DEVELOPING QUALITY MANAGEMENT COMPETENCIES IN SOFTWARE ENGINEERING: A CDIO APPROACH

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ABSTRACT

This paper explores the development of quality management within theFIRMA, a project-based learning environment at Turku University of Applied Sciences (TUAS), Finland. TheFIRMA operates like a software company, providing students with real-world experience in project management and software development. Despite its success in software development projects, theFIRMA faced challenges in quality management, particularly in maintaining long-term commitment and ownership among students. To address these challenges, several initiatives were implemented. The management team was restructured to include a Head of Operations (HOO) responsible for overseeing quality management. Quality metrics were developed to measure and improve project outcomes. New practices in project management and software development were introduced, requiring students to follow either the waterfall method or Scrum, use GANTT charts, and track tasks with Product Backlogs. Additionally, course content was updated to include information-sharing sessions, and lectures on time management and scope management. The paper discusses the impact of these changes on student learning and project outcomes, emphasizing the importance of adequate training, mentoring, and support. Future work includes finalizing the quality manual, testing quality metrics, and encouraging collaborative coding practices. Future research will include the impact on the new quality management measures to students' learning outcomes.

KEYWORDS

Quality management, quality development, Project-based learning, ICT, Standards 3, 7, 8.

INTRODUCTION TO THEFIRMA AND ITS QUALITY CHALLENGES

TheFIRMA is a project-based learning environment within the Software Engineering and Project Management (SEPM) competence track at the Turku University of Applied Sciences (TUAS) Faculty of ICT and Industrial Engineering, Finland. Established in 2015, theFIRMA operates similarly to a software company, offering a multitude of services ranging from website and web/mobile application development to marketing surveys and short-term IT support. As a student-led project office, all managerial positions are held by students, including a paid student CEO, a student Vice CEO, a student Head of Operations (HOO), and a student Marketing Manager. Together with two lecturers overseeing operations, this group forms the managerial team of theFIRMA. Each project also has a project manager or a Scrum master and various other roles depending on the project's nature, such as developers, designers, videographers, composers, social media content creators, etc.

Annually, approximately 200 undergraduate ICT engineering and business administration students participate in theFIRMA projects in various roles. In the autumn semester, second- and fourth-year students participate in project work as part of their ICT project courses, while in the spring semester, the participants are mainly third- and fourth-year students. In summer, students work in theFIRMA as interns. The simplified organization structure of theFIRMA is described in Figure 1.

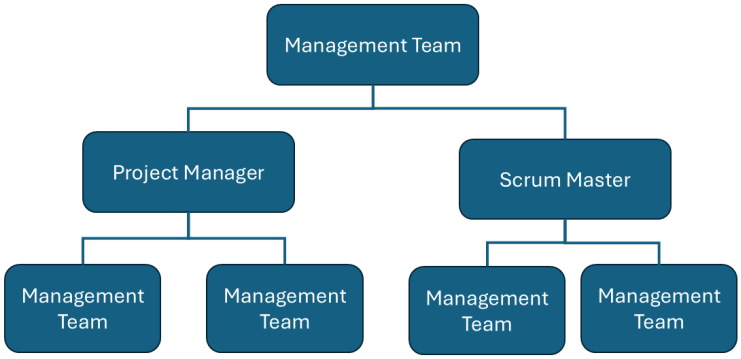

Figure 1: Simplified organization structure of theFIRMA

Course Structure and Duration

TheFIRMA is integrated into three main courses within the SEPM competence track: Introduction to ICT Projects, ICT Projects, and Advanced ICT Projects. The first two courses each take one semester, with students working 81 and 108 hours respectively. The Advanced ICT Projects course spans the entire academic year, requiring 135 hours of work. Additionally, students can earn credits for optional studies by working in theFIRMA with 27 hours equating to 1 ECTS.

During summer internships, students work 270 hours. Students can also complete their thesis in theFIRMA, either by being commissioned for specific tasks or by working on projects and writing a learning diary. These projects provide hands-on experience in project management and software engineering, aligning with the CDIO (Conceive, Design, Implement, Operate) framework to enhance learning and professional growth.

Project Categories

TheFIRMA projects can be roughly divided into three categories. The first category consists of projects for external customers, primarily small and mid-sized local companies, focusing on website design and development and web/mobile application development. TheFIRMA has also undertaken EU-funded projects aimed at developing the digital skills of small and medium-sized companies or private citizens.

The second category includes TUAS internal projects and collaborations with other universities of applied sciences in different countries (see, Säisä, et al., 2020). Internal projects are not paid and often have lower scheduling priority. The third category is the Citizen's Help Desk (KITT), which provides free IT support to local citizens, primarily elderly individuals, with issues related to their mobile devices and computers.

Growth and Quality Challenges

The aim of theFIRMA's quality assurance process is to ensure good project outcomes for customers while supporting students' professional growth. Students set learning goals at the project's start, track their working hours, and evaluate goal achievement at the end (Määttä, Roslöf & Säisä, 2018). Over the years, theFIRMA has made many changes to the project process, usually reactive and educator led. To improve quality, we added instructions to virtual learning platform, defined our project processes, and required four documents: Project Plan, Kick-off, Final Report and Project Closing. Despite these measures, we lacked a comprehensive understanding of the root causes of our challenges, such as late project deliveries and scope issues.

The rapid growth in student numbers and closer integration with SEPM track courses have presented challenges related to project quality. Since most students leave after completing their courses, project teams change almost entirely three times a year: at the beginning of autumn and spring semesters and at the start of the summer.

SEPM track adheres especially to CDIO standards 3 (Integrated Curriculum), 7 (Integrated Learning Experiences), and 8 (Active Learning) in project courses. Students learn project-related practices in lectures and then apply this theoretical learning in theFIRMA projects (Säisä, Määttä & Roslöf, 2017). This approach works very well in software development projects but poses challenges long-term quality management. The short-term nature of project courses disbands project groups, breaking the development process. Educators must pay extra attention to teaching and mentoring subsequent project teams to maintain long-term perspectives. The short-term approach hinders students from creating ownership and long-term commitment to quality, making it difficult to standardize improvements in theFIRMA processes (Tiura & Säisä, 2018).

This paper discusses how we have developed quality management in theFIRMA to better include the CDIO framework. It answers the following questions: 1) How we have developed theFIRMA quality management, so that it better implements the CDIO framework? 2) What have our experiences been with this development process? 3) What impact have these quality management improvements had on student learning outcomes and project success?

THEORETICAL FRAMEWORK AND LITERATURE REVIEW

In an environment such as theFIRMA, the concept of quality must be considered from multiple, interrelated perspectives. Firstly, from an educational standpoint, quality is reflected in how

well the learning objectives are achieved, how students engage in authentic, practice-based learning, and how effectively the learning environment supports their professional development (Biggs & Tang, 2011). Secondly, the quality of the projects themselves must be evaluated in terms of outcomes, stakeholder satisfaction, and the value delivered to real clients. Thirdly, project management quality plays a crucial role in bridging educational goals and project success. Effective project planning, communication, risk management, and team coordination are essential for ensuring both a positive learning experience and a successful project outcome (PMI, 2017). In this type of learning-by-doing environment, quality is not a singular metric but a multi-dimensional construct that encompasses pedagogical value, technical deliverables, and managerial processes.

In project management, quality is defined as the degree to which a set of inherent characteristics fulfills requirements. Quality management ensures that the project deliverables meet both stated and implied needs, through processes such as quality planning, quality assurance, and quality control (PMI, 2017).

Educational quality in the context of a CDIO-based software engineering program is reflected in the integration of project-based learning across all study years, supporting the development of both technical competencies and professional skills. This approach ensures students gain practical experience in teamwork, design, implementation, and reflective evaluation, aligning learning outcomes with industry expectations (Levy, 2009).

The implementation of the CDIO framework in the Hacking Exposed course at Duy Tan University illustrates how integrated, project-based learning can significantly enhance educational quality. By aligning learning activities with CDIO Standards 5 and 7, students developed both technical and professional competencies through structured design-implement experiences and interdisciplinary collaboration. This pedagogical approach not only improved students' problem-solving, self-learning, and teamwork skills, but also provided practical exposure to real-world cybersecurity challenges, thereby bridging the gap between theory and industry expectations (Vo et al., 2017).

The integration of the CDIO framework into the Diploma in Chemical Engineering at Singapore Polytechnic demonstrates how structured self-evaluation can be effectively aligned with institutional quality systems and external accreditation requirements. By embedding CDIO Standards within their Academic Quality Management System (AQMS) and professional development processes, the program has systematically enhanced curriculum design, teaching quality, and student learning outcomes. This alignment enabled continuous improvement while also satisfying the rigorous expectations of external bodies such as IChemE, affirming CDIO's value in supporting high-quality engineering education (Cheah et al., 2013).

IDENTIFYING CHALLENGES IN THEFIRMA PROJECTS

To better understand the quality challenges, we investigated students' perspectives on project management. We commissioned Jani Pöllänen to research this in his thesis project. Through 17 semi-structured interviews, Pöllänen identified three major factors affecting project quality:

- *Lack of Documentation:* Inadequate documentation caused delays as new project teams struggled to understand previous work, especially when the entire team changed at the start of a new semester.

- *Time Management:* Students lacked time management skills and projects did not use tools to track schedules, making hard to monitor time against plans.
- *Communication:* Students had insufficient technological skills to use message boards effectively, missing notifications and important messages (Pöllänen, 2024).

In addition to Pöllänen's study, theFIRMA management team conducted informal discussions and reviewed projects by going through project documentation of selected projects to identify major issues that led to scheduling and scope challenges. The informal discussions were held with students working in theFIRMA in various roles to gather qualitative insights. Although these efforts were not systematic or scientifically rigorous, they revealed patterns and major issues.

To gain deeper insights into project practices, we also examined study diaries (e.g., Hermans, 2025; Jalava, n.d.). These diaries, though not focused on quality, provided valuable information about everyday practices that we do not have time to oversee. They helped us understand how projects were executed on a day-to-day basis, highlighting areas where improvements were needed.

Investigations revealed that many projects were not properly using project management tools like Product Backlogs or were using inadequate tools like Excel. This made it difficult for students to stay within scope and meet schedules. Students also did not consistently follow any project management methods, leading to impractical and inefficient ways of working and unclear responsibilities.

In application development projects, infrequent discussions on coding practices and lack of code sharing and mob coding led to merge conflicts, overlapping code, and poor variable naming. This resulted in low code quality, poor reusability, and missed bugs and functional errors, increasing technical debt and knowledge silos. In some cases, lack of collaboration necessitated extensive code rewrites.

ENHANCING QUALITY MANAGEMENT THROUGH STRATEGIC CHANGES

In the next phase, we aimed to develop theFIRMA's quality management processes within the context of the CDIO framework (standard 1, context). Our focus was on the three perspectives highlighted in the literature review: educational, project management, and project outcomes. Our investigations highlighted several areas needing improvement: restructuring the management team, developing quality metrics and a manual, enhancing project management practices, revamping the quality assurance team, and updating the project course content. The following subsections detail the specific changes and improvements we have implemented to address these challenges.

Restructuring the Management Team

From the perspective or project outcomes, one of the major issues with quality management was the lack of ownership, long-term perspective, and commitment to quality. Previously, the student CEO and student Vice CEO, along with two lecturers, oversaw operations. Both the CEO and Vice CEO already had a heavy workload and demanding schedule, so the main responsibility for quality development fell to the responsible teachers. However, this situation did not align with theFIRMA principles, where the aim is for students to take responsibility for operational activities, and teachers to have mainly a mentoring role (Tiura & Säisä, 2018).

To address this, we created the role of Head of Operations (HOO). The HOO is part of the management team and is responsible for overseeing working hours, monitoring projects, and managing and developing quality together with the quality assurance team. This role fosters ownership, commitment, and long-term perspective, while giving students responsibility and enhancing active learning, which conforms to standard 8 of the CDIO framework.

Creating Quality Metrics and Quality Manual

Another measure taken toward the improvement of the project outcomes was to find effective ways to improve the quality by providing clearer metrics and instructions. We discovered that although students take an active role in developing quality, close cooperation with responsible teachers is required. Often, the initiative for changes comes from the students rather than the teachers. One initiative that came through Pöllänen's study was to create a quality manual for theFIRMA. The management team also decided to find ways to measure quality to assess if changes have improved processes and project outcomes. The teachers decided to set these as thesis projects in early summer 2024, with an initial deadline of late December 2024.

The thesis project on metrics was exemplary, with students in various roles collaborating to create a set of metrics to measure projects effectively. Metrics include standard software company measures and pedagogical goals, such as how well students use certain tools, how frequently they meet with customers, and how consistently project management methodologies are used. Developing the quality manual as a thesis project proved challenging due to its complexity. We decided it would be more effective as a group project involving the quality assurance team and the HOO.

For thesis projects, integrating the entire CDIO cycle is difficult due to time constraints. By involving other students in discussions and contributions, we create opportunities for them to experience the full CDIO model. Teachers act as supervisors, providing guidance and oversight, while students actively participate in these projects.

Enhancing Project Management and Software Engineering Practices

From the project management perspective, we aim to follow CDIO standard 3, Integrated Curriculum. We teach project management methods like waterfall and Scrum, along with scheduling, risk, and quality management. However, students often do not use the tools and methods they have been taught in their projects.

To reinforce learning, we implemented new practices starting spring semester 2025. Projects must choose a project management method (waterfall or Scrum). This choice is documented in the project plan and monitored by the audit team. Long-term projects are required to use GANTT charts for tracking, and all projects must use Product Backlogs or similar tools. Requiring students to follow certain methods necessitates supervision to ensure compliance. This might cause resistance and demotivate students. Thus, it is crucial that the project team finds the additional documentation helpful for their work as well.

Many students were confused about the documents they needed to submit at the end of the course. Previously, we used project closing and final report, where project teams reflected on their work and assisted the next team in starting their work more quickly. However, the titles of these documents were confusing as the project managers in continuing projects were not sure if they are required to submit them. To address confusion, we created project handover documents and reports, eliminating questions about ending documentation.

We recommended code review meetings and mob programming to enhance collaboration among the developers. Code reviews improve code quality and problem-solving and help develop reusable code. Mob programming helps share knowledge and solve complex problems together, aiding junior developers' growth. Despite recommendations, few projects use these methods, so we integrated them into our programming courses. Challenges remain as students tend to divide tasks instead of coding together.

Encouraging students to use learned methods and skills in real-life projects is challenging. Additional training helps, but sometimes requiring students to use certain methods is necessary. Support from educators lowers the threshold for using new skills. To alleviate limited teacher resources, older students mentor younger ones, especially in coding and project management.

Updating the Content of the Project Courses for Better Outcomes

To address the identified issues, we revised project-related course content, drawing on the principles of effective learning environments as outlined by Biggs and Tang (2011). Previously, many second-year students struggled with theFIRMA processes, causing extra work for teachers and the CEO and Vice CEO. We added four information-sharing sessions managed by older students, which proved very useful. The second-year students actively participated in all the sessions, and the feedback was very positive. We noticed that when students are clear about what they are supposed to do, they often deliver better results, which in theFIRMA often leads to higher quality project outcomes.

Time management is often difficult for students, who often procrastinate. We incorporated a lecture on time management and an assignment to create weekly schedules However, improvement was minimal and this part of the course needs readjustment. To address project scope issues, we incorporated scope management as a primary topic in a project-related course. This helps students understand the importance of adhering to the agreed scope, preventing scope creep and improving project quality.

These changes aim to enhance students' personal skills by teaching them in theory and providing practical opportunities, following standards 3 (Integrated Curriculum) and 7 (Integrated Learning Experiences) of CDIO framework. Despite theoretical lectures and home assignments, students do not always adapt their learning in projects.

Student Feedback

Student feedback on the ICT project courses has been generally positive. Students have reported that the revised course content effectively supports their project work and enhances their skills in both project management and various roles within the projects. They feel more confident and clearer about theFIRMA processes, which has contributed to a more cohesive and collaborative environment.

The implemented changes have also fostered improved cooperation among students, leading to further suggestions for enhancements in theFIRMA processes. The general atmosphere in the office is very positive, with students actively engaging in collaborative activities and demonstrating a genuine willingness to work together. This cohesiveness and mutual support have significantly contributed to the overall success of the projects and the learning experience.

DISCUSSION AND REFLECTIONS ON QUALITY IMPROVEMENTS

TheFIRMA's core values emphasize learning by doing, especially the CDIO standards 3 (Integrated Curriculum), 7 (Integrated Learning Experiences), and 8 (Active Learning). In theFIRMA projects, students actively engage in problem-solving, designing, and implementing real-world solutions. While the CDIO model well-implemented in software development projects, quality management often relied heavily on teachers. Our goal was to develop quality management processes that provide students opportunities to conceive, design, implement, and operate.

Educational Perspective: To achieve this, we identified challenges in theFIRMA projects and implemented changes within the CDIO framework to give students more independence. We commissioned thesis work to enhance project quality. We also adjusted project work requirements and course content to strengthen CDIO standards 3 and 7. Training sessions for second-year project courses were added, resulting in fewer questions and better integration into project work. Mentoring by older students has proven beneficial, leading to faster learning curves. Support is crucial for students to feel comfortable using new skills, so responsible teachers have their workstations in theFIRMA office.

Project Management Perspective: We required students to use either Scrum or waterfall methods for project management, with larger projects using GANTT charts. Supervision is necessary for these additional requirements, so we must be cautious given our limited resources. Enhancing project management practices included developing quality metrics and a manual, revamping the quality assurance team, and updating the project course content. Despite these changes, students do not always apply classroom learning to projects, emphasizing the need for ongoing support and mentoring.

Project Outcomes Perspective: In addition to the commissioned thesis work, we restructured the management team to enhance project quality further, and strengthen ownership, and commitment to quality management. Our experience highlighted the importance of training, mentoring, and support. We revised course content to better support students, introducing time management and scope management for second-year students. These changes aim to improve project outcomes by ensuring students are well-prepared and supported throughout their projects. The focus on quality metrics and continuous improvement processes helps maintain high standards and successful project deliveries.

FUTURE WORK

In the coming summer we will have test runs to see how well our quality metrics work. We are also developing clearer descriptions of our testing and quality assurance process to make it easier for the projects to use the services our Quality assurance team provides.

TheFIRMA learning environment is rather unique, functioning as a software company that provides services to small and medium-sized businesses within the Southwest Finland region. Establishing similar student-led project offices in other countries could significantly enhance collaborative learning and knowledge exchange. Such initiatives would allow students from diverse backgrounds to share best practices, learn from each other's experiences, and contribute to the global advancement of quality management and project development methodologies.

Future studies should investigate the impact of quality management process development on various aspects of student engagement and well-being in project-related courses. Specifically, research should examine whether these measures have positively influenced students' motivation to participate, the number of project hours completed, job satisfaction, stress levels, and perceived sense of accomplishment. Such studies could provide valuable insights into the effectiveness of quality management practices in enhancing student experiences and outcomes across diverse learning environments.

CONCLUSION

This paper has explored the strategic changes implemented to enhance quality management within theFIRMA, focusing on educational, project management, and project outcomes perspectives. By restructuring the management team, developing quality metrics and a manual, enhancing project management practices, and updating project course content, we have significantly improved the quality management processes.

The impact of these changes has been substantial. Students now have clearer guidelines and better support, leading to improved project outcomes and a more effective learning environment. The introduction of new roles, such as the Head of Operations, has fostered ownership and long-term commitment to quality, aligning with the CDIO framework.

Our experiences have highlighted the importance of training, mentoring, and continuous support. While challenges remain, the overall improvements have been positive. The focus on quality metrics and continuous improvement processes has helped maintain high standards and successful project deliveries.

In conclusion, the strategic changes in theFIRMA have enhanced quality management, providing valuable insights for other educational contexts and project-based learning environments. Through ongoing efforts and collaboration, we aim to achieve excellence in both project outcomes and student learning.

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BIOGRAPHICAL INFORMATION

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