PEER LEARNING AND FEEDBACK THROUGH THE CDIO FRAMEWORK IN ENGINEERING EDUCATION

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ABSTRACT

This paper examines how peer learning, knowledge sharing, and peer feedback can be systematically embedded in CDIO-based engineering education through an industry-integrated learning environment. The study presents theFIRMA, a project-based learning environment at Turku University of Applied Sciences, where student teams work on real ICT projects for internal and external industry clients. Grounded in the CDIO framework, theFIRMA integrates professional practice with academic learning through structured project processes, flexible participation, and multi-layered peer learning. The paper describes how mixed-level project teams, student-lead roles, peer-based quality assurance, and student-led Tech Clubs support active learning, integrated skill development, and continuous feedback in line with CDIO Standards 7 and 8. Particular attention is given to how peer learning and knowledge sharing are enabled across different competence levels, supporting both junior and senior students while mirroring professional engineering work practices. Lessons learned from the long-term implementation highlight the effectiveness of mixed-level teams, the importance of structured documentation for knowledge transfer, and the need for curricular integration to sustain peer-led activities. The findings suggest that combining authentic industry projects with structured peer learning and feedback mechanisms creates a learning environment that supports technical competence, professional skills, and readiness for working life. The paper contributes to a practical CDIO-aligned model that can inform the design of scalable, industry-collaborative learning environments in engineering education.

KEYWORDS

R&D learning environment, ICT, multi-layered peer learning, peer feedback, knowledge sharing, Standards: 7 and 8.

INTRODUCTION

Engineering education increasingly emphasizes the development of professional competencies alongside technical expertise. The CDIO framework supports this shift by promoting active and experiential learning environments that integrate technical work with skills such as teamwork, communication, and adaptability. CDIO Standard 7 emphasizes learning experiences in which technical knowledge and professional skills are developed simultaneously, with peer learning and knowledge sharing supporting this integration through collaboration, discussion, and shared problem-solving. Standard 8 highlights active learning approaches in which students engage directly in the learning process, and peer learning and knowledge sharing occur through interaction, joint activities, and the exchange of ideas and experiences.

Knowledge sharing is the intentional exchange of information, skills, and experiences among individuals or groups to support learning, problem-solving, and innovation. It involves not only sharing information but also interpreting and applying knowledge in meaningful contexts through both formal and informal interactions. (Ashikuzzaman, 2025). Knowledge sharing enables individuals to understand, apply, and further develop knowledge, thereby supporting effective decision-making, problem-solving, and performance in organizational and social contexts (Cummings, 2004).

Peer learning is a collaborative learning process in which individuals of comparable status or experience learn with and from one another through ongoing interaction, shared activities, and mutual support (Topping, 2005; Boud & Cohen, 2014). In engineering education and CDIO-based learning environments, peer learning takes place mainly in project and design work, where students learn together by discussing ideas, solving problems, and sharing knowledge. Through these interactions, students develop technical understanding while also practicing professional skills such as teamwork and communication.

Within project-based and CDIO-oriented learning environments, peer learning and knowledge sharing occur through collaborative tasks, shared problem-solving, and continuous interaction among students. This paper presents theFIRMA, a project-based learning environment at Turku University of Applied Sciences (TUAS), as an example of how peer learning, knowledge sharing and peer feedback can be systematically embedded into engineering education. TheFIRMA is an ICT project office in which student teams work on real industry projects, providing an authentic context for collaboration, knowledge exchange, and the development of professional competencies alongside technical skills. The paper examines how industrial collaboration within theFIRMA enhances student learning experiences and supports engineering education through authentic, industry-driven projects.

KNOWLEDGE SHARING AND PEER LEARNING IN CDIO-BASED ENGINEERING EDUCATION

Peer learning is increasingly recognized as a powerful approach within CDIO-based education, particularly when combined with knowledge sharing among students. Research shows that structured peer interaction, such as collaborative laboratory work, project-based learning, and peer feedback, supports the exchange of knowledge, experiences, and perspectives, thereby enhancing engagement, creativity, and knowledge retention. Hansson, Kolmskog, Odemark, and Högfeldt (2011) demonstrated that even small-scale peer learning interventions in laboratory exercises improved student performance and satisfaction without significant additional instructor effort, partly by encouraging students to explain concepts and share problem-solving strategies with one another. Bienkowska and Lovén (2017) integrated peer feedback into a large CDIO leadership course and reported improvements in writing skills, assessment competence, and perspective-taking, while also highlighting challenges such as uneven feedback quality. At the program level, Hussmann et al. (2011) emphasized peer-based evaluation across universities to support organizational learning, knowledge sharing, and continuous improvement.

CDIO Standard 7 (Integrated Learning Experiences) highlights the importance of learning activities that integrate disciplinary knowledge with personal and interpersonal skills. Such experiences are intended to help students practice teamwork, communication, and collaboration while connecting technical content to professional competencies. Peer learning, knowledge sharing, and peer feedback support Standard 7 by requiring students to interact, explain concepts, negotiate solutions, review each other's work, and share expertise within teams. Through these processes, students make both explicit and tacit knowledge visible and accessible to others, while peer feedback helps students reflect on both technical and professional aspects of their work. Learning from and with peers enables students to simultaneously develop technical understanding, interpersonal competence, and feedback skills in an authentic context aligned with professional engineering practice.

CDIO Standard 8 (Active Learning) encourages student-centered approaches that promote engagement, reflection, and hands-on participation. Peer learning combined with knowledge sharing and peer feedback is inherently active, as students contribute ideas, articulate reasoning, and collaboratively construct solutions. Activities such as peer instruction, small-group discussions, collaborative problem solving, and peer feedback create opportunities for students to exchange knowledge and learn through interaction rather than passive reception. These practices align directly with Standard 8 by increasing student participation, motivation, and responsibility for learning while supporting deeper understanding through shared sense-making.

THEFIRMA: A CDIO-ALIGNED INDUSTRY-INTEGRATED LEARNING ENVIRONMENT

Operational Model and Student Participation

TheFIRMA is a student-centered learning environment that operates like a company, offering IT services and development projects for both internal and external clients. Students apply theoretical knowledge to real-world challenges, creating mutual benefits for universities, students, and industry by supporting relevant skill development and collaboration. (Säisä, Määttä & Roslöf, 2017).

Each year, about 200 students take part in theFIRMA as part of their studies. The majority of participants come from the Software Engineering and Project Management (SEPM) competence track, while additional students join from other competence tracks at TUAS. Students work in roles that match their interests, including project management, software and web development, application development, testing, and UI/UX design. This flexible arrangement supports individualized learning paths, skill development, and a smooth transition into professional engineering roles after graduation. (Säisä & Kinnari, 2025).

TheFIRMA operates year-round and does not follow the standard academic schedules of TUAS. Students may join and leave theFIRMA at any time, participate in multiple projects with varying timelines, and completely different workloads that result in varying credit amounts. As a result, theFIRMA functions with continuously changing human resources. While this flexible structure is considered a normal and even beneficial mode of operation, it requires well-defined processes to manage effectively. (Määttä, Roslöf & Säisä, 2018).

Nevertheless, new projects are typically initiated three times per year: in September at the start of the autumn semester, in January at the start of the spring semester, and in May after the official academic year has ended, when students transition to full-time internship work at theFIRMA. If additional projects emerge mid-semester, staffing is reallocated to accommodate them.

At the start of the academic year, approximately 120–130 students participate in theFIRMA projects. The cohort is typically evenly divided between second-year SEPM students entering the competence track and theFIRMA, and fourth-year SEPM students with substantial prior project experience in the environment. In the autumn semester, second-year students are required to complete 81 hours of project work, corresponding to 3 ECTS credits within the 10 ECTS course “Introduction to ICT Projects”. Fourth-year students are required to complete 135 hours of project work, corresponding to 5 ECTS credits, i.e., half of within the 10 ECTS course “Advanced ICT Projects”. At the start of the spring semester, third-year students begin the course “ICT Projects” and complete 108 hours of project work, corresponding to 40% of the course workload (10 ECTS). (Säisä & Kinnari, 2025). Students return the completed hours on a weekly basis. If students complete the required hours before the course concludes while the project continues, they may either continue their participation to earn additional ECTS credits or be replaced to ensure appropriate resourcing.

Project Process and Learning-Oriented Quality Practices

Projects in theFIRMA follow a structured yet flexible process that supports continuity and knowledge sharing across project phases. At the start of each project, a kick-off meeting is organized to align stakeholders on goals, roles, and expectations, and the kick-off document is completed to formally initiate the project. During the first weeks of project work, the project team prepares a project plan that defines objectives, tasks, schedules, and responsibilities. When a project phase ends typically at the end of a semester, the process differs depending on whether the project continues or concludes. If the project continues into the next semester or the project team completes its allocated working hours, a handover report and a handover checklist are completed to ensure the transfer of knowledge and project status to the next team. If the project is completed, the team produces a final report and completes a project closing document to formally conclude the work and document outcomes.

The FIRMA’s project process serves a dual purpose: improving the quality of project outcomes and enhancing student learning. On one hand, it ensures that customers receive high-quality deliverables; on the other, it supports the professional growth of students. Because theFIRMA operates like a small ICT company but is fundamentally a learning environment at TUAS, its process combines both quality assurance and learning objectives. While the quality process focuses on meeting client expectations, the learning process provides students with credits and grades, reinforcing their competence development. At the start of each project, students define specific learning goals, track their working hours throughout the project, and evaluate whether these goals have been achieved at the end. (Määttä et al. 2018). In addition, at the end of the project, students complete self- and peer-assessments that contribute to their project grade, thereby encouraging reflection, responsibility, and active engagement in the learning process. These assessment practices also help make individual contributions visible within team-based work, reducing the risk of unequal participation. By combining documented work effort, self-reflection, and peer feedback, theFIRMA supports fair and transparent assessment while motivating students to actively contribute to shared project goals.

Peer Learning, Knowledge Sharing, and Feedback Practices

A distinctive feature of theFIRMA model is its multi-layered peer learning structure. Project teams are composed of students with varying levels of competence, ranging from junior to senior within the context of higher education, to mirror common practices in professional software and ICT organizations. Within these teams, junior-level students learn through participation and guided practice, while senior-level students take on more demanding tasks and support others by providing guidance and feedback. This structure supports knowledge sharing, peer learning and skill development within the team while preparing students for real-world working environments. For example, during the autumn semester, project teams often include both second- and fourth-year students from the SEPM competence track, enabling learning across different stages of study.

Each project team begins by setting shared learning goals, ensuring that professional development is a collective responsibility. Teams then produce project documentation following theFIRMA's structured process, which is assessed by a dedicated Quality Assurance (QA) team composed of peer students. The QA team provides detailed feedback, enabling project teams to refine their deliverables iteratively. At the end of each semester, students present the project they have done and what they have learned for the other project teams.

In addition to mixed-level project teams, selected advanced-level students take on lead roles in key competence areas, including front-end development, back-end development, UI and UX design, and project management. These student-leads mentor project teams, support problem-solving, and provide guidance and constructive feedback throughout the project lifecycle based on their area of expertise. Student-leads have an open session on weekly basis where students can come to ask questions as needed. They also play a central role in ensuring that teams follow theFIRMA's project processes and quality practices. Furthermore, the leads contribute to the development and continuous improvement of shared guidelines, tools, and working practices, thereby supporting consistency, knowledge sharing, and learning across projects. This mentorship fosters knowledge transfer and supports the development of leadership and coaching skills. In addition, teachers and other theFIRMA experts provide regular support to the teams, for example during bi-weekly Sprint Review meetings, offering guidance, feedback, and professional oversight.

In addition to project-based learning, theFIRMA organizes Tech Clubs as informal peer learning activities in which students share their expertise related to technologies, tools, and working methods with other students. Tech Clubs are facilitated by students and take the form of short information sessions or hands-on workshops, with durations typically ranging from 30 minutes to two hours. These sessions provide a low-threshold opportunity for students to disseminate practical knowledge, introduce new technologies, and exchange experiences across project teams. They contribute to a culture of knowledge sharing, collaboration, and continuous learning within theFIRMA. A few topics from fall 2025 were: “Using computer vision libraries for sports analysis”, “Designing for the Mind: Psychology in UI/UX”, and “From /brrrr to REST API with Go”.

By integrating peer assessment, iterative feedback, mentoring, and peer-led skill sharing, theFIRMA creates an authentic learning environment that closely mirrors professional engineering practice. These mechanisms support active and integrated learning by combining disciplinary knowledge with personal and interpersonal skills, in line with the principles of the CDIO framework. Through continuous peer interaction and reflection, students develop competencies related to collaboration, communication, and professional responsibility while engaging in realistic Conceive–Design–Implement–Operate activities. The multi-layered peer learning and feedback structure underlying these mechanisms is illustrated in Figure 1.

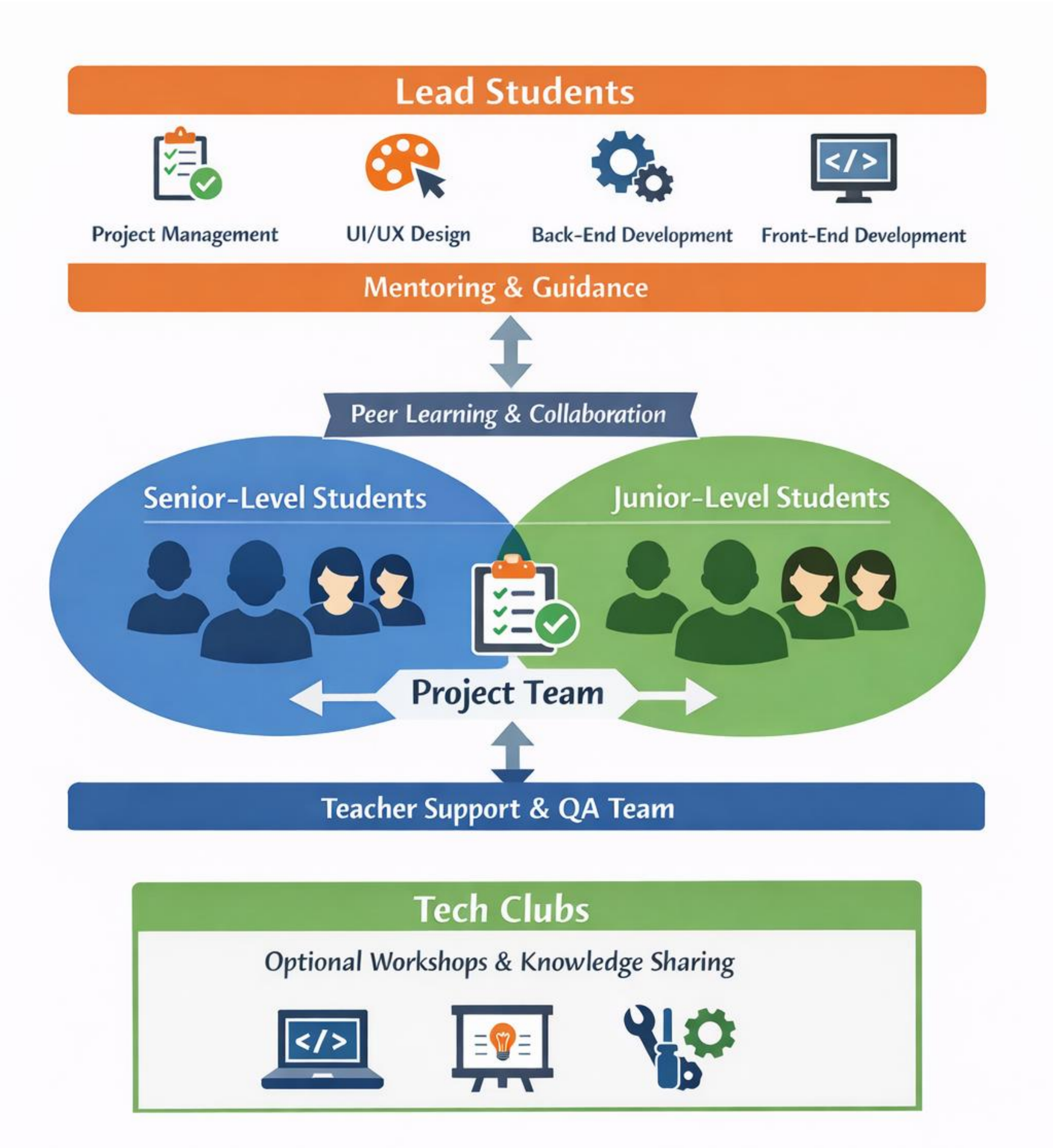

Figure 1. Multi-layered peer learning in theFIRMA

LESSONS LEARNED

TheFIRMA's project process strongly supports project implementation, communication, peer learning, and quality in line with the principles of the CDIO framework. The structured use of project documentation aligns with CDIO's emphasis on integrated and active learning by making project goals, design decisions, and implementation progress visible throughout the Conceive–Design–Implement–Operate phases. Support from the peer-based Quality Assurance team further reinforces this approach by guiding teams in producing clear and consistent documentation, thereby supporting both learning and professional quality standards. When projects continue into the next semester and new students join the team, up-to-date and comprehensive documentation is essential for effective knowledge transfer and continuity, enabling incoming teams to engage smoothly in ongoing CDIO activities.

Mixed-level project teams generally function very well and effectively support peer learning. Senior-level students provide valuable support to junior-level students, for example by mentoring a newly appointed junior-level Scrum Master and helping them develop confidence and competence in their role. However, because multiple projects are available and students apply to three preferred projects, team composition is not always balanced. As a result, some teams may consist primarily of junior-level or senior-level students. In cases where teams are composed mainly of junior-level students, additional support from students in lead roles is often required. This support is typically initiated either once a predominantly junior team has been formed or when the team's Scrum Master signals a need for assistance during theFIRMA's weekly meeting, which is chaired by theFIRMA CEO. All Scrum Masters are required to attend this meeting and provide a brief progress update on their projects. Increased involvement from lead students has proven effective in compensating for uneven team composition and ensuring that learning and project progress are maintained.

A further lesson learned relates to the organization and sustainability of theFIRMA Tech Clubs. Initially, Tech Clubs were arranged on an ad hoc basis when motivated students volunteered to run workshops on technical topics of their choice. While student interest and attendance were consistently high, the number of students willing to act as facilitators remained limited, despite many possessing strong technical expertise. For many students, presenting to peers was perceived as challenging, which raised the threshold for leading a Tech Club and resulted in irregular scheduling. To address this, Tech Clubs have since been integrated into the SEPM competence track curriculum. Third- and fourth-year students are now required to facilitate one Tech Club per year, and all SEPM students are expected to participate in at least three Tech Clubs as attendees. This curricular integration has helped establish a more regular rhythm for Tech Clubs while maintaining strong student engagement, as participation as an audience member has not been a challenge. However, because individual sessions have typically been scheduled separately as students sign up to facilitate a Tech Club, the distribution of sessions has remained uneven. As a result, only a few Tech Clubs are offered at the beginning of the semester, whereas the second half of the semester often includes two sessions per week. To ensure a more balanced distribution, future Tech Club sessions will be scheduled on a weekly basis, for example by designating one day per week for one to two sessions.

Student feedback on the Tech Clubs has so far been collected through informal interviews, as the initiative is still under development. Overall, the feedback has been positive: students report that they find the format valuable and that facilitating a Tech Club increases their confidence in their own expertise. Students have also suggested several improvements, including a predefined schedule and more detailed session descriptions to support informed participation choices. In response, the Tech Club timetable is being redesigned to achieve a more even distribution across the semester. In addition, facilitators will be asked to provide session topics and brief content descriptions earlier, enabling students to assess relevance in advance and plan their attendance accordingly.

CONCLUSIONS AND FUTURE WORK

In summary, theFIRMA represents a CDIO-aligned, student-centered learning environment that integrates real industry projects with structured project processes, flexible participation, and multi-layered peer learning. By operating year-round and accommodating varying student roles, workloads, and competence levels, theFIRMA mirrors professional ICT organizations while maintaining a strong educational focus. Its project processes support both quality outcomes for clients and students' professional development, while peer learning, mentoring, feedback practices, and Tech Clubs foster continuous knowledge sharing and skill development. Together, these elements create an authentic learning environment that supports technical competence, professional skills, and readiness for working life.

TheFIRMA learning environment has been in operation for more than 11 years. During its early years, participation was limited to a few dozen students (Säisä & Kinnari, 2025). As participation has increased to approximately 200 students per year, sustained emphasis has been placed on the scalability of the operating model. Key milestones in this development are reported in “Building Scalable Industry Collaboration in Engineering Education Through the CDIO Framework”, presented at the 21st International CDIO Conference in Melbourne, Australia (Säisä & Kinnari, 2025), whereas the present paper focuses specifically on peer learning and peer feedback.

Peer learning and peer feedback are central to the development of future software engineering professionals because they cultivate the collaborative practices through which software is produced in contemporary organizations. Working with peers requires students to articulate technical reasoning, negotiate requirements and design decisions, and align their work with shared standards, thereby strengthening both disciplinary understanding and professional communication. Peer feedback further supports professional growth by fostering reflective practice: students learn to evaluate artefacts against explicit criteria, to justify and act on feedback, and to provide constructive, actionable input, competencies that are essential in code reviews, sprint reviews, and quality assurance processes. In addition, repeated peer interaction supports the development of professional identity and perceived competence, as students gain confidence by both receiving guidance and contributing expertise to others. Together, these mechanisms help students internalize norms of responsibility, transparency, and continuous improvement that characterize professional software engineering work.

Customer feedback is collected regularly during Sprint Review meetings and again at the final project closing meeting. In addition, customers are invited to complete a structured feedback form that includes background questions, five Likert-scale items, and an open-ended section for written comments. The five Likert-scale items assessed whether clients perceived that (1) the project met the agreed objectives, (2) the deliverables were useful to their organization, (3) the project team was motivated and worked actively, (4) the team had sufficient skills and competence to execute the project, and (5) they would recommend theFIRMA's services to other companies. Based on 40 responses, the results are consistently positive across all items, with average scores ranging from 4.43 to 4.65. Most ratings are 4 or 5, indicating high levels of satisfaction with project outcomes, team motivation, and the usefulness of the deliverables. Ratings below 4 are infrequent, suggesting that negative experiences are rare. Overall, these findings indicate that clients generally perceive the projects as successful, are willing to recommend the services, and view the project teams as motivated and capable.

The outcomes of the learning environment have also gained external recognition. In 2025, the Software Engineering and Project Management competence track and theFIRMA received the PM Academic Award from the national Finnish Project Professionals association, which acknowledged the high quality of project management education and the innovative project-office model and collaboration.

Future work will further develop learning structures that respond to the rapid learning cycles of project-based engineering education. Because students in environments such as theFIRMA acquire new competencies quickly and often transition to employment during the final stages of their studies, team composition and competence levels change continuously. This highlights the need for operating models that are both flexible and clearly structured to sustain learning continuity, support knowledge transfer, and strengthen students' readiness for professional practice in fast-changing project settings.

In addition, future development must address the ongoing transformation of software engineering work driven by advances in artificial intelligence (AI). From a CDIO perspective, AI is reshaping how engineers conceive, design, implement, and operate software systems, and therefore must be explicitly integrated into engineering education. Within the SEPM competence track, this transformation has been addressed by updating course contents to ensure that students learn to use AI tools as an integral part of their engineering workflow across the CDIO lifecycle. At the same time, emphasis is placed on developing strong foundational knowledge and professional judgment, enabling students to use AI tools effectively, critically, and responsibly. Furthermore, the curriculum update planned for students starting in autumn 2026 is in its final stages, with the aim of ensuring that future graduates are prepared for AI-augmented engineering practice. This includes strengthening competencies related to collaboration, communication, ethical awareness, and interaction with diverse stakeholders, all of which are essential in contemporary CDIO-oriented software engineering environments.

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BIOGRAPHICAL INFORMATION

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