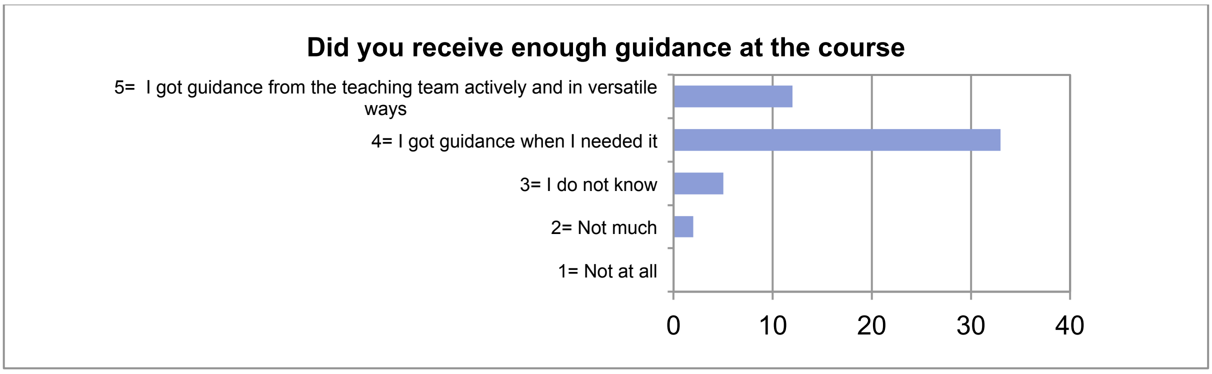

Figure 7 [Year 2013]. 87% of the second year's course participants felt that they got guidance when they needed it. More than 23% claimed that: "I got guidance from the teaching team actively and in versatile ways". In the first year the same overall result was 80%. What is alarming, however, is that from the first year cohort more than 27% gave the best grade (vs 23%, 2013). Also in the open answers some students pointed out that the teaching team was not always so keen on and ready to help, which is a trend that must be rooted out and changed. Out of the three teaching assistants who taught the second part of the course one stood out as being more active than the two others.

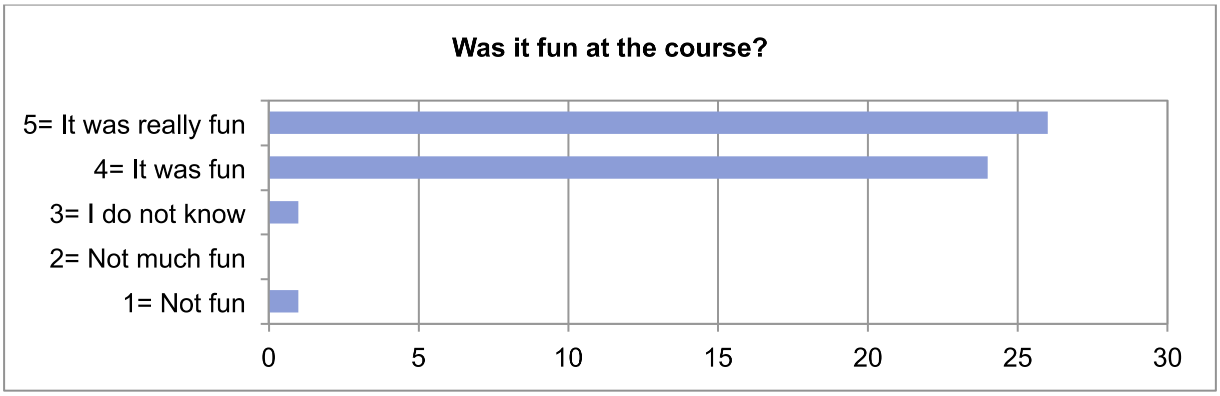

Figure 8 [Year 2013]. Is having fun important? Based on the questionnaire, the students had fun during the courses in both years, but the question remains. Giles et al. (2010) showed that having fun catalyses learning and when a student attaches emotions to the learning situation the learning process becomes immediately more thorough. Our research and students' learning outcomes confirm that having fun does not rule out serious learning; when learning is an emotional experience the student will achieve a deeper and more holistic understanding of the issue at hand (Giles et al., 2010)).

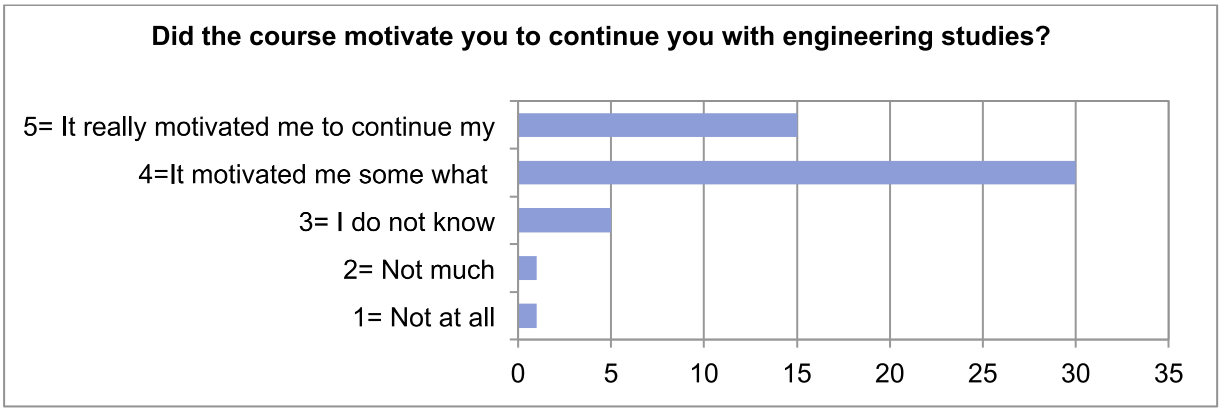

Figure 9 [Year 2013]. One of the most important roles of the ITE course is to motivate the first year students to continue their studies. 87% of the students were really motivated (29%) or motivated to continue their studies. Previous year the result was 80%.

DISCUSSION

The *Introduction to Engineering* course has been up and running for two consecutive years. In terms of engineering education development this means that the first preliminary baby steps have been taken and first results have been achieved. In this perspective, the results from ITE are encouraging. The first evolution of the course has been incremental because no radical changes were adopted; especially ILO´s have stayed very much the same after the initial changes discussed in the chapter "evolution of the course". The change of the programming language, the modification of the exam, emphasis on team skills and reducing the amount of study journals considerably were the main development steps; these changes ensured that the following skills were gained by majority of the students: problem solving, ability for teamwork, tolerance towards ambiguity, linking theory with practice and having fun while learning engineering. Year 2013 a "team lunch" concept was also introduced. In a team lunch, the responsible teacher invited each team to a lunch to talk about the course, the rationale behind the course, what it is means to be an engineer, studies in general and student life, The results clearly show that the teaching team succeeded in the first evolution process. Notwithstanding these results, the teaching team must put emphasis on how the students are guided as there was some negative trends in this even the teaching team has remained the same during the years. Furthermore, engineering ethics received very little attention. For year 2014, this will be added integrated into as a content module for language studies. Students will learn how to communicate with their mother language (Finnish) using articles about engineering ethics as their reference.

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BIOGRAPHICAL INFORMATION

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