INTEGRATION OF CDIO SKILLS INTO
PROJECT-BASED LEARNING IN HIGHER EDUCATION

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ABSTRACT

ICT is a demanding industrial domain where continuous development takes place. In Engineering Education, it is important that students gain competences relevant for the requirements of the working life. Learning environments providing opportunities for active participation and facilitating the intrinsic motivation of the students are important tools when reaching this goal. Furthermore, joint projects with external stakeholders enable universities to develop wider and closer cooperation with companies in order to help them with growth, digitalization and internationalization. Especially small and medium sized companies (SMEs) have lots of potential to grow but they need partners outside their own competence area to help them with product and service development. However, tight economic situation often limits the possibilities to buy these kinds of services from other companies and, thus, there is mutual interest in university-industry collaboration.

This case study presents how CDIO skills can be integrated into a learning environment based on projects assignments. This study focuses on "the FIRMA" that is a student-centric learning environment of ICT Education and Research Unit of Turku University of Applied Sciences (TUAS). The FIRMA is a student-driven project office that operates like a small company providing development projects to both university internal and external customers. Typical assignments include website designs, small-scale database applications, and end user training sessions. In addition, the FIRMA participates in several externally funded R&D projects, such as "SparkUp Gateway" and "Inside the Box".

The CDIO Initiative has defined general goals for engineering education. That is, the aim is to educate students who are able to: 1) Master a deep working knowledge of technical fundamentals, 2) Lead in the creation and operation of new products and systems, and 3) Understand the importance and strategic impact of research and technological development in society (CDIO, 2010). A set of knowledge, skills and attitudes of future generation engineers is described in the CDIO Syllabus. Students in the FIRMA learning environment gain these skills by participating actively in many customer and R&D projects. Multicultural and multidisciplinary teams from different universities do innovative work together to meet the goals of the projects and develop a successful change process and increased competitiveness in customer pilots. This approach not only deepens the personal and professional skills and attributes but also interpersonal skills of teamwork and communication in authentic context. In addition, university-industry collaboration helps revealing new insights, helps the networking, and creates new and promising joint ventures with national and also international actors.

INTRODUCTION

In the ICT technical solutions and customer requirements change rapidly. Especially small companies might have lack of resources in ICT development if their core business is outside of the field. Universities of applied sciences among other higher education institutions are under increasing pressure to meet the rapidly changing needs of working life (Penttilä, Kairisto-Mertanen, Putkonen & Lehto 2013, 11). The curricula are often slow to respond the changing needs of the economy and fail to anticipate the careers of tomorrow. Therefore education should not aim at individual pieces of information that quickly become outdated or obsolete, but instead transprofessional qualifications (Kumpula 2014, 10). Students tend to work more systematically and accurately when the teaching of different professional skills alongside disciplinary knowledge is integrated in business context (Mejtoft 2016, 689). Also, the new funding models of the higher education has set up a pressure to improve operational efficiency, to strengthen the output-oriented approach and to increase the external funding. Developing and offering customer-orientated services to companies will deepen the academia-industry co-operation.

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The FIRMA is a student-centric learning environment that works like a company. IT services and development projects are being offered for both TUAS internal customers as well as external customers, such as companies and foundations. Students use the knowledge gained in theory classes to solve practical challenges given by authentic customers. The main idea is that "everybody learns something, everybody benefits something". Universities keep up the constantly changing edge of need in industry, students' gain competences relevant for the requirements of the working life, SMEs get help and training to use technology more efficiently and ICT service providers do cooperation in order to make sure that they get more professional workforce later on.

In this paper, the focus is set to present a case study on integration of CDIO skills into project-based learning in higher education. First the methodologies used in the FIRMA are introduced. Thereafter the activities and the roles of the FIRMA are described and externally funded R&D projects are presented. Finally, the experiences on the past and current activities are discussed, and future development thoughts presented.

CDIO AND INNOVATION PEDAGOGY

One pedagogic goals of the applied universities in Finland is learning to learn. Students ought to be capable of collaborative learning as well as knowledge sharing in teams. They should learn how to plan, organize and develop their own actions (Roslöf & Tuohi 2012, 89). Pedagogical objectives are met by using CDIO methods and innovation pedagogy in the FIRMA learning environment.

Innovation pedagogy is a learning approach that activates students to take an active and responsible role in their own learning. Innovation pedagogy emphasizes interactive dialogue

between the educational institution and students as well as the surrounding working life and society. The methods used and the interaction between teachers and students establishes the basis for learning and thus enables the development of innovation competencies. Chosen methods and working with companies facilitate intuitive and unexpected learning during the learning process and transmission of tacit knowledge. The format of intuitive and tacit learning occur in the learning situation and it can be for example experiences on cultural differences or on working with customers (Penttilä et al. 2013, 17-18). Teams in the R&D projects customer pilots consist of variety of multicultural and multidisciplinary teams. Customer pilots are in most cases heterogeneous since the industry, size or background of the company is not restricted beforehand. Thus, intuitive and tacit learning varies case by case and the results as well as the learning outcomes depend on the co-operation between team members and co-operation between the team and the customer.

The CDIO Initiative has defined general goals to engineering education. However, using the CDIO principles should have influence not only in learning outcomes but also in RDI activities (Luimula, Suominen, Roslöf, Pieskä & Lehtiniemi 2016, 219). The 12 CDIO Standards (CDIO Standards v2.0, 2010) describe the features of CDIO programs. Integrating externally funded R&D projects and deep co-operation with working life via customer projects meets the standard 3. "Integrated Curriculum" objectives as learning experiences of the students lead to the acquisition of personal and interpersonal skills as well as product, process and system building skills. The standard 6, "Engineering workspaces", emphasizes the importance of physical learning environment and hands-on learning. The FIRMA has own dedicated facilities at the campus where the students are able to work within teams during the customer projects. The FIRMA office is refurnished with workstations for the FIRMA "employees", a negotiation corner and a small kitchen. The physical office provides opportunities for social learning and networking with other students. The standard 7, "Integrated learning experience", focuses on acquisition of disciplinary knowledge, as well as personal and interpersonal skills, and product, process, and system building skills. Implementing authentic customer pilots will naturally lead to a result where the learning of disciplinary knowledge is simultaneously. The standard 8, "Active learning", engages students directly in thinking and problem solving activities. The FIRMA is a company-like learning environment that calls for students to take an active role in their own learning. Hands-on project-based learning is a learning method of the environment. While working in customer pilots, students gain not only relevant technical competencies, but also social and problem-based learning skills.

A set of knowledge, skills and attitudes that alumni, industry and academia desire in a future generation of young engineers are being summarized in the CDIO Syllabus. The first-level set of knowledge, skills and attitudes are divided in four divisions: 1. Disciplinary knowledge and reasoning, 2. Personal and professional skills and attributes, 3. Interpersonal skills: teamwork and communication, 4. Conceiving, designing, implementing and operating systems in the enterprise, societal and environmental. First division include knowledge of underlying mathematics and science, core fundamental knowledge of engineering and advanced engineering fundamental knowledge, methods and tools. Second division consists analytical reasoning and problem solving, experimentation, investigation and knowledge discovery, system thinking, attitudes and learning, ethics, equity and other responsibilities. Third division consists teamwork, communication and communication in foreign languages. Forth division include external, societal and environmental context as well as enterprise and business context, conceiving, designing, implementing and operating. (Crawley, Malmqvist, Lucas & Brodeur 2011).

THE FIRMA IN ACTION

The FIRMA is a student-driven learning environment that operates like a company providing development projects to both university internal and external customers. Most of customers are small or medium-sized companies. Typical assignments include website designs, small-scale database applications, and end user training sessions. (Roslöf 2016, 425). Operation consists of four different units: externally funded projects, customer projects, sysadmin and help desk. The FIRMA participates actively in several externally funded R&D projects of TUAS. Sysadmin unit is responsible for the FIRMA network, software and hardware. Help desk is divided in two: external helpdesk provides services for external customers and internal helpdesk is part of TUAS helpdesk providing services for students and personnel of TUAS. The units of the FIRMA are presented in Figure 1. This paper focuses on externally funded R&D projects and customer projects of the FIRMA.
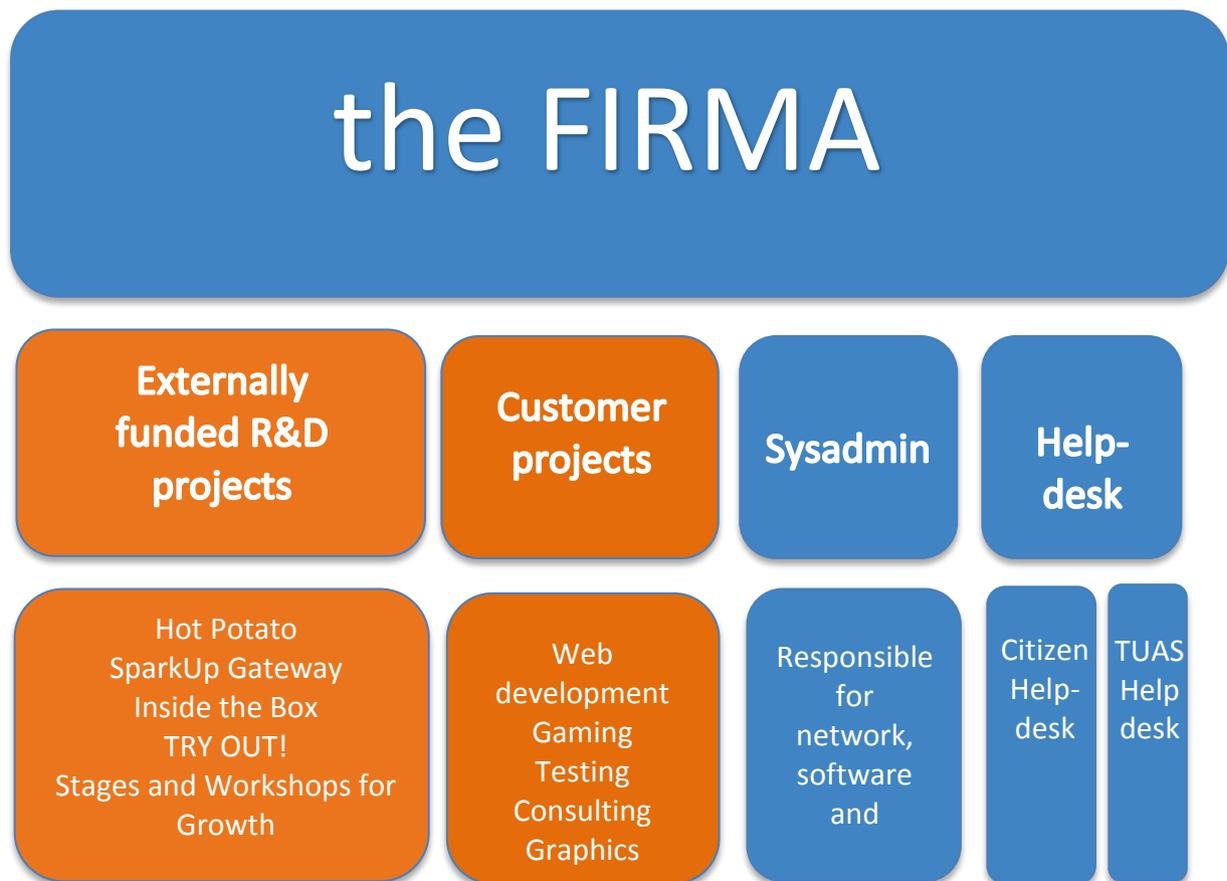

Figure 1. The FIRMA's fields of operation.

The FIRMA was conducted in 2015 when the former project learning environments of TUAS ICT unit were united. Earlier, there were four different learning environments: "Education Support Centre Finland", "Network Support Centre Finland", "ICT-portti" and "Citizen's Helpdesk". The ultimate goal of combining the learning environments of TUAS ICT unit was to increase the performance of learning environment, standardize processes and expand the operation. The best practices of each learning environment was put in practice in the FIRMA. When developing the learning environment of higher education, one should keep in mind that

the learning environment is not trying to compete with regional IT companies. For example in most customer cases, the schedule of the project is much longer than it would be when ordered from an IT company. Students always have time to learn during the projects since students are not professionals, they are still learning.

The FIRMA has an internal organization that consists of students. The student CEO is responsible for general administration, staffing and selling activities. In addition, the customer of the FIRMA is divided web development, game technology, marketing and communications, technical support and Helpdesk. One student project manager is responsible for each operation. The student project manager coordinates the assignments and is a contact person with the customers. The other students will join one or two of the operations based on their interest and competencies. The roles of the FIRMA operation is presented in Figure 2.
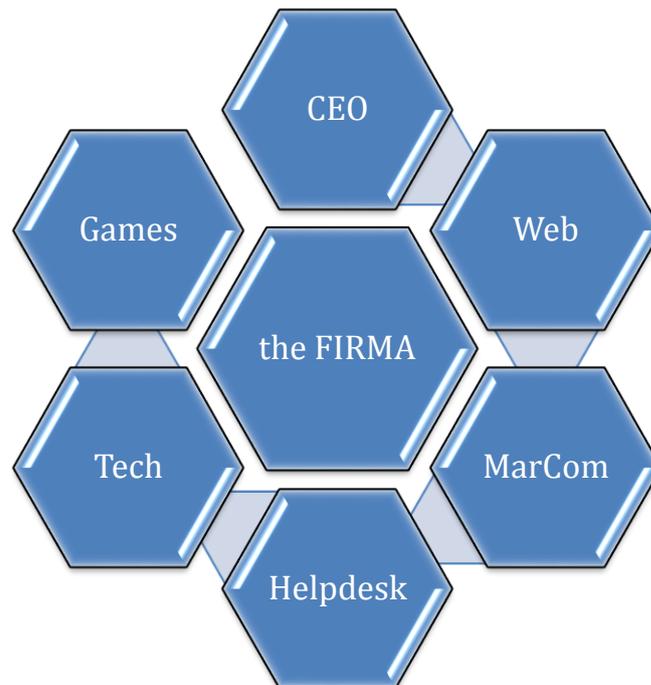

Figure 2. The roles of the FIRMA.

The students apply to the FIRMA either by joining ICT Services and Projects –course or by applying to a work placement in learning environment. The introductory course is for 15 ECTS credits, which includes a Microsoft Technology Associate exam, 5 participations in regional company presentations and project work done in the FIRMA. When applying to the work placement in the learning environment, students apply via light-weight recruitment process in the same way as they would apply to any small company position (Roslöf 2016, 427). Work done in the FIRMA is integrated in the curriculum so that the students gain credits for the introductory course, work placement, thesis or separately agreed courses if the contents of the customer project is similar to contents and learning objectives this certain course. In addition, it is possible to complete tailored advanced professional studies in the FIRMA as well.

Once the applicant is accepted to work in the FIRMA the student can participate either on one project or continue to work in several projects and tasks throughout the studies. The customer requests and the projects are implemented using predefined processes. The customers are

provided an offer including an initial version of the project plan as well as the cost offer. Most of the projects have a price tag, which means that customers pay to TUAS an agreed fee once the project has been successfully delivered. The income of the customer projects is used to cover some of the staff expenses as well as software and hardware updates of the learning environment. Most of the students get credits for working in project office. However, some of the most senior students (for example the student CEO) may get a limited number of hours per week salary in a student assistant role. (Roslöf 2016, 427)

TUAS staff provide guidance and mentor the students when needed, helps with the negotiations with customers and make sure that the learning goals are met during the projects. Currently there are three roles: staff project manager, responsible teacher and technical consultant. A staff project manager has the overall responsibility of the FIRMA and its operations. S/he participates also in customer negotiations and helps defining feasible project goals, pricing levels and formal contracts. Responsible teacher takes care of the learning process and defines the learning objectives for the students and the projects. In addition, the responsible teacher agrees the amount of credits an assessments for the students. Technical consultants mentor the students in difficult engineering tasks that students are not able to solve by themselves. (Roslöf 2016, 429)
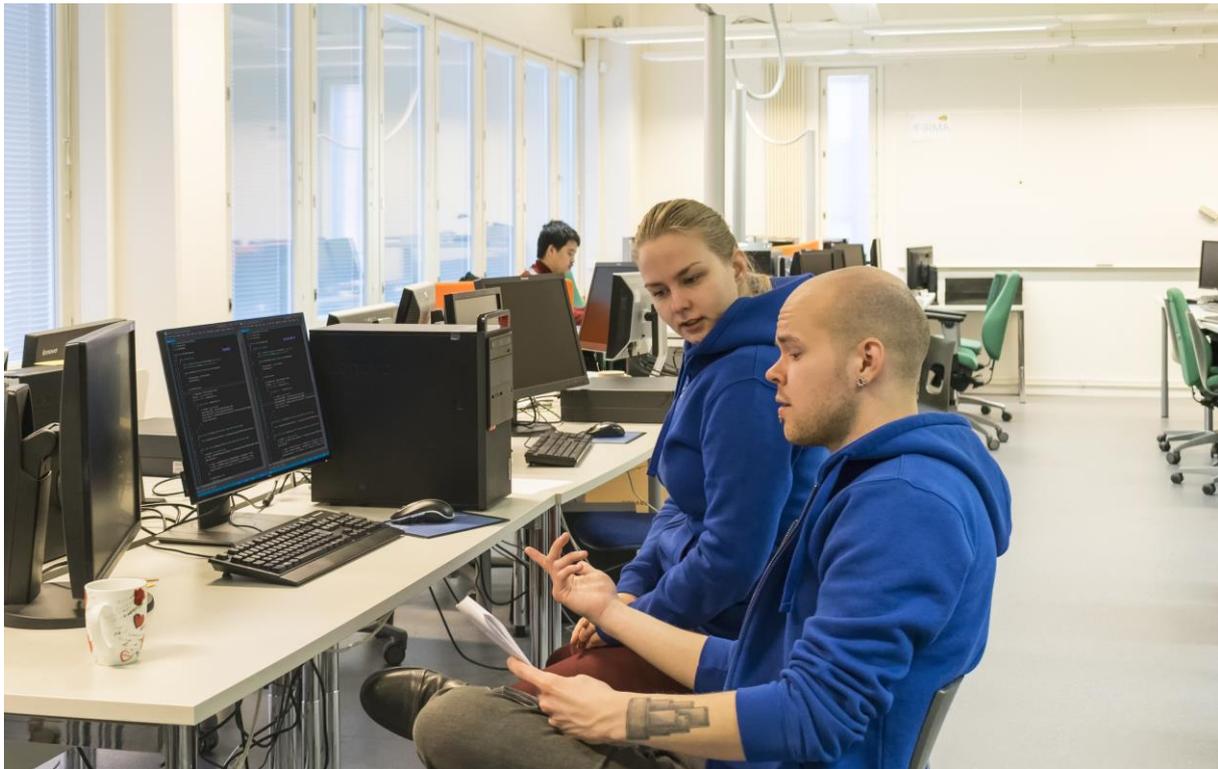
Picture 1. The FIRMA premises.

EXTERNALLY FUNDED R&D PROJETS

Project-based learning approach not only deepens the technical competences but also leads to innovative co-creation with product and service development. In addition, university-industry collaboration helps revealing new insights, and help the networking and creates new and promising joint ventures with national and also international actors. Currently the FIRMA

participates in five different projects: "SparkUp Gateway", "Inside the Box", "Hot Potato", "TRY OUT!" and "Stages and Workshops for Growth".

The main aim of the "SparkUp Gateway" project (2015-2017) is to enhance the competitiveness, growth and internationalization of the SMEs in Southwest Finland, and to strengthen and diversify the business services of the Turku region and the business development environment SparkUp, by taking advantage of the potential in higher education student collaboration. The goals will be met by 1. Executing multidisciplinary student projects to entrepreneurs and SMEs, 2. Productising the multidisciplinary competences of the higher education students in selected themes, 3. Developing the processes of student collaborations within the higher education institutions, 4. Producing new forms of student collaboration that meet the needs of the industry and 5. Establishing a unified path of student oriented entrepreneurship, from student driven projects to business development services, thus contributing to the promotion of student oriented entrepreneurship. The project is done in co-operation with Turku University of Applied Sciences, University of Turku, Turku Science Park Ltd. and Humak University of Applied Sciences. The project is funded by European Regional Development Fund. The Firma students have been active part of this project by participating in several customer pilot projects with other students of TUAS as well as with students from other universities. Working in international and multidisciplinary projects strengthens especially competencies in the area of cooperation and language skills.

"Inside the Box" project (2016-2018) goes right into the core of business, inside the company and seeks and creates digital insight, or inspiration that fits to the company's situation. With this case-sensitive insight the company is able to implement a successful and effective digital leap, a development project and a change process. The ground for these actions is the skilled and experienced employees, that is, the business and work. The suggested development ideas contain new arrangements of work practices, new ways to work and (self-) manage work. These digitalization ideas and the development approach help companies to develop in a viable way especially the knowledge work. The results, new methods to engage digitalization leap projects, help also to improve work satisfaction and work satisfaction on employee level. The result of the project is new digitalization leap services that are tested and created with 40 customer pilots. The results of these pilot projects will also be presented to 160 SMEs in four seminar during the project. The project is done in co-operation with Turku University of Applied Sciences and University of Turku and it is funded by partner universities, companies and European Social Fund. Students in the FIRMA work with these customer projects, help organising the event, design and implement graphical ads and brochures for the project. Also, by joining the projects they gain deeper understanding of the work processes in the companies, which brings ideas how to do work more efficiently or how digital solutions might help companies to enhance their workflows or services. Working closely with customers' give students' even better understanding of the role of IT in companies outside of IT.

"Hot Potato" project (2017-2018) creates development services with a lever to meet the unique needs of SMEs in such a way the content fits to the adaptability capability of the SME. The levers are digitalization (including knowledge work, work flow), gamification (including learning, training, and user satisfaction), and knowledge management (including management methods and objects in relation to productivity and well-being at work). The purpose of these rapid experiments is to inspire and motivate the staff and management at target companies to persevering development practice using collaborative experiment-oriented culture. The briefcase is the concrete product that enables the efficient dissemination of the lever-based tool for increasing productivity and work-being at work. The briefcase is used by the SMEs to evaluate and develop their performance and manage the change process. During the Hot

Potato project, there will be done 50 customer pilots in co-operation with Turku University of Applied Sciences, University of Turku and nationally companies in Finland. The project is funded by partner universities, companies and European Social Fund. Students in the FIRMA will actively participate in the customer pilots as well as other tasks of the project, such as organizing three events for 200 companies. In the figure 3 students of the FIRMA are getting ready to meet a customer.

Picture 2. The FIRMA students.

TRY OUT! -project builds an innovation platform for circular economy and cleantech. The platform will be created based on experimentations and co-creation and it provides possibilities for new kinds of business models, cross sectoral cooperation and experimentations in circular economy and cleantech. The most vibrant models will be used and proceed into markets. Project promotes innovation activities and entrepreneurship in the fields of circular economy and cleantech. The innovation platform provides opportunies for participating companies to develop their products and services through pilot projects supported by experts, user communities and a multidisciplinary company networks. The platform will cover entire development cycle from an idea through piloting to market ready product. The innovation platform enables sharing of new insights, methods and innovations among participating companies, researchers and institutions. Therefore the project is set to promote attitude that endorses open-minded experimentations and fail fast and learn approach. TRY OUT! –project is done in co-operation with Turku University of Applied Sciences, University of Turku, University of Helsinki and Demos Helsinki. The project is funded by partners and European Regional Development Fund. The FIRMA students join this project by doing a requirement analysis for digital platform that enables companies and other users to share their surplus materials in order to find another company that could reuse it in their products or operations. In addition, the FIRMA students develop digital pilots for companies in the field of circular economy.

"Stages and Workshops for Growth" project (2016-2018) is done in co-operation with Turku University of Applied Sciences, City of Tampere, Tampere University of Applied Sciences, Helsinki Metropolia University of Applied Sciences, University of Turku, and Turku Science Park Ltd. The aim of the project is to create and test a new kind of an approach for activating companies, students as well as experienced and skilled job seekers. Motivated and energized workgroups are established to solve identified growth challenges of local business. As a result of the project, work opportunies will be created for those looking for employment. TUAS organizes innovation workshops in co-operation with regional companies based on the needs of the company. The project is funded by partners and European Regional Development Fund. Students from TUAS will actively participate in the workshops. The FIRMA students gain

relevant competences, more knowledge of the working life and connections while participating in workshops.

DISCUSSION & CONCLUSIONS

In this paper, integration of CDIO skills into project-based learning in higher education has been described and discussed. The student-driven ICT project office the FIRMA has been operating in its current form for two years now and the experiences are promising. It seems that the engagement of the students will enhance their learning, motivation and future career prospects. Especially combining larger amount of externally funded R&D projects into learning environment activities has expanded the academia-industry co-operation. In addition, the co-operation with other faculties of TUAS and other universities has strengthened.

The ultimate goal of combining the learning environments of TUAS ICT unit was to increase the performance of learning environment, standardize processes and expand the operation. Externally funded R&D project where not part of the former learning environments except in ICT-portti, which was able to implement one externally funded project at a time. Currently there are five different externally funded R&D projects going on at the same time as well as the customer projects of the FIRMA.

The difference between regular customer projects of the FIRMA and customer pilots of the externally funded projects (SparkUp Gateway, Inside the Box etc.) is that in most of the cases customer pilots are wider, multidisciplinary and done in closer co-operation with TUAS staff and other universities. In the FIRMA customer projects, a company might order for example a web site or Microsoft Excel training. The FIRMA students implement the project as agreed and then the project is ready. In customer pilots of externally funded projects, the scope of the project is typically wider. For example the idea of project might be developing and implementing suitable solutions to increase the digitalization of the company. In order to implement these kinds of customer pilots, deep understanding of the company goals, needs, processes, services, products and customers have to be met in the beginning of the project. This is done in co-operation with TUAS staff. Students that work in the FIRMA for a long period of time during their studies, work in customer projects of the FIRMA as well as customer pilots of externally funded projects. Innovation pedagogy methods and CDIO standards are relatively easy to adapt in externally funded R&D projects and especially in high-demanding customer pilots within the R&D project. According to standard 7. "Integrated Learning Experiences" the faculty is able to be more effective by helping students apply disciplinary knowledge to engineering practice and better prepare them to meet the requirements of the engineering profession. High-demanding customer pilots of externally funded R&D projects are excellent environment to provide integrated learning experiences to students.

The feedback from the students of the FIRMA is positive. According to the feedback, in the field of personal and professional skills, a deeper understanding of their own set of skills has strengthened and the analytical reasoning and problem solving is more goal-orientated. In addition, the subfield of IT that a student wants to focus on in the future is crystallized. The outcomes of the projects motivate students in their studies once they understand better the connection between theory and practice. In the field of interpersonal skills and especially teamwork and communication has developed during the projects. Communication skills with customers as well as with other team members are in a significant role of the project. That is, industry want the future workforce to be not only technically capable, but also future generation of engineers should have socials skills, passion to constantly learn more and capability to work in multidisciplinary and international teams. Combining these different sets of skills into

environmental context will give results of future engineers that will meet the requirements of working life. In addition, students feel professionally more confident which supports the transmission to working life after graduation.

Naturally, there are also development ideas to consider in order to improve the activities of the learning environment. Currently students join the FIRMA either by enrolling to ICT Services and Projects course or by applying to work placement in the FIRMA. Most of the students that work in the FIRMA are in first or second year at their studies. The group of students that are in advanced stage of their studies is a lot smaller. This leads to the fact that the senior student group is not big enough to share their knowledge with all the junior students working in the FIRMA. In the future, the goal is to expand also the senior team so the knowledge sharing, social learning and interaction between junior and senior students is more active and fruitful.

Currently, feedback from the students is collected during a development day organized biannually. In order to evaluate the FIRMAs actions in more depth, quality metrics should be carefully planned. For now, the feedback from the students as well as customers have been mostly positive. Many of the students that have been active in the FIRMA have been recruited to the local IT companies either already during their studies or in couple of months after their graduation. However, currently there is no detailed recruitment statistics available.

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BIOGRAPHICAL INFORMATION

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