

# **Evaluation of students' capstone software development projects**

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## **INTRODUCTION**

Capstone projects are important part of engineering education studies in software development field. In the project, a student team implements a software product usually for a company. Because of group work, complex project topics and external

stakeholders, evaluation of students' work is challenging. Our studied project course is aimed for Master's students, during their last year of studies. It is compilation of all information and competence, what students have learned during their studies in computer science so far.

In this paper, we introduce a new detailed evaluation model for software engineering capstone projects. The model has the following three main dimensions; project team implementation, customer feedback and individual level performance. We have tested the evaluation model with over 25 projects and 146 students during two academic years, and the benefits of the model are clear and transparent requirements in addition to fair credits to students. There may be variation within a project group both on the credit units and on grade.

The rest of this paper is organised as follows. Next, we give an overview to engineering education capstone projects, and evaluation of group work. Section 2 gives a detailed description of a capstone project implementation at Tampere University of Technology (TUT). In Section 3, new project evaluation model is given and analysed.

## **1 CAPSTONE PROJECTS IN ENGINEERING EDUCATION**

### **1.1 Capstone projects**

Project work skills are recognised widely as core knowledge in software engineering [1]; [2] and also in other engineering fields. In software engineering capstone projects, students have a possibility to apply all their knowledge and skills from earlier studies to implement a software product.

The following issues characterise academic software engineering capstone projects: i) The project is done during the last study years before graduation. ii) Group size varies between 4-7 developers, often one team member acts as a project manager. iii) Outcome from the project is a software product. iv) Customer comes from a company or some other external organisation. v) Size of the project is relatively large, students can receive up to 10 ECTS and the project may last 4-6 months. vi) The team must follow widely recognised software development models and good project working practices. vii) Teachers supervise the team. viii) Traditional project constraints, like scope, schedule and quality are important, but usually there is no real budget.

Exact learning goals of capstone projects vary between disciplines and organisations, but for example, ACM's Software Engineering Curricula [1] guideline describes content of a project course as follows: *"Group software engineering project requiring completion of a software system for an approved customer. Tasks include project planning, risk analysis, use of standards, prototyping, configuration management, quality assurance, project reviews and reports, team management and organisation, copyright, liability, and handling project failure."*

### **1.2 Evaluation**

Assessment refer to evaluation of learning outcomes, but it can also refer to activities that teacher use to help students to learn, and to measure student's progress. If assessment is shown to students, it works as a feedback. All aspects that are related to teaching should be aligned to support students' learning, understanding and professional development.

Assessment can be formative, when it happens during the course, or it can be summative, when it happens at the end of the course. Formative assessment helps

students to know whether they are on a right track or not, and it aids and motivates to improve activities during the course. Summative assessment is used to summarise what the student has learned. The summarisation can be a grade or it can be just passed or failed evaluation. In self-evaluation, student assesses his/her learning by him/herself, while in peer feedback, evaluation is done by other students. In addition, a group can evaluate together the group's learning.

Pickford and Brown [3] have identified several key questions for the evaluation process itself, when evaluating students learning and performance: 1) Why are we assessing? 2) What it is we are assessing? 3) How are we assessing? 4) Who is best placed to assess? 5) When should assessment take place? Pickford and Brown [3] also raise up challenges in assessment. Learning outcomes can be difficult to assess, if they are vague, over-ambiguous, expressed with complex terms, or inappropriate in terms of level, scope or extent.

Group work brings even more challenges to assessment because group's performance must be mapped into individual grades. When discussing about weights of different evaluation components, teacher is recommended to consider the following aspects [4]: i) What percentage of the student's total project grade will be based on the group's performance vs. individual components? ii) What percentage will be based on assessments of product vs. assessments of process? iii) How much weight will be given to peer evaluations or self-evaluations? iv) Will feedback from external customers also be incorporated into teachers' assessment of the group's work?

## **2 CAPSTONE PROJECT COURSE AT TUT**

The project course has over 26 years' history [5]; [6]; [7]. From the very beginning in 1990s, project work topics from companies have been accepted. Some topics from university research projects (from different faculties) have been done occasionally. Non-profit organisations and individuals (e.g. researchers, hobbyists or entrepreneurs) could also have been customers. Previously students could also suggest their own project topics (for their personal use), but those are not accepted anymore as there should be an external customer.

Evaluation of projects in 1990s and early 2000s was based on project Demo meeting (Product Check), Final Presentation, documentation, inspections (a few documents and code), and weekly reports. At evaluation product's quality and usefulness to customer was considered, as well as the process quality (including deliverables in time). Customer's feedback was not systematically asked.

Learning goals of the course are: Implementation of a software project. Planning, tracking and executing of a project of several people, made to some customer. Professional contribution of own technical skills to the project. Controlled process of project work with quality activities. Teamwork with different roles. Technical documentation and reporting.

Actual project size varies depending on the technology and students' motivation. Sometimes students make over 250 personal working hours, which equals 10 ECTS.

TUT project course is aimed at Master's studies last year, and it has been respected very much among local ICT companies, and students themselves. Course's current process model is in Appendix A.

### 3 EVALUATION MODEL

#### 3.1 Evaluation model

New evaluation model for Project Work on Pervasive Systems course in Tampere University of Technology (TUT) has been created, among other things, to improve the quality of grading. Grades achieved by students are based on points given in different parts of the evaluation. Total points can be varied from zero to 60. Student need to have at least 30 points to pass the course (see Table 1).

Table 1. Project work course grade/points table.

<b>Points</b>	0 – 29 p	30 – 36 p	37 – 42 p	43 – 48 p	49 – 54 p	55 – 60 p
<b>Grade</b>	0	1	2	3	4	5

Other drivers for new evaluation model were to improve fairness and professionalism. Evaluation model is divided to three different parts (see Table 2 and Appendix B). Each of those parts have several viewpoints how evaluation is established. **First and main part** is evaluation of **project implementation** and it is done by course staff. The evaluators need to use their intuitions and judgments to subjective evaluation criteria for different quality factors of the projects. Maximum points for this is 30. This part of evaluation has three viewpoints. **First**, end result of project is evaluated and key evaluated elements there are quality of implementation, usable user interface, quality of documentation and reasonable architecture. This evaluation is done based on common project practices and comparing different projects to each other. Quality of end product is carefully evaluated based on these criteria to ensure that the students' projects are rated fairly.

This part of evaluation is done as staff effort to achieve the objective of fair and accurate evaluations. **Secondly**, quality of work in project is evaluated and key evaluated elements there are implemented SW development framework, quality of work split and effort estimation in planning, risk management, established meetings, quality of delivered reports and product quality assurance activities and finally perfectness of delivery. Furthermore, project related presentations (mid and final presentations) are evaluated from quality point of view. **Thirdly**, project schedule related issues are evaluated and important deadlines there are delivery of Project Plan, Testing Plan, final product, bi-weekly reports and Final Report. Keeping schedule and acting accordingly for delays is one of key elements for any project. All these deliveries will left timestamp to course learning platform called Moodle with one exception on bi-weekly report, where timestamp will be found from e-mail system. In this part of evaluation points from all three viewpoints are added together.

**Second part** of the evaluation model is **customer feedback** for project and project team. Customer feedback is collected from customers by sending feedback request to customer's key contact person after one to two weeks actual project result has been delivered to customer. Usually one customer's key contact person give feedback to project, but if there are several of those average of given points are calculated. Maximum points for this is 15 points. Customer give points from three viewpoints, as well as give free written feedback. Those viewpoints are product itself, quality of delivered result and co-operation with the project team. **First**, customer is evaluating delivered product and key elements on that are implemented features, fulfillment of

requirements given by customer, layout and capability to develop it further as well as transformability. Customer evaluate these issues by evaluating and using the delivered product during couple of first weeks. **Secondly**, customer is evaluating quality of results, delivered product and related required documentation. Key elements in this evaluation are implemented functionality, logicity of implementation, easiness to maintain as well as quality and usefulness of related documentation. **Thirdly**, co-operation with project team is evaluated and key elements there are quality and level of communication, usefulness of meetings held, quality and timing of reporting as well as customer contact availability. Also, in this part of evaluation points from all three elements are added together.

Table 2. Project work course evaluation model.

Evaluation model	Viewpoints	Key elements in evaluation	Points
Project team implementation together (0-30p)	End result quality	Usability, architecture, documentation, implementation, user experience, etc.	0–10 p
	Quality of work	SW development process, work split, effort estimation, meetings, reports, planning, QA, etc.	0–10 p
	Schedule related	Keeping deadlines; plans, delivery, reports, meetings, etc.	0–10 p
Customer feedback for project results and team (0-15p)	End product itself	Features, requirements, layout, capability develop further, transformability, etc.	0–5 p
	End result quality	Functionality, logicity, easy to maintain, documentation, etc.	0–5 p
	Co-operation with team	Meetings, reporting, availability, communication, etc.	0–5 p
Individual level performance (0-15p)	Self-evaluation	Students make self-assessment themselves (performance, importance)	0–10 p
	Peer-evaluation	Giving peer feedback to other project team members (performance, importance)	
	Staff evaluation	Project course staff giving feedback for individuals (performance, professionalism)	0–5 p

**Finally, third and last part** of the evaluation model is evaluation of individual level performance of each project member (students). Maximum points for this is 15 points. Students are receiving points from three viewpoints, as well as some free-form written feedback. **First**, in the end of the project work course, called Final Meeting is established for every project. Last item on that meeting is self- and peer-evaluation. Every project member of the project team is filling a form, where they are giving

feedback (written and points) to every team member. Furthermore, they are giving feedback to themselves as points, how well they have performed during the project. Result from these evaluations is average points (0-10p) to all students. **Last viewpoint** of this evaluation model is individual level feedback given by course staff (project coach and other staff). Key elements in this evaluation are performance in course and specifically in project work and quality professionalism in SW engineering.

Two most important **evaluation events** for creation of presented project evaluation model are called "Final Meeting" and "grade meeting". **Final Meeting** is established about one week after end of the project to evaluate one project at a time. Content of that two hours meeting consists of review of project, Final Report content and self- and peer-evaluations. Project is reviewed by going it through from early phase with help of a comprehensive checklist, project team creation, to its later phases delivery and final presentation. Main method used is discussion between project team members and course staff to review of key learnings, problems, realised risks and other key elements of the implemented project. **Grade meeting** is established when all information related to evaluation model (usually waiting for customer evaluation results) has been collected. In this meeting, course staff is doing final evaluations and discussions related evaluation model and grades. Best project is also selected based on evaluations and discussions and the best project team is rewarded by grant, which will be granted in some suitable conference or theme day established at the university.

### 3.2 Assessment of the evaluation model

Evaluation of the evaluation model is done by applying Pickford's and Brown's [3] key questions. **First question** (what) you need to answer is that is your theory and practice in balance. Students need to have knowledge to solve problems during the project. Our project course have several lectures in the beginning of the course, so that all related knowledge and information is available for students to use. Learning of theory is currently yet evaluated, but we are planning to improve process of evaluation to that direction as well. Our course content and process (see Appendix A) are presented to students in the beginning of the course. We also present key points for our evaluation model in that process. Furthermore, we go through all objectives for students in learning and project development point of view.

**Second question** (Why) is mostly related to motivation as well as giving and receiving feedback. Students are more motivated, when they know both course learning objectives and how their learning and achievements are evaluated. In project work course, we take care that all students have that information during the first lecture. Evaluation model and results from previous years are gone through with students. Motivation of students getting up during last two years and one reason for that can be seen in evaluation model and its visibility to students. Reflection of higher motivation can be seen in grades (Figure 1) and credits (Figure 2) during last two years. There in the pictures can be seen year 2012-2013 as a baseline. During years 2013-14, 2014-15 and 2015-16 grades scale 0 to 5 were not in use, evaluation results was only pass or fail (which was later considered very bad for students' motivation).

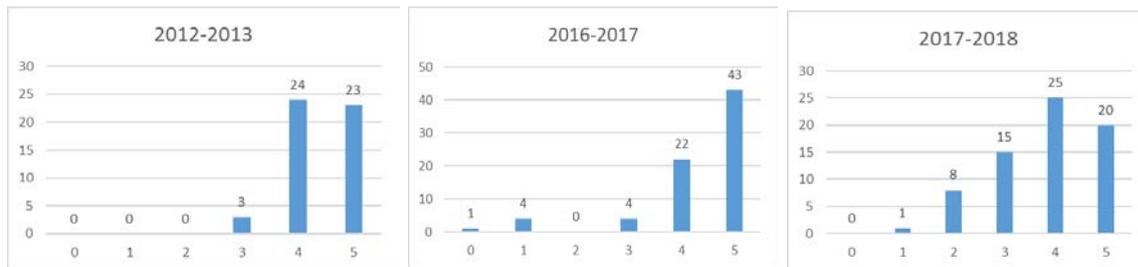


Fig. 1. Course grade distributions 2012-2013, 2016-2017 and 2017-2018.

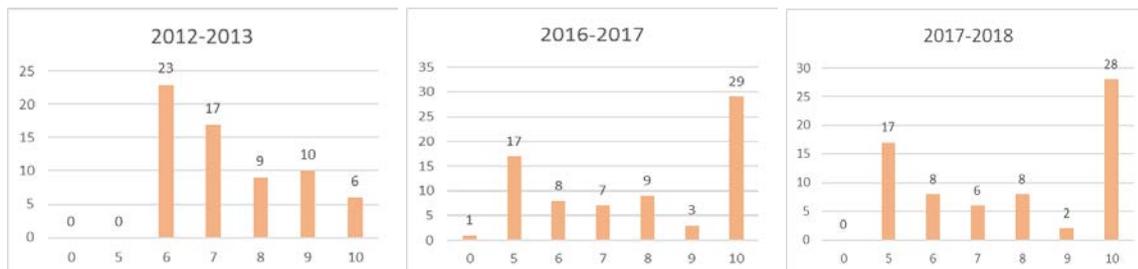


Fig. 2. Course credit unit distributions 2012-2013, 2016-2017 and 2017-2018.

**Third** (How) question is related to evaluation methods and how evaluation data is collected. In this course, also students know this process. Focus and weight is on course staff evaluation of result and process to get there. Last year customer feedback weight was increased as result of feedback from students. As projects are all customer projects, students think and staff think that also weight of customer feedback needs to be higher. To reward individual excellence and to get difference between students from performance point of view, individual part of evaluation data have also impact to given grade. One part of learning what needs to be improved is evaluation of theory of project work learned in this course. Of course, theory is used to solve problems in project and so been evaluated as part of project results and way of work.

**Who** should be part of an evaluation? As a summary of evaluation model, manner of an approach is to get evaluation data from all relevant stakeholders for this course. Those are course staff review data, customer feedback data, peer evaluation review data and self-evaluation results. Quite often end users can be seen stakeholders of course project as well, but also almost every time production usage of implemented product is not yet started before course is in the end. End users feedback can be and has been quite often collected as part of usability or other testing activity established during the project.

**When** evaluation should be then done? Best practice is to evaluate all learnings and doings during the course. In project work course focus is in the project itself, process and end-result. In this evaluation model, part of the evaluation data is collected during the project (e.g. schedule, documentation, communication, etc.). Also in the Final Meeting project will be evaluated from its early phases to the delivery of ready product. Other part of evaluation will be done in the end of the project, when e.g. end-result and Final Report can be analysed. Projects also need to present their doings and results in sprint reviews, mid-presentation and final presentation. Those are excellent opportunities for course staff and customer to analyse project achievements. Self and peer reviews are done in the end of Final Meeting after project has ended. Furthermore, customer feedback will be collected one or two weeks after delivery, so that customer has opportunity to use and analyse the product.

### 3.3 Conclusions and future improvement

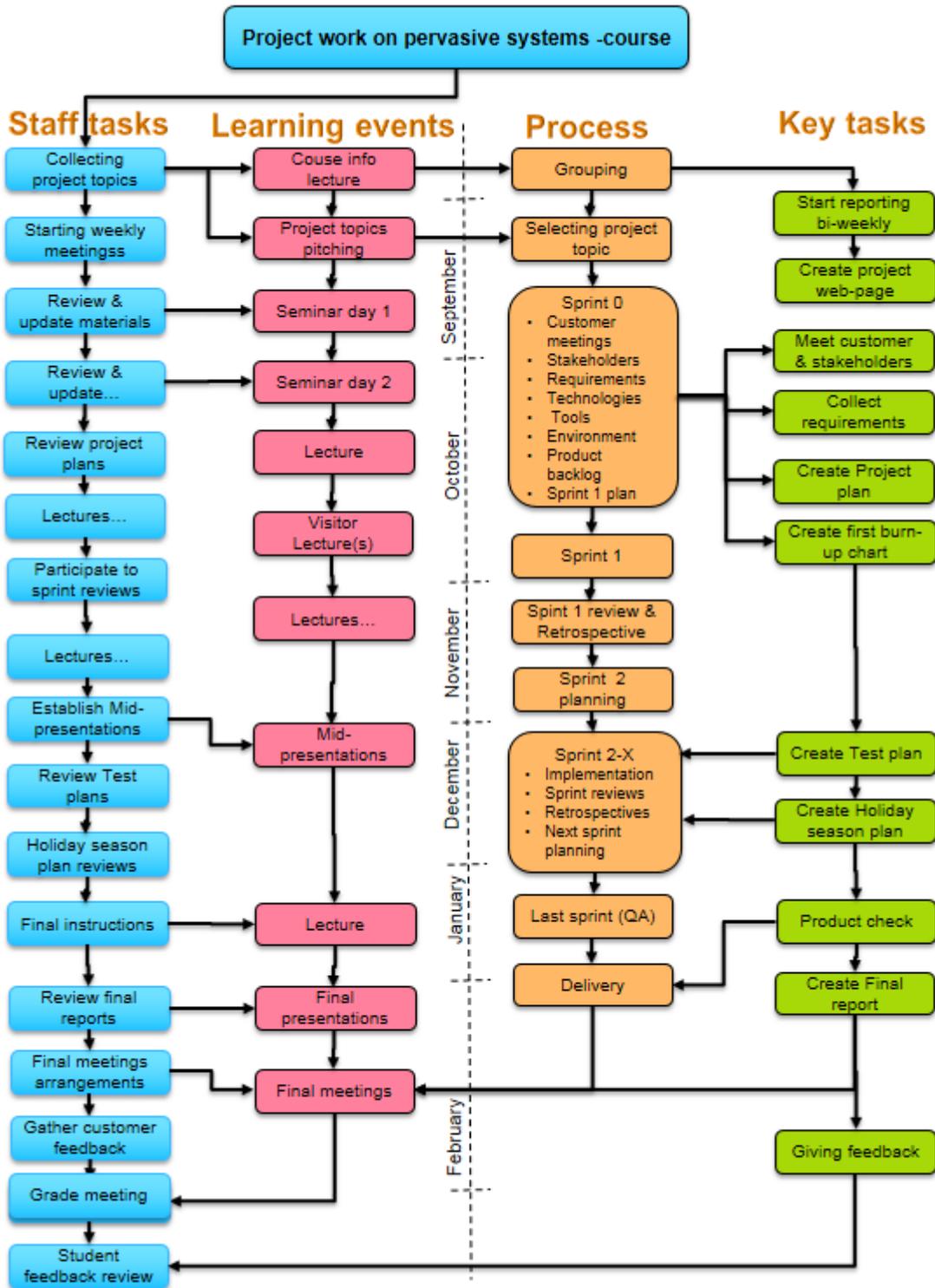
Evaluation model introduced in this paper gives wider view on evaluation of customer projects and how it is part of an university course evaluation. This model establishes one useful tool for that kind of evaluation based grading. Students have not complained about this model. Positive educational point is that it teaches also peer feedback and self-assessment to students.

However our model still leaves some room for improvements during coming years. To be really equal between all students, e.g. technology coefficient would be needed.

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Appendix A. Project course process at TUT.



Appendix B. Example of Project course evaluation matrix at TUT.

Student	Role	Team implementation together (0-30p)	Schedule (0-10p)	Process / Quality of work (0-10p)	Quality of end result (0-10p)	Customer feedback for project (0-15p)	End product itself (0-5p)	Quality of end product (0-5p)	Co-operation with the project	Individual performance (0-20p)	Comparative feedback (0-10p)	Coach / Other staff evaluation (0-5p)	Total points	Grade	Working hours	Credit points
XXX	PM	19	5	6	8	11	3	4	4	11,17	8,17	3	41,17	2	160,5	6
XXX	PO	19	5	6	8	11	3	4	4	14,67	9,67	5	44,67	3	230,0	9
XXX		19	5	6	8	11	3	4	4	10,33	7,33	3	40,33	2	149,5	6
XXX		19	5	6	8	11	3	4	4	12,17	8,17	4	42,17	2	151,0	6
XXX		19	5	6	8	11	3	4	4	12,50	8,50	4	42,50	3	183,0	7
XXX		19	5	6	8	11	3	4	4	13,17	9,17	4	43,17	3	202,0	8
Average		19	5	6	8	11	3	4	4	12,33	8,50	3,83	42,33	2,50	179,33	7
XXX	PM	26	9	8	9	14	4	5	5	12,17	8,17	4	52,17	4	145,0	5
XXX	PO	26	9	8	9	14	4	5	5	11,17	7,17	4	51,17	4	153,5	6
XXX	QA	26	9	8	9	14	4	5	5	14,83	9,83	5	54,83	5	181,0	7
XXX		26	9	8	9	14	4	5	5	12,33	8,33	4	52,33	4	178,5	7
XXX		26	9	8	9	14	4	5	5	14,00	9,00	5	54,00	4	151,0	6
XXX		26	9	8	9	14	4	5	5	11,00	7,00	4	51,00	4	136,0	5
Average		26	9	8	9	14	4	5	5	12,58	8,25	4,33333333	52,58	4,1666667	157,5	6