

Reflections on Teaching Software Engineering Capstone Course

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Abstract: For students, capstone project represents the culmination of their studies and is typically the last milestone before graduation. This paper reflects on organizing IT capstone projects in computer science and software engineering Master programmes in a Sino-Finnish setup. Based on our analysis we introduce various aspects based on our observations for improving course practicalities, introduction lectures, students' initiative group working and overall interaction. We also discuss the importance of active learning and transferring the responsibility of learning from teachers to students in order to achieve the intended learning outcomes. During a capstone course students design and implement a solution to a complex, ill-defined real-life problem. We present and discuss the results from student feedback surveys and propose areas for further development.

1 INTRODUCTION

During the past years, capstone project has been an important part of the curricula for studies in Information Technology (IT). Based on Merriam-Webster dictionary capstone means: "the high point: crowning achievement". Therefore, the project is the capstone of IT studies where the students use all their acquired skills and knowledge in culminating their academic experience. The main idea behind the capstone course is to provide an opportunity for IT students to demonstrate their true capacity to integrate and apply their knowledge and skills to a real-life (software) engineering problem.

Based on Rasul et al. (2012), capstone project is a unique type of learning experience for the students as they mainly work in a self-directed approach and they are expected to carry out various and numerous tasks related a large problem without structured approach provided by teachers. Naturally, the students are not fully out-of-support, but the idea is to transfer the learning process to be student-led instead of teacher-led. While the learning approach is different, also the assessment is based on different aspects. The consistency of the assessment practices of the capstone course needs to be ensured and clearly communicated to the students. As Mills (2007), Bramhal et al. (2012) and Gardner and Willey (2012) identified, the capstone assessment can include various tools from self- and peer-

evaluation, process and product assessments, formative and summative assessments (such as the working process and the final outcome of the development), and students self-reflection of their learning in course-diaries/blogs.

The aim of this paper is to reflect on various aspects of organizing capstone projects as courses. Structured student feedback collected at the end of the course expresses student experiences and provides data to discuss the relevance of various parts of the course. The students' feedback and teachers' observations are used to provide recommendations for iterative course development at the University of Turku, Finland. The University of Turku and Fudan University, China, have a strategic partnership of collaboration and provide a dual master's degree in Technology. Therefore, the two main student groups during the capstone courses were Finnish and Chinese students. In this research we analyse the master level capstone course feedback materials from years 2014 to 2017 and complete the findings with teachers' observations on the courses.

The rest of the paper has been divided into four parts. Section 2 deals with existing research and the theoretical dimensions of Problem-based Project-oriented Learning (POPBL). Section 3 describes the research design. Section 4 presents the findings. Section 5 includes the conclusions and introduces a few tasks for further research.

2 LITERATURE REVIEW

Over the years, one of the most used approaches has been the teacher-centric approach, where the teacher has the full control and authority while lecturing at the front of the class-room. Senge (1996) wrote that most people expect to get answers from people above them, because they have grown up in an authoritarian environment and culture. Nowadays, this type of approach does not support the target to prepare students for their future workplace and face constantly changing working environment and requirements. Therefore, the responsibility of learning and own actions need to be pushed onto the students' side. Problem-based learning (PBL) is an example of a student-centered educational model (Barrows, 1996; Gwee, 2008, Savin-Baden, 2012) although based on literature PBL's effects are controversial (Dochy et al. 2003; Kirschner et al. 2006; Schmidt et al. 2009). In PBL approach, students' own learning process is placed at the centre of the educational process by supporting the students to construct their own knowledge, and to develop problem-solving and group work skills (Dolmans et al. 2005).

PBL and POPBL based capstone project is one implementation of a student-centric approach to provide opportunities for students to apply their content specific knowledge and workplace skills gained during their several years of studies (Dunlap, 2005; Lehmann et al., 2008; Dondlinger and McLeod, 2015). The focus is not only on technical skills but also on having the ability to identify non-technical aspects, interaction of those and propose possible solutions (Lehmann et al., 2008). Since the 1980s, the capstone type of learning approach has been part of universities' curriculum (Vanhanen et al. 2012). The capstone approach is commonly used, for example, in software development project courses where students design and develop software solutions in teams for external customers (Vanhanen et al., 2012).

Havelka and Merhout (2009) reported IT professional competences that IT professionals should have. In addition to technical aspects, many of the needed skills were non-technical and behaviour related. Havelka and Merhout (2009) categorized those skills under four categories: 1) Personal traits (passion, experience, conscientiousness, attitude, character, and flexibility). 2) Professional skills (organization skills, leadership ability, analytic skills, team-oriented, interpersonal skills, and problem-solving). 3) Business knowledge (business concepts, business

process knowledge, and organization knowledge). 4) Technical knowledge (enterprise systems, development methods, application software, project management, production data management, architecture, infrastructure, programming, security & control, business intelligence, and communication networks). Practicing these competences is typically at the core of IT software development capstone projects' learning targets.

Reifenberg and Long (2017) wrote that students value the capstone experience. Based on Dondlinger and McLeod (2015) and Dondlinger and Wilson (2012) the capstone experience include challenges, but still the main approach has been favourable. The students reported to gain vital skills and competences, such as, learning new skills when applying prior knowledge; cultural understanding and new appreciation for people within their own culture; interaction and negotiation skills; and self-awareness (Dondlinger (2012). At the same time, Reifenberg and Long (2017) wrote of the capstone challenges, such as mismatch of expectations, information gaps, misunderstandings and challenges in cooperation among the capstone project team members.

In literature, it has been identified that one of the main challenges in capstone type of course assessment has been the tendency to focus primarily on written or product outcome (Todd et al., 1995; Jawitz et al., 2002; Lawson et al. 2014). This same challenge remains although it has been recognized that the main assessment criteria should be focused on skills developed during the project, such as teamwork, communication, life-long learning, and technical skills. Therefore, the final software coding outcome should not determine the passing grade for the course. Even if the coded software does not work, the team can still pass the course if they have achieved the planned learning targets. The capstone course teachers can use a variety of tools and practices to get insight into capstone teams activities, such as self and peer-evaluation, process and product assessments, formative and summative assessments, and students' course-diaries/blogs (Mills, 2007; Bramhal et al., 2012); Gardner and Willey, 2012, Lawson et al. 2014).

Capstone projects can also provide students a valuable opportunity to be exposed to diversity already during their studies when the students operate in a multi-national and multi-cultural situation. During the capstone project implementation the team members have to take into account member's national culture impact upon the whole team (Duran and Popescu, 2014). Morkos et

al. (2014) conducted a comparative study between domestic and international students. They found that quite often the domestic students took the leading position, and the teams had to overcome the frustrating situations caused by cultural and language barriers by improving their communication and interaction skills. Morkos et al. (2014) pointed that the students may not immediately recognize the lessons they learned from the multicultural situation. The recognition of diversity related lessons happens afterwards.

3 CAPSTONE COURSE IMPLEMENTATION

3.1 Software Engineering Capstone Course – Targets and Preparations

The software engineering capstone course is a mandatory course in the master level IT studies at the University of Turku. To provide it as a compulsory unit, timely linked to the degree program, and including all the degree program students, it has been organised formally as a traditional course in the teaching program. The course needs to have a clear structure, but at the same time it is important that the teachers only facilitate the students' learning, and the implemented activities are managed by the students themselves to achieve the expected learning outcomes.

The courses take three academic periods, about nine months, and the course is structured with regular predefined classroom activities (e.g., status reports, pitching, demonstrations). The focus of the capstone course is on designing and implementing a proof-of-concept level solution to a fairly complex real-world problem via practical test and try approach. The idea is to provide a situation that simulates various aspects from working life phenomena in a safe environment that also allows failures. Sometimes learning from failures can be a better learning experience than learning from success. Based on our observation, teams that face failures during their project often analyse, identify root causes for their situation and actions, and they even are able to take the needed corrective actions. Analysing the causes behind failures during a common class activity provides a viewpoint for students in other teams of these critical project factors.

Capstone project utilizes both PBL and POPBL methods and some elements from Problem-Solving

Learning (PSL). As Sotto (2007) highlights, it is better that the students are quickly able to practice their knowledge and skills instead of spending significant amount of time to understand the problem. In this course, the intended learning outcomes (ILOs) focus on team working, communication and problem-solving skills. The students practice those skills with preselected project topics stretching out of their comfort zone. The teachers spend a significant amount of time to discuss with potential topic owners and prepare the project topics beforehand. The main idea of the capstone course is to provide open-ended problems to students. The topic owners need to accept that they cannot give exact solution requirements to be implemented. Instead, they get a proposal for their problem from the students, often in a form of a working proof-of-concept.

3.1.1 Attendance

The practice is that students enrol to the course beforehand. That way the teachers are able to evaluate the students' current level of studies. If the student does not fulfil the requirements (i.e. being master level students), the teachers can inform them to attend the needed courses prior taking the capstone project on coming semesters.

The full attendance is mandatory, but the demand for 100% presence is adjusted, because students can have situations when they cannot attend (e.g. doctor's appointments). During every lecture, the attendance is recorded with signature on the student list. That way the teachers can follow-up the attendance (which is one aspect of course evaluation) and also show that teachers care for students' presence. In case of a student missing multiple compulsory sessions, the student needs to agree on activities to compensate for their absence. This kind of social contracts are linked with professionalism (Vu, 2014) and applying those between teachers and students is good practice for working life. That way the students can practice the impact (positive or negative) of unspoken norms and rules.

One of the challenges in organising this course is timing. Typically, the Fudan students spend one academic semester, about six months in Finland. Still, the course takes longer, about nine months. This means that the teams built of students from both universities need to find ways to continue and finalize work even when located in two continents. At the early stage of capstone course implementation, it was found that the Fudan students

considered their course related activities ended when they returned back to China and then the Finnish students alone had to finalize the project work. However, during the past few iterations this scheme of thinking has gradually been changed by planning and placing common course activities to the final stage of the project. Also holiday seasons of two cultures impact on the course. For example, the course that starts around January will be finalized around October. This means a summer break in the middle of the course in Finland, and Chinese National Day break in early Fall.

3.1.2 Lectures

The main teaching approach during the capstone project course is on active learning activities. However, due to the high amount of students (35-50 students) some traditional type of lecturing is also included to activate the students in the classroom to further process the topic inside their project teams. Every lecture focuses on a different topic related to the common stage of the projects by providing a short introduction to the students. The idea is to give “mental hooks” for directing their focus on digesting new topics and activities. The capstone course lectures include two parts. One part focuses on project management and communication specific skills. The second part focuses on team work and interaction skills. These lectures and hands-on practices provide the basic knowledge for the students to apply in their project team.

The course utilizes Moodle online tool to share and communicate course related materials. The materials are created by teachers, and there are no specific textbooks to be used during the course. This also encourages students to be active and write their own notes. Earlier research has shown that when students make their own notes, they internalize the topic better (Mueller and Oppenheimer, 2014). Earlier research indicate that slides can make students passive listeners or they focus on other activities (such as, Facebook, WhatsApp messaging, etc.) as they do not bother to make their own notes.

During the series of lectures the students will give several presentations, such as status reports, project plans and project pitch. The students get assignments during lectures to work independently and then during the next lecture they present the outcomes. Every lecture has a slightly different topic or focus to keep students motivated to work around the project with clear focus areas and deadlines. Although, based on observations, it has been noticed

that many of the students are not motivated to listen other teams’ presentations.

3.1.3 Student Groups and Selection of Group Members

Based on experience gained from several capstone course iterations, it has been found that team dynamics can be a core element of success or a serious hindering effect. Since student self-motivation is expected to be one fundamental element to successfully meet numerous project challenges, students are asked to choose their preferred topics with a motivation letter. At the beginning of the capstone course, teachers will present the project topics to the students. The students can choose three most interesting topics which they would like to participate in. Based on the motivation letters the teachers will form the groups. It can also mean that the students may not be assigned with the topic they primarily preferred. The teachers spend quite a lot of time to form the groups by reviewing students’ prior courses and interests to ensure diversity and the needed skills to succeed.

As the course participants consist of students both from the University of Turku and the Fudan University (China), the teachers ensure that every team is multinational. That way it can also be ensured that the teams practice their English language skills during their project work. At the same time, the students also learn to interact with people from different cultures and with way-of-working habits.

Since team working skills are in the core of intended learning outcomes of the course, the team size is normally aimed for minimum of four or five, but can reach up to eight students. However, larger team size can more easily include “free-riding” type of behaviour. In a smaller team members tend to take bigger responsibility for ensuring the overall success and they also support each other around the tasks and competences. In larger teams the division of work and responsibilities requires more attention from teachers.

Quite a lot of the students have working life background or they are even already working in industry. Having prior working life experience can help to excel in capstone projects and reach even more demanding goals, via deeper understanding of what they need to do and what is required from them. In other words, the students are able to fill the knowledge gaps of teachers’ presentations with their own practical experience knowledge.

3.2 Project Activities and Course Assessment

3.2.1 Topic Owner Interaction and Project Budget

All of the project teams have an external project topic owner, who is not a teacher on the course. The students interact with the topic owner, often seen as their customer, collect requirements and later present their solution proposal. Ideally the topic owner is an external/industry representative, but also some of the research groups from the University of Turku have been in this role. It is also to be noted that the teams have a very small budget that can limit their activities.

3.2.2 Project Implementation

The project team assigns different roles to its members during the project activities. One of the key roles is that team leader, who usually is also responsible for customer communication. The idea is to learn to manage communication between the team and its project stakeholders.

Project planning is an important phase, because it shows how well and to what depth students have understood the problem and the requirements. The idea is to revise the project plan several times during the capstone course. The first plan is the first best guess, but the main lesson is that the project plan needs to be updated and re-estimated regularly. The idea is also to practice how to divide a complex tasks into smaller implementable entities. That way the students also practice how to schedule activities and what is the impact if they do not take the responsibility or ownership of implementing the tasks. Based on our observations we have identified ownership of the activities to be the most relevant success factor. If the students feel the ownership of the project, they are also willing to invest time and effort to the outcome and interaction.

The project teams also meet regularly with the teachers to discuss the details of their project. These sessions provide a tool for the teachers to assess the dynamics of interaction in the team and their potential need for support or advice to improve the situation.

3.2.3 Course Assessment

From teachers' perspective, assessing the student and team performance can contain challenges. Due to the nature of the initial open ended problems,

teachers cannot give grades only based on the level of technical outcome. Sometimes the students are not able to finalize their plans or they do not have a tangible result to present as a final outcome. Still, they may have achieved the intended learning outcomes.

The course does not have any summative exam. Instead, the teachers use different kinds of materials, tools and practices to get insight into the students' performance among their team members. One of the main evaluation aspects include participation and activeness, observations during the lectures and individual group sessions. The main materials are: project plans, status reports, pitching sessions. In addition, students have to write a personal work diary where they describe the amount of hours and activities they have done for the project. The students also answer to the course feedback survey where they conduct self-assessment and peer-assessment.

3.3 Technologies and Tools Supporting Learning Outcomes

As the teams are allowed and expected to organise themselves, they also have freedom in choosing the tools they use. Each team is required to keep a project repository to store their digital outcomes, and teachers are given access to it. Each team presents their choice of tools in their presentations in order to share experience and provide best practices within the course.

Used tools include common file sharing tools, such as Dropbox, Google Drive, etc., task boards like Trello, distributed version control systems like Git. These tools are used regardless of the technologies related to building the actual project result.

Technologies experimented in building the project outcomes have included various sensor technologies, app and web development frameworks and flexible computing platforms specially designed for learning purposes, such as Raspberry Pi.

4 RESULTS AND ANALYSIS

4.1 Students' Feedback Analysis

To evaluate how the course succeeds in guiding students to the intended learning outcomes we analysed the student feedback collected after the capstone courses. The focus in this study was to analyse if the students report development in skills

related to the course intended learning outcomes. The student feedback is collected by using online survey tool after the course. At the beginning of the capstone course, the assessment process including self and peer-evaluations was introduced to the students. After the course the students self-evaluated their own participation and contribution to their project. They also provide an evaluation for each of their team members. These self-reflected evaluations provide to teachers an insight into the team’s operation and how the work load was balanced among the team members.

The students identified technical skills as essential to succeed in a capstone project. Three examples from the student feedback: “*Technical support is really necessary*”, “*The biggest problem was to do software project without actual programmers*” and “*We are all expected to understand and implement software programs. This was a huge issue in my group*”. Based on the feedback material it was possible to identify that technical aspects could be seen as potential discipline knowledge gaps and were one of root causes to teams’ challenges.

The students identified various technical topics (Table 1) as development areas to better succeed in capstone project activities. Also the students’ self-evaluation of their prior technical skills indicated that many students did not have the needed technical skills to excel in their capstone project (Figure 1).

Table 1: Students’ self-identified areas for developing their technical skills.

<p>Algorithms and analytical skills:</p> <ul style="list-style-type: none"> - Algorithm and algorithm analysis - Mathematical modeling - Learning analytics - Data-analytics
<p>Programming:</p> <ul style="list-style-type: none"> - C/C++ - Java courses - Object-oriented programming courses - Web programming - Python programming
<p>Networks and Databases:</p> <ul style="list-style-type: none"> - Network knowledge - Database technologies - Network and Operation systems
<p>Other technical skills:</p> <ul style="list-style-type: none"> - Cloud computing - Software and HTML design - Graphical design - Robotics - Geographical information systems and developing geo-informatics software

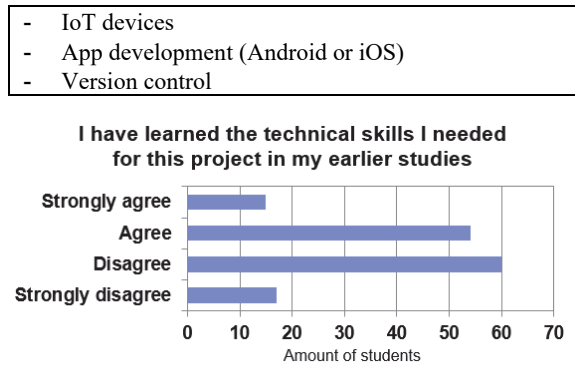


Figure 1: Sufficient technical skills to succeed in a capstone project.

The new situation in which the students independently managed their capstone project and its activities caused question marks for some students. In typical approach teachers give more exact tasks and activities to be performed. However, the capstone project learning target is to practice team skills, take active responsibility on both defining and implementing project tasks, and the accountability remains on the student side.

Based on the feedback results some of the students expected more strict supervision and guidance from the teachers: “*I had a feeling throughout the course that there should have been more supervision that the team members were doing their job*”, “*I wish we can get more supervision in the course, because our team was confused sometimes*”, and “*Provide more detailed directions and motivating or pushing teams to start the project activities*”. Yet, some of the students recognized that the supervision should come from inside the team, such as to be conducted by the project manager/leader: “*There should have been more supervision that the team members were doing their job. However I think this should be something that is the responsibility of the project manager not the person managing the course. Maybe this should be emphasized more when talking about the role of the project manager*”. Some students also proposed to have a teaching assistant who would focus on supporting a specific team: “*I hope each project team can have one assistant teacher who is familiar with the project so that we can get the necessary help*”.

Also motivation and interaction aspects caused some concerns. One of the key success factors to succeed in capstone project is student’s own motivation. If a student does not have the needed motivation, it can affect the rest of the team. Few examples from the student feedback: “*Kick out*

unskilled and unmotivated students”, “Capstone required a lot of motivation and hard work. Students of IT department are not usually very eager to make suggestions nor working without someone pushing them forward.” Some even proposed direct approaches to deal with unmotivated or non-participative team members who negatively impacted on their team working: “I can only come up with two ways to improve motivation towards team working: either punishing students for not doing anything relevant or encouraging them to improve their teamwork skills”.

The interaction and experience sharing with the fellow capstone teams could provide opportunities to learn and cooperate. Sharing situations and challenges could provide a new kind of reflection window to team working: “I would have some interaction session with other groups on how they are managing the project, what difficulties they are facing and what went so well, are we facing the similar kind of situations? This way we could figure out the common problems and complete the project better”. The communication between the different capstone project teams was very little and limited to the common all-class sessions. The interest to work together with other teams was identified: “I hope we could have an open working atmosphere to exchange ideas and solutions with other teams”.

Based on the student feedback, the majority of the students reported skill improvements or they learned new technical or project management skills during their capstone project (Figure 2). As an example, the students reported: “I got valuable information on project management and leadership and got to practice my presentation skills”. “It is the first formal project course I have ever taken and

most of the skills needed are new for me. So I have learned new things which makes me feel happy”.

Some students also identified that the capstone project was an opportunity to practice the skills and knowledge gained during the several years of studies: “I believe the whole idea of a Capstone project is to employ the skills and competences learned in school and working life”. The students identified team working skills as an outcome of the capstone project: “I liked the practical teamwork approach for common problems that required learning new skills and problem solving with different types of people. An eye-opening experience”.

The capstone project also provided an opportunity to learn new knowledge in another subject and thereby expanding the students’ skills and working life capabilities.

4.2 Analysis and Recommendations for Further Course Development

Based on the student feedback, teachers’ observations and hands-on experience, the following focus areas and recommendations for further development were identified.

Clarify the goals of capstone project experience. At the beginning of the capstone course, it is important to highlight to the students the opportunity to apply the knowledge and skills acquired in their studies and extend their academic experience by thinking critically and creatively during their capstone project. The capstone project provides a safe environment and an opportunity to demonstrate their proficiency in various areas and thus can be used as an asset on job markets.

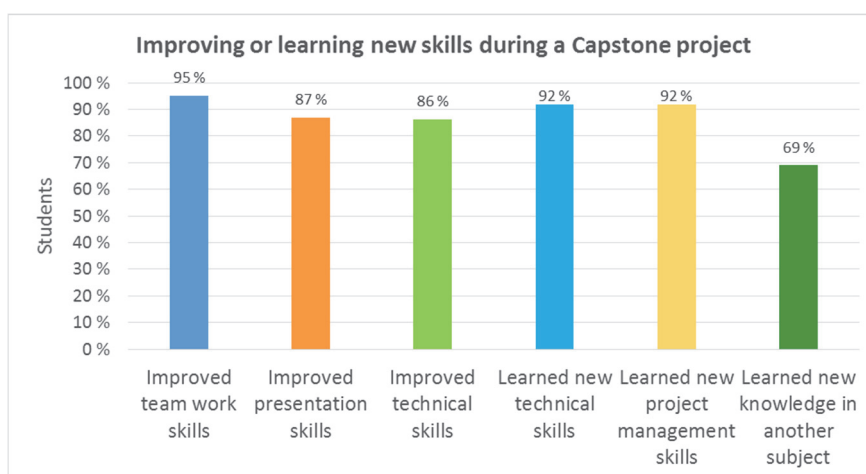


Figure 2: Students’ self-evaluation of their skill development after the Capstone course.

Highlighting the importance of student commitment to the project and the team. Students' commitment has a key role in the success of a capstone project. This course is quite unique in making the students mainly responsible for their activities, schedules, team work practices, atmosphere, and deliverables. The teacher provides support, but the students have to take the initiative to raise the need for support and guidance. Still, some students try to push the responsibility back on teachers and stay passive waiting for more instructions. During the recent iterations of the capstone course the expectation for the students active role has been discussed more both at all-class sessions and when teacher meets individual teams. More communication and educating the learning method at the beginning of the course needs to be highlighted.

More focus on technical studies. The students need to gain the basic technical knowledge in their pre-capstone studies. Capstone project provides a tool for students to conduct self-evaluation of their current professional skills. For the university the success level of capstone project gives input for planning how to teach these skills at right, early-enough points in curriculum.

Interaction between the capstone teams. A more low-profile interaction between teams could enable sharing and reflecting team challenges without the pressure of presenting the case to the entire class. Topics and situations encountered in capstone projects could be discussed in small groups being a mixture of several capstone teams. The groups would share a summary of their discussion and reflected viewpoints.

Having assistant teachers and technical support. Quite many of the students experienced challenges with technical aspects during their project. Due to budget limitations, various practical exercises on earlier courses have been reduced (Majanoja et al., 2017). In the project students may also operate with technologies they are not familiar with and they need more technical support. Therefore, it is recommendable to have more resources for technical support and course assistants to support the capstone teams.

Expanding the course together with other faculties. While the majority of the students on past capstone project teams have been students of IT, providing a viable solution to most project topics could have benefitted from an interdisciplinary team. Engaging other subjects and faculties on IT focused projects could provide opportunities. To succeed, the project topics should systematically be developed

together with other faculties. Linking IT and business students is a realized approach (e.g. Kruchten et al., 2011). In a multidisciplinary university such as University of Turku, several disciplines could ideally be involved.

5 CONCLUSIONS

The aim of a capstone project is to provide students a safe environment to practice their current knowledge and abilities, such as knowledge of discipline or content area and diversity including cultures, perspectives and belief systems. The target of the capstone project is also to strengthen students' ability to think critically, communicate efficiently and use various technologies. In addition, the capstone project provides a lesson about commitment towards social responsibilities, leadership, providing service to others, and how the lack of commitment affects the whole project team. This study set out with the aim of reflecting on arrangements of capstone projects in University of Turku, Department of Information Technology, and to provide recommendations for developing the course and supporting curriculum. To form our recommendation the students' feedback was analysed and conclusion reflected against teachers' observations.

Based on the analysis it was identified that technical aspects cause significant challenges. Quite many of the challenges culminate around the students' lack of programming skills and the capstone course currently as such does not have the resources to provide detailed technical guidance in all team specific issues. Therefore, more focus should be given on strengthening students' technical skills before joining the capstone course.

The results of this study also indicate students' challenges to perceive their student-led role being in charge of all of the activities instead of following the traditional teacher-led approach. The change from rather passive receiver to active doer can be challenging. Students' prior working life experience has a positive effect on the whole team. Those teams are found to achieve deeper understanding of what they are required to do and more effectively fill the knowledge gaps with their practical experience.

We acknowledge the limitations of this study as the results come from only one university. At the same time, however, the results are well aligned with the existing capstone research and discourse.

Future research should investigate the impact of students' prior working life experience on

performance at the capstone project. Another research topic would be to analyse the relevance of the capstone project as a self-assessment tool for students' working life capabilities.

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