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Bridging higher education and practice: a one-week live-case model supporting interdisciplinarity and lifelong learning

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ABSTRACT
Universities face the dual challenge of preparing full-time students for real-world work-life challenges and offering practitioners lifelong learning (LLL) opportunities. The purpose of this article is to develop and assess a small-scale live-case model that focuses on both full-time and LLL students' learning, reflecting on its implications for students, practitioners, and universities to better understand how to simultaneously promote lifelong learning and work-life integration in higher education. The model addresses two key challenges in previous live-case literature: high resource demands and the tendency to focus on organisational rather than individual learning. By focusing on a shared, small-scale live case involving quality improvement in healthcare, the small-scale live-case model offers a resource-efficient and time-bound format promoting mutual learning and engagement between engineering students and healthcare practitioners.

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Case-based learning; lifelong learning; live case; work-life integration; engineering students

Introduction

It is widely recognised that there are a number of factors in contemporary workplaces that contribute to the need to prepare students for a constantly changing labour market, e.g. new technologies, new industries, and increasing complexity in organisations. Such a dynamic workplace implies a need for engineering students to face realistic, complex, and open-ended problems (Leite 2017; Van den Bossche et al. 2004). Problem-based learning (PBL), as 'an educational design that emphasizes active participation, problem-solving, and critical-thinking skills' (Shin and Kim 2013, 1104), is an approach to train students in tackling such realistic problems. In reviews of PBL outcomes, it is argued that this educational approach is more effective than traditional classroom teaching in terms of long-term knowledge retention (Strobel and van Barneveld 2009; Yew and Goh 2016).

Live cases as a means for interdisciplinary learning

Within PBL, the live case is an established method to create a work-life connection for students while at the same time supporting their learning by applying theoretical concepts in practice. There are, however, challenges. First, live cases are often relatively large-scale projects that span entire courses and/or semesters and are perceived as resource-demanding (Elam and Spotts 2004; Schonell

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and Macklin 2019), and thus become resource-intensive both for the university's teachers and for the practitioner with the need in question. Second, live cases often focus on individual learning for students and for the organisations that participate, and not on their potential to also support lifelong learning (LLL) for individual employees from the organisation involved. The positive effects of live cases for external organisations are usually described from the perspective of the organisation, in the form of, for example, operations assessments and access to students as potential future employees (Elam and Spotts 2004; Roth and Smith 2009; Schonell and Macklin 2019). Thus, there is an unrealised potential to conduct live cases in a way that both benefits the students and contributes to LLL.

Moreover, when live cases combine multiple groups of learners, they open up an arena for interdisciplinarity. As argued by Kolmos et al. (2024), PBL is strongly linked to interdisciplinary learning, yet many applied projects in engineering education remain within single disciplines. Integrating different disciplinary backgrounds and also different student groups – such as full-time engineering students and practitioners in healthcare – adds new layers of knowledge exchange, practical application, and boundary-crossing collaboration, as well as exposure to the healthcare sector as a possible future employer. In a traditional live case, students work directly with an organisation *represented* by a practitioner to solve a real problem, which gives students direct access to a 'real' needs owner (Burns 1990; Elam and Spotts 2004). Live cases have been reported to have positive effects for students' learning, both in terms of understanding the course content and in terms of developing communication and interaction skills (Roth and Smith 2009). The organisations involved also report positive experiences, such as an influx of new ideas and being provided with in-depth analyses of current problem areas (Roth and Smith 2009). However, in a continuously changing and developing work life, not only future employees (i.e. students) but also current employees need to develop their competencies continuously (Boud and Solomon 2001).

Supporting professional development through lifelong learning

As the world changes, so does the world of work, and thus it 'is altering enterprises' skills requirements and hence producing a skills mismatch when skills needs are not properly addressed through the education system and lifelong learning' (World Employment and Social Outlook: Trends 2023, 27). As a result, a lot of focus in society in general, and at universities specifically, has been on supporting LLL for practitioners to continuously develop and adapt their knowledge and competences (Aspin and Chapman 2000). There is no consensus on how to define lifelong learning in the literature (Alla 2024; Tuyaerts et al. 2025); however, in this article, LLL comprises the continuous development of knowledge and skills throughout a professional career, closely integrated with work practice and aimed at supporting learning in one's professional role. Naturally, LLL can be supported in various ways, under the headings of work-integrated learning as a 'curriculum design in which students spend time in professional, work or other practice settings relevant to their degrees of study and to their occupational futures' (Smith 2012, 247), or as executive education addressing upcoming needs, e.g. for cross-border management skills (Scalberg 2013).

With pressure to deliver more teaching to address both students' and practitioners' needs, it would be beneficial to explore ways of teaching to fulfill this end. An interdisciplinary approach that brings together diverse learners and connects theoretical knowledge with real-world workplace challenges is one possible way forward (Kolmos et al. 2024). However, current research highlights several challenges that still limit the full potential of such approaches. Existing live-case models have been criticised for being resource-intensive for both educators and practitioners (Elam and Spotts 2004), and for mainly supporting learning at an organisational rather than an individual level for participating practitioners (Roth and Smith 2009; Schonell and Macklin 2019).

Challenges of PBL and the need for alternative educational models

Reviews of implementing interdisciplinary projects in practice show that PBL in engineering education often remains confined to narrow course settings, which can uphold disciplinary silos instead of bridging them (Chen, Kolmos, and Du 2021; Helle, Tynjälä, and Olkinuora 2006). Further, although PBL is widely promoted as a promising path to develop interdisciplinary competence among engineering students (Hadgraft and Kolmos 2020; Van den Beemt et al. 2020), students frequently encounter challenges when working in interdisciplinary teams, especially when it comes to building shared ways of working and mutual understanding across fields (MacLeod and van der Veen 2020; Richter and Paretti 2009; Routhe et al. 2021). Recent work also points out that there is still a limited understanding of how student team projects can best be designed to prepare engineers for real interdisciplinary collaboration (Beddoes 2020).

Against this background, the purpose of this article is to explore how interdisciplinary project structures can support knowledge integration across contexts by developing and assessing a small-scale live-case model that combines full-time students and lifelong learners, and to reflect on its implications for students, practitioners, and universities to better understand how to promote interdisciplinary collaboration, lifelong learning, and work-life integration in higher education simultaneously.

The purpose is addressed by the development of a live case integrating two groups of learners: full-time engineering students enrolled in a mandatory master's level course and healthcare practitioners participating in a professionally endorsed LLL course. The Master's Programme in Quality and Operations Management is part of Industrial Engineering and Management, one of the most attractive engineering programmes in Sweden, which is consistently ranked among those with the highest admission scores and application rates. This reflects a motivated student group with a combined technical and managerial profile. The LLL participants are healthcare professionals with extensive work experience, often working in managerial or development-oriented roles. While most have a nursing background, physicians and other professions are also represented. Their course, Quality-Driven Organisational Development (15 ECTS), runs over 1 year at a quarter of full-time and focuses on quality improvement in healthcare. The two courses are delivered in parallel in both time and location by the same teaching team. This shared structure enables synchronisation and joint activities between the courses, creating opportunities for interaction and knowledge exchanges between the two student groups. We argue that the model presented in this article contributes a less teacher-resource-intensive case model, with the main part of the work carried out at a concentrated pace for a week.

With our example, we aim to contribute to this field by showing a model for how interdisciplinary elements can be created for engineering students. In doing so, we build on existing research on interdisciplinarity in engineering education (Borrego and Newswander 2010; Kolmos et al. 2024; MacLeod and van der Veen 2020) by answering calls in the literature for more concrete examples of how interdisciplinary project-based formats can be designed to overcome disciplinary silos (Chen, Kolmos, and Du 2021; Kolmos et al. 2024) and to better connect PBL principles with authentic contexts and multi-professional collaboration (Illeris 2010; Hadgraft and Kolmos 2020). By addressing known barriers such as resource demands (Elam and Spotts 2004) and the need to extend learning beyond organisational benefits (Roth and Smith 2009), this study contributes to the ongoing discussion on how PBL and live cases can be more effectively aligned with contemporary requirements for lifelong, work-integrated, and interdisciplinary education in engineering and healthcare.

Conceptual background

The purpose of this article is to explore how a small live-case model can support interdisciplinary learning by combining full-time students and lifelong learners. This section gives an overview of two main areas from earlier research. First, it describes different types of interdisciplinary projects in engineering education. Second, it describes the use and challenges of live cases in teaching. In the last part of this section, the conceptual model used in this article is presented.

Different types of interdisciplinary projects

Interdisciplinary projects in engineering education are designed to let students work across disciplinary boundaries in order to solve complex and realistic problems. Such projects often combine knowledge from different fields and help students develop the ability to integrate multiple perspectives (Borrego and Newswander 2010; Kolmos 2021). In the literature, interdisciplinary projects are often described as either narrow or broad (Kolmos et al. 2024). Narrow interdisciplinarity means collaboration between disciplines that share similar knowledge paradigms, for example different branches of engineering. Broad interdisciplinarity refers to work across more distant fields, such as engineering and social sciences, where students must cross epistemological and cultural boundaries. Kolmos et al. (2024) highlighted a typology for engineering education that is based on three forms of interdisciplinarity: multidisciplinarity, interdisciplinarity, and transdisciplinarity (Borrego and Newswander 2010; Keestra and Menken 2016; Klein 2010). Multidisciplinarity means that different disciplines contribute side by side without much integration. Interdisciplinarity goes further by combining perspectives into a joint solution, while transdisciplinarity also includes collaboration across academic and practice boundaries, sometimes leading to new knowledge fields (Kolmos et al. 2024). These distinctions are central, as they connect to earlier attempts to categorise project work in engineering education.

Several typologies of project types have been suggested in previous literature. For example, De Graaf and Kolmos (2003) distinguish between the assignment-based project, where the problem and methods are predefined, the subject project, where either the subject or the problem is fixed but students choose the other, and the problem project, where the problem defines the choice of methods and disciplines, often leading to interdisciplinarity. Helle, Tynjälä, and Olkinuora (2006) proposed another classification: the application project where students apply existing techniques, the project component with a broader and more interdisciplinary scope, and the project orientation as the main driver in the curriculum with strong student freedom. These frameworks mainly describe single-team projects. More recent work has pointed to the need for updated models that also capture collaboration in networks of teams and across broad disciplinary boundaries. Building on this, Kolmos et al. (2024) presented a typology of interdisciplinary project types in engineering education along two axes: the level of interdisciplinarity, ranging from disciplinary to broad interdisciplinary, and the team structure, ranging from discipline projects to inter-team projects, contextual projects, system projects, mixed micro projects and M-projects (e.g. Megaprojects). Together, these various categorisations show how interdisciplinary collaboration can be organised in different ways, which also underlines the importance of considering the specific knowledge bases that students and practitioners bring into such projects.

In our case, interdisciplinarity is created through the meeting of two different knowledge domains: the master's students' theoretical knowledge on quality management and the practitioners' practical knowledge about improvement work in healthcare. This combination represents a bridging of improvement knowledge and professional knowledge, both of which Batalden and Stoltz (1993) highlight as necessary for driving change in healthcare. Traditionally, professional knowledge has been the basis for improvement, for example medical knowledge or nursing expertise. More recently, improvement knowledge focusing on stakeholder analysis, systems thinking and process management has proven equally important for the sustainable development of healthcare systems (James and Savitz 2011; Smith et al. 2019). Bringing these two perspectives together in one project thus provides an example of how interdisciplinary collaboration can create new opportunities for learning and for developing solutions, showing how interdisciplinary collaboration can lead to outcomes that are not achievable within a single knowledge domain.

The use of live cases in teaching

Live cases have been widely applied in education, for example in business ethics (Raman, Garg, and Thapliyal 2019), marketing (Cummins and Johnson 2023; Elam and Spotts 2004), management (Roth and Smith 2009; Schonell and Macklin 2019), healthcare (McLean 2016), and engineering (Leite 2017). The learning is typically designed for one particular student group (Leite 2017; Raman, Garg, and Thapliyal 2019; Roth and Smith 2009; Schonell and Macklin 2019), and runs during one course and semester (Elam and Spotts 2004; Markulis 1985; Roth and Smith 2009). An exception is

Elam and Spotts (2004), who provide an example of involving students from three different courses in one live case, where the students are given different tasks depending on their course.

The literature describes multiple benefits and challenges of live cases from students', teachers', and client organisations' (practitioner) perspectives (see Table 1). Examples of benefits include that it is a flexible teaching method suitable for group work (Elam and Spotts 2004; Raman, Garg, and Thapliyal 2019; Schonell and Macklin 2019), that students are generally engaged and get to apply theoretical knowledge in practice while practising teamwork, time management, and communication skills (Cummins and Johnson 2023; Elam and Spotts 2004; Leite 2017; Raman, Garg, and Thapliyal 2019; Roth and Smith 2009; Schonell and Macklin 2019), and that the client organisations get enhanced insights into their operations (Elam and Spotts 2004; Markulis 1985; Roth and Smith 2009; Schonell and Macklin 2019). Some challenges are that students may perceive the workload to be high (Elam and Spotts 2004), that preparation and performance are time-consuming for teachers (Elam and Spotts 2004; Schonell and Macklin 2019), and that clients need to be committed and available to the students (Roth and Smith 2009).

Overall, using PBL in general and live cases specifically alters the roles of students, teachers, and – in the case of live cases – client organisations. As stated by Yew and Goh (2016, 76) regarding the role of teachers:

> A tutor – also known as a facilitator – acts as a guide to scaffold students' learning, particularly in the problem analysis and reporting components of the PBL tutorial, as well as facilitate students' inquiry paths as they make sense of their ideas through discussion and sharing.

Table 1. Examples of benefits and challenges for students, teachers, and client organisations.

Students	Benefits	Face real-life contexts and problems, and apply theoretical knowledge to current issues	Elam and Spotts (2004); Leite (2017); Raman, Garg, and Thapliyal (2019); Roth and Smith (2009); Schonell and Macklin (2019)
		Generally high engagement and performance levels	Elam and Spotts (2004); Markulis (1985); Schonell and Macklin (2019)
		Interaction with practitioners and access to organisation	Markulis (1985); Raman, Garg, and Thapliyal (2019); Roth and Smith (2009); Schonell and Macklin (2019)
		Applying project, office, and team management skills, as well as interpersonal and business communication skills	Cummins and Johnson (2023); Elam and Spotts (2004); Leite (2017); Raman, Garg, and Thapliyal (2019); Roth and Smith (2009); Schonell and Macklin (2019)
	Challenges	Reluctance to criticise the client organisation	Markulis (1985)
		Difficulty in understanding the client's context	Raman, Garg, and Thapliyal (2019)
		Teamwork	Elam and Spotts (2004); Schonell and Macklin (2019)
		Time management, high workload	Elam and Spotts (2004)
Client organisation	Benefits	Unbiased and 'free' operations assessment Gain new/deeper knowledge about operations	Elam and Spotts (2004); Markulis (1985); Roth and Smith (2009); Schonell and Macklin (2019)
		Get to know potential new employees and get insight into what is taught	Roth and Smith (2009)
	Challenges	Transparency of information from client organisations	Markulis (1985); Raman, Garg, and Thapliyal (2019); Roth and Smith (2009)
		Insufficient client commitment and availability Assignment of contact persons	Roth and Smith (2009)
Teachers	Benefits	Flexible design Efficiency through group grading	Raman, Garg, and Thapliyal (2019); Elam and Spotts (2004); Schonell and Macklin (2019)
	Challenges	Difficulties in delimiting the case Get the students on the right track without providing reading instructions	Raman, Garg, and Thapliyal (2019)
		Preparation and performance are time-consuming Integration of students and courses	Elam and Spotts (2004); Schonell and Macklin (2019)
		Finding and selecting case organisations	Elam and Spotts (2004); Roth and Smith (2009)
		Provide reasonable expectations for scope and output to the client organisation	Roth and Smith (2009)

Moving to the specific context of this study, students on both master's and LLL courses join forces with the potential for mutual support and learning, where students' and practitioners' complementary knowledge bases allow them to become tutors of each other in the live case.

Method

To simultaneously develop and assess a small-scale model for live cases, an action research approach was applied (Jacobs 2019), as action research is useful in education where improvement is part of teachers' professional responsibilities (Corey 1954). In an action research project, data collection, analysis, and continued development unfold over time. Thus, the study is of a processual nature (Pettigrew 1997; Voss, Tsikriktsis, and Fröhlich 2002), and to capture this, there is a need for data collection that takes place at several points in time. Further, to gain contextual insights, the study is based on a single case study design (Eisenhardt 1989), which is based on data collected from a sequence of events over time.

Data collection

In the live-case model studied in this article, the two student groups are engineering students with limited knowledge and experience of the healthcare context, but with improved knowledge, and healthcare practitioners enrolled in an LLL course with extensive professional knowledge but limited improved knowledge. To get multiple perspectives on the live cases as a learning activity, data were collected from three groups of stakeholders: full-time engineering students, healthcare practitioners, and teachers. The student groups participating in the study were engineering master's students taking a course in quality and operations management and healthcare managers taking an LLL course in quality management. Multiple data collection methods were applied, as outlined in Table 2. The survey data were collected by the two authors who were not involved as teachers on the master's course. The two authors who were involved as teachers collected data from the focus groups and jointly reflected on the various steps in the live-case teaching activity.

To capture the student perspective in a processual manner, data collection was conducted through a pre-case survey, a post-case survey, the course evaluation questionnaire, reflection papers, and the case reports submitted. The pre-case study focused on the students' perceptions of different sectors as future employers (e.g. manufacturing, construction, finance, and healthcare). The post-case study included the same questions to allow for comparisons, but it also included additional questions about perceived benefits from the small-scale live case as well as suggestions for improvements.

The reflection papers were submitted individually and focused on key learnings from the whole course, of which the live case was one part. Focusing on the actual content of the cases, data were captured through the case reports. In total, 20 live cases were carried out by ten student groups (each with five or six members).

Turning to the practitioner's perspective, there was a need to understand the challenges and opportunities when working practically with quality improvement in healthcare to support the

Table 2. Overview of data collection methods, participants, and response rates.

Perspective	Data collection method	Participants and response rates
Full-time students	Pre-case survey	Students, n = 53, response rate 51%
	Post-case survey	Students, n = 53, response rate 70%
	Live-case reports	Student groups, n = 10
	Reflection papers	Students, n = 53, response rate 100%
	Course evaluation questionnaire	Students, n = 53
Practitioners and LLL students	Focus group	Healthcare practitioners, alumni, n = 4
	post-case survey	Practitioners; LLL students, n = 23, response rate 100%
Teachers	Meeting notes, reflections	Faculty members*, n = 4
	focus group	

*Faculty members involved in some of the university's courses with mixed student groups (students and practitioners).

LLL students in planning and participating in the live case. Thus, data were collected through a focus group with Quality and Operations Management alumni now working in healthcare, focusing on their experiences of what key contributions their knowledge base allowed them in their daily practice. To capture the LLL students' actual experiences of the small-scale live case, a post-case survey was conducted. Examples of questions were: 'What was most valuable in the live-case set-up?', 'Do you have any suggestions for improvements?', and 'What is your overall rating of the live-case set-up?' (Likert scale, 1–5).

Finally, the teacher's perspective was captured in two ways. First, to aid in the design of the small-scale live-case model, a focus group was held with a group of faculty members who were experienced in teaching mixed groups (students and practitioners) but were not involved in the small-scale live cases studied here. The focus group was based on an affinity diagram (Shahin, Arabzad, and Ghorbani 2010), with a structured brainstorming process on the question 'What are, in your opinion, the key success factors for integrated teaching of practitioners and full-time students?'. Second, the teachers involved in the live cases had regular meetings and reflection sessions during the entire process, from design to evaluation and improvement, which were captured in meeting notes.

Data analysis

Data analysis was continuous throughout the study, with the qualitative parts of the pre-survey data being thematically analysed beforehand to serve as input for the design of the live cases. Further, data from the focus group with teachers running other courses with mixed student groups were analysed and thematised by the participants using the affinity diagram method (Shahin, Arabzad, and Ghorbani 2010), and were used as input when developing the small-scale live-case model. As the authors were involved in different parts of data collection, they acted – despite joint data analysis – as external investigators in the analysis of certain data (Eisenhardt 1989), thus enhancing confidence in the findings by allowing for complementary insights (Meredith 1998).

The quantitative analyses are based on survey data collected over two consecutive course iterations and rely on relatively small samples. The results should therefore be interpreted with caution and are intended to provide complementary and indicative insights rather than to support strong or generalisable conclusions. In the first year of implementation, the pre-case survey was completed by 26 students (9 women and 17 men), while the post-case survey was completed by 37 students (17 women and 20 men). In the second year, the corresponding numbers were 25 respondents in the pre-case survey (8 women and 17 men) and 14 respondents in the post-case survey (4 women and 10 men). Differences in response rates between pre- and post-case surveys, particularly in the second year, limit the possibility of making robust inferences about changes over time. Accordingly, the quantitative findings regarding students' interest in non-profit sector work are presented as exploratory and are interpreted in conjunction with the qualitative data.

An independent two-sample *t*-test and multiple regression analysis were employed to test the difference between the pre-case and post-case surveys. The software SAS JMP v.18 was used to perform the statistical analysis and data visualisation. Specifically, the multiple regression analysis was used to test the mean difference of a selected dependent variable while controlling for the differences in students' characteristics in the sample. The two-sample *t*-test was used to test the mean difference of a dependent variable of interest before and after exposure to the small-scale live case.

Results

This chapter presents the findings from the study and presents both the small-scale live-case model named SMILLA and students', practitioners', and teachers' perceptions about the live-case model.

SMILLA – the live-case model

The small-scale live-case model developed, focusing on learning for both engineering students and LLL students (i.e. healthcare practitioners), was labelled SMILLA: SMall-scale live cases to Integrate Lifelong Learning and Access to work-life examples (see Figure 1).

The live cases are part of two courses that run in parallel: one in the first semester of a Master's Programme in Quality and Operations Management and one in an LLL healthcare manager course (quality-driven organisational development). The entire live case is performed during one study week in six main steps:

1) With the purpose of unifying language as well as developing a common ground, both the engineering students and the LLL students watched the same video lectures on (a) basics of cyclic improvements, (b) a practical improvement example, and (c) instructions for the live-case model.
2) Guided by their teachers, the healthcare managers develop and document problem formulations related to a current issue in their workplaces.
3) The documented problem formulations are handed over to a group of engineering students by a teacher, with possibilities to ask clarifying questions.
4) The engineering students act as project leaders and work on these problems in groups of five or six students during one work week.
5) After the week, there is a course conference in which the projects are presented and results are handed back to the LLL students.
6) After this week, the LLL students will continue the project work by using the input on possible solutions as a kick-start and inspiration.

In the following, these steps will be elaborated on and exemplified.

The set-up of the small-scale live case

The small-scale live case is a shared mandatory improvement project that the healthcare managers perform as part of the 'putting theory into practice' logic within the LLL course. The live case entails an improvement project based on an organisational-related problem experienced by customers/patients in the LLL students' workplace. To utilise competences and expertise from the organisation, the LLL students were encouraged to involve colleagues and patients/customers from their organisation in the project. The problem formulations are developed as part of the LLL course, under

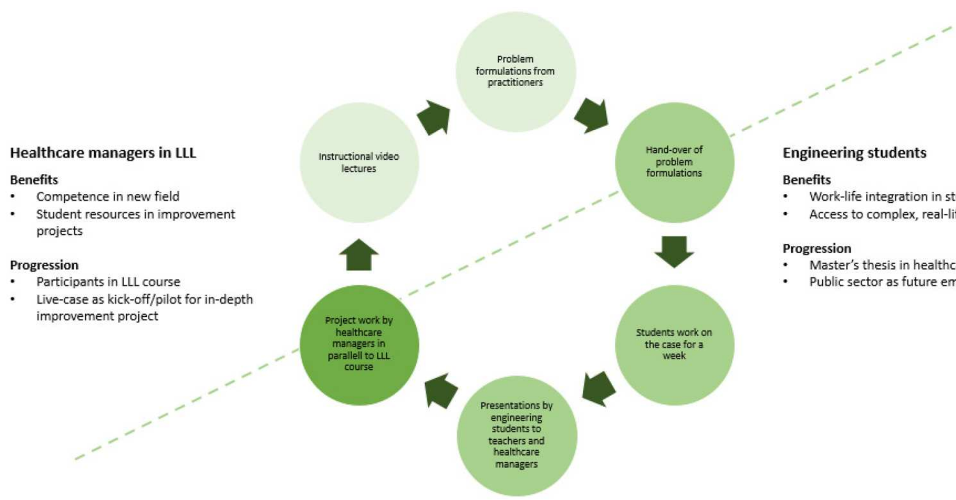

Figure 1. SMILLA: SMall-scale live cases to Integrate Lifelong Learning and Access to work-life examples.

supervision and in discussion with the other LLL students on the course. The supervision has a designated time slot of about three hours in the LLL course's schedule before the problem formulations are finalised. This time slot has been important to support interdisciplinary communication, especially targeting challenges to describe problems in a way that could be understood by engineering students lacking healthcare experience.

To formulate the problems, a cyclical improvement model, define, measure, analyse, improve and control (DMAIC) was utilised. Note that an additional 'L' for learning was integrated into the model to ensure reflections on the project work itself. A problem description was documented using a structured template with fixed headings and shared with the engineering students (see Appendix). Due to the difference in student count in the two courses, each engineering student group had two live cases each.

To properly prepare the engineering students for the live case, each case was introduced by one of the teachers along with an overview describing some of the healthcare sector's logic and challenges and the LLL students' problem description. After familiarising themselves with the problem and context, in the middle of the week, the LLL students were interviewed to provide the engineering students with a more profound understanding of the context and challenges experienced. Thereafter, the engineering students work with the cases for the remaining part of the week. Compared with other cases (paper-based about fictive industrial organisations), the engineering students interacted more with the teachers about the work and on understanding the healthcare context, which was new to most of them. A brief example of a finished live case is outlined in Figure 2.

To conclude the engineering students' part of the live case, their case report is orally presented, attended by the other engineering student groups and the LLL student who presented the problem. In this session, the students get feedback on interpretations, understandings, and their suggested ways forward. After the presentations, the LLL students continue to work with the cases in their own organisation for approximately one year. The LLL students' part of the live case ends with public presentations open to stakeholders (managers, researchers, heads of regional development, and course colleagues) and the engineering students to further deepen the work-life integration.

Perceptions of the live-case model

Engineering students' perceptions

The engineering students had little prior experience working with professionals in healthcare. Many described the collaboration as challenging but rewarding. They were surprised by how complex even small changes could be in this context, and how limited the use of systematic improvement tools appeared to be. Several reflected on the lack of process thinking and structure, which they

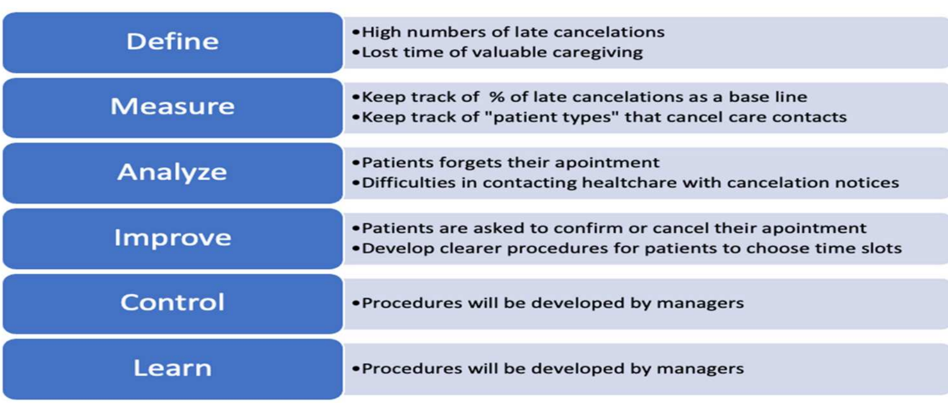

Figure 2. Example of a finished live case with the problem of 'Late cancellations in a rehab unit'.

had assumed was more widespread. At the same time, many practitioners were perceived as open, committed and appreciative of the students' input. One student noted: 'They were very prepared and wanted our opinions'. A recurring observation was the difference in how problems were defined and communicated. Students reported that it was sometimes difficult to understand the practitioners' framing of the issue, or that the practitioners' expectations differed from their own. This led to some confusion and required adjustments in how students approached the task. One student commented: 'We realised we had interpreted the problem description wrong after talking to them'. These differences, however, also offered opportunities to reflect on how professional backgrounds shape ways of thinking.

The chance to work on a real case was frequently described as motivating. Meeting the practitioners in person or through interviews helped students better understand the setting and feel more confident about their contributions. Several mentioned that structured methods, such as DMAIC or PDCA, helped them make sense of the problem and avoid jumping to solutions too quickly.

Importantly, many students experienced the assignment as meaningful beyond the academic setting. They described a sense of making a real contribution, and of seeing how their skills could be applied in areas they had not previously considered. As one student expressed it: 'I would like to have a position where I feel I make a difference … I now realise there are a lot of areas where I, as an engineer, could offer my help and expertise'. Another noted: 'Earlier I felt most tools had been explained in the context of manufacturing … The focus on healthcare and quality has made me more interested in the public sector'.

Several students suggested improvements to the assignment, such as reducing the number of cases per group, allowing more time and ensuring clearer communication about expectations. Despite these challenges, the students described the experience as both instructive and personally relevant. A summary of the engineering students' perceptions can be found in Table 3.

LLL students' perceptions

The professionals participating in the course had limited or no previous experience working with engineering students. Several expressed surprise at how quickly the students understood their problems and how engaged they were during the interaction. Many mentioned that the students asked

Table 3. Responses to the post-survey after the first course round by the engineering students.

Survey question	Theme	No. of responses	Illustrative quotes
Surprising elements in contact with practices	Lack of structured improvement or quality focus	7	'The simple tools we use (e.g. fishbone diagram) were unknown to them'
	Communication issues and expectation gaps	5	'We realised we had interpreted the problem wrong'
	Different mindsets and perspectives	6	'How differently you can look at problems with different backgrounds'
	Value seen in student contributions	4	'That we actually can give them some helpful input'
Successful aspects of the assignment	Real-life/practical application	10	'Interesting to work with a real case and give advice in a field we don't know'
	Practitioner interaction and interviews	5	'Interview with the contact person'
	Structured problem-solving (DMAIC, PDCA)	4	'Strict focus on DMAICL so one doesn't jump to solutions too early'
Suggested improvements	Reduce the scope to one case per group	8	'Workload was heavy with two cases'
	Extend the time for the assignment	5	'Make the project longer – needed much more time'
	Clarify the task, expectations, and roles	4	'More communication about expectations to the practitioners'
	Improve presentation and interaction methods	3	'Workshops instead of presentations could give more value'

relevant and thoughtful questions, and that they seemed genuinely interested in the topics. One professional commented on what was most surprising: 'Their quick insight into what the problem was. Their good ability to familiarise themselves with a context that they were completely unfamiliar with'. One commonly reported value, in the post-survey, of the task was the opportunity to explain a complex clinical challenge to someone outside the healthcare sector. This required the professionals to clarify their thinking, which led to new reflections about their own work. As one participant described: 'Having to explain the problem to them. [It] requires afterthought and carefulness'. The written feedback provided by the students was also appreciated.

The professionals highlighted that the students' suggestions and references were useful for developing their projects further. Some professionals noted that the students' suggestions often included perspectives that differed from those typically found in clinical settings, which encouraged new ways of thinking. One participant wrote: 'The proposal on how to proceed with our project [was the best], and the references they suggested will make our work easier'. Several participants appreciated that the students applied structured problem-solving methods, such as PDSA or DMAICL, and commented that this supported their own learning. One person noted: 'It helped me start thinking early about how to structure the project'.

Some challenges were also raised. A few participants had expected more contact with the students and suggested that more time for dialogue would be beneficial. There were also requests for clearer instructions, more time to prepare and better scheduling. A summary of the LLL students' perceptions can be found in Table 4.

Teachers' and faculty's perceptions

A helpful input given during the focus group with faculty was the suggestion of 'scaffolding' the engineering students' case work by using a template for documentation and reporting their work. Consequently, such a template was developed and later used by the engineering students. The template was deemed helpful by both the teachers and the students to frame and limit the scope of the case.

The teachers involved in the teaching activities linked to the live cases perceived it to be a fulfilling way to teach and a good way to stay updated on contemporary healthcare challenges. An unexpected challenge arising during the live cases was the anxiousness of the engineering student about 'what contributions they could possibly make', and extra supervision outside of the scheduled hours was needed to support the students. To better support the students in future rounds of the live case, some sample projects could be distributed at the start to illustrate the students' possibilities to

Table 4. Responses to the post-survey after the first course round by the LLL students.

Survey question	Theme	No. of responses	Illustrative quotations
Most valuable aspects	New perspectives	9	'Integrating 'engineering thinking' with clinical experience'
	Useful feedback	6	'Good feedback on how to continue the work'
	Clarifying the problem	6	'Having to formulate your problem so that someone outside understands'
	Structured methods (PDSA/ DMAICL)	3	'Learning from working with the models'
What surprised them most?	Student engagement and curiosity	9	'They seemed genuinely interested'
	Student competence and quick understanding	7	'Relevant work in just a few days'
	New insights from dialogue	3	'Short notice'
Suggestions for improvement	Clearer structure and communication	6	'They gave our task another dimension'
	More/longer student interaction	5	'More time with the students'
	Technical/scheduling issues	4	'Technology that messed up'
	More critical dialogue	1	'Wanted more questioning'

deliver valuable suggested solutions. Moreover, a reflection was that the live cases enhanced both student groups' learning on both specific (e.g. cyclical improvement) and generic work-life skills (e.g. handling incomplete information, teamwork, and presentation skills). Although the LLL students developed well-defined problem descriptions, the process would benefit from a longer time frame. One suggested improvement for future rounds is to start the course earlier in order to allow more time for problem formulation.

Learning outcomes from interdisciplinarity in the live case

The live case brought together students from different educational and professional backgrounds, creating a setting in which collaboration across disciplinary boundaries was a central part of the learning process. For the engineering students, the interdisciplinary context contributed to learning by challenging taken-for-granted assumptions about how problems are defined, structured and addressed in practice. Interacting with healthcare professionals made them realise the contextual complexity of clinical work and the constraints under which improvement efforts take place.

As previously described, students reported surprise at the limited use of systematic improvement tools and at the difficulty of implementing even small changes, which prompted reflection on the transferability of engineering methods across sectors. Differences in how problems were communicated and understood required the students to adapt their analytical approach, clarify assumptions and refine their use of structured problem-solving methods such as DMAIC or PDCA. In this sense, interdisciplinarity supported learning not only about applying tools, but about when and how such tools need to be translated, negotiated and contextualised in dialogue with other professionals from other disciplines. In addition, the live case provided opportunities for study visits and direct exposure to healthcare settings that many engineering students had not previously encountered. This was described as a valuable complement to the industry visits that are more common in engineering programmes, as it broadened students' understanding of where and how engineering competencies can be applied. Experiencing an unfamiliar organisational and professional environment further supported reflection on contextual constraints, stakeholder roles and the situated nature of improvement work.

For the LLL students, learning from interdisciplinarity was closely tied to articulating and reframing their own practice-based knowledge. Explaining complex clinical challenges to engineering students required them to make implicit assumptions explicit, clarify problem boundaries and reflect on their own ways of working. This process was frequently described as valuable in itself, as it led to new insights into the nature of the problems and how they might be approached. Exposure to engineering students' structured methods and external perspectives supported learning related to project structuring and early-stage problem formulation, and encouraged alternative ways of thinking about improvement work. Several participants highlighted that the students' questions, feedback and references added new dimensions to their projects and supported further development beyond the course.

The engineering students' perceptions of work in non-profit sectors

To analyse whether or not participating in the live case influences engineering students' willingness to work in non-profit sectors like healthcare, two surveys were conducted: one pre-live-case study and one post-live-case study.

Responses to the question 'How likely is it that you would apply for a job in non-profit sectors?' showed a shift in the mean score from 2.27 (pre-case, N = 26, whereof women n = 9 and men n = 17) to 2.76 (post-case, N = 37, whereof women n = 17 and men n = 20), indicating an increase of 0.49 units. An independent two-sample *t*-test assuming equal variances confirmed that this difference was significant ($p = 0.0296$, df = 61), indicating an association between exposure to the live case and higher reported interest in non-profit sector employment. For more information, see Figure 3.

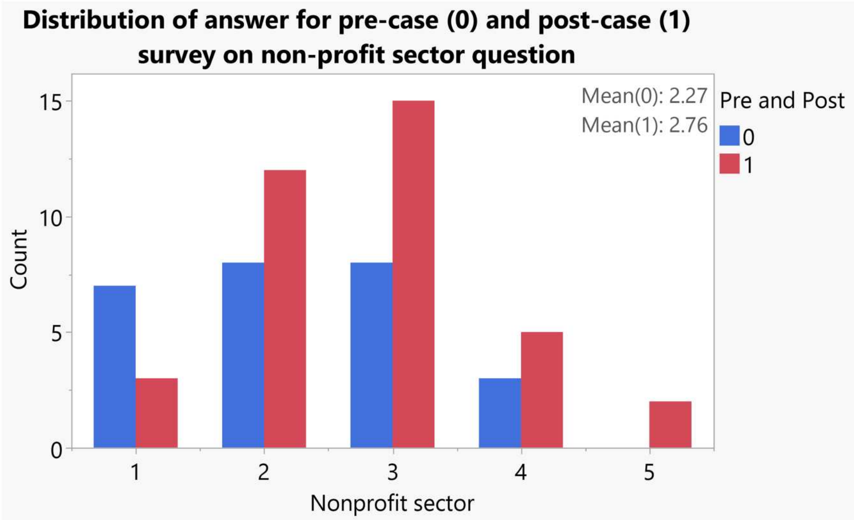

Figure 3. The distribution of answers for pre-case and post-case in the non-profit sector.

To further explore what influences students' perspectives on non-profit sector employment, a multiple regression analysis was conducted with two independent variables: participation in the live case (binary continuous variable coded as X1 = *PrePost* {0 = pre-case, 1 = post-case}) and gender (sex at birth) (category dummy-coded as variable X2 = *Gender* {'male', 'female'}). The results are given in Figure 4.

Including gender as an additional predictor nearly doubled the explained variance, increasing the model's R^2 from 5.7% to 12%. The results show that, when controlling for case participation, female participants scored on average 0.5 points higher than their male counterparts on the non-profit sector interest variable both before and after the live case. This difference was statistically significant ($p = 0.0441$), suggesting that gender may be associated with differences in students' reported interest in non-profit sector work. A visualisation of the above analysis is provided in Figure 5.

In order to strengthen the previous results, data from another student group taking the course 2 years after the first were collected and analysed. The same settings were used (pre-case N = 25, whereof women n = 8 and men n = 17; post-case N = 14, whereof women n = 4 and men n = 10). Of the three identical analyses on the same two variables, one shows a similar pattern to that observed in the previous analysis, i.e. whether participants' gender (sex at birth) is associated with differences in responses to the question concerning interest in non-profit sectors, when controlling for the PrePost variable. Including gender as a predictor is associated with a notable increase in the explained variance, with the model's R^2 increasing from 0.005% to 18%. The results of the multiple regression analysis are presented in Figure 6. Holding the PrePost variable constant, female participants scored on average 0.96 points higher than male participants on the non-profit sector interest variable. This difference was statistically significant ($p = 0.011$).

Indicator Function Parameterization

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	2.0921316	0.20809	10.05	<.0001*
PrePost	0.4295566	0.248789	1.73	0.0894
Gender[Female]	0.5116199	0.248789	2.06	0.0441*

Figure 4. Results from the analysis using multiple regression for the first course round.

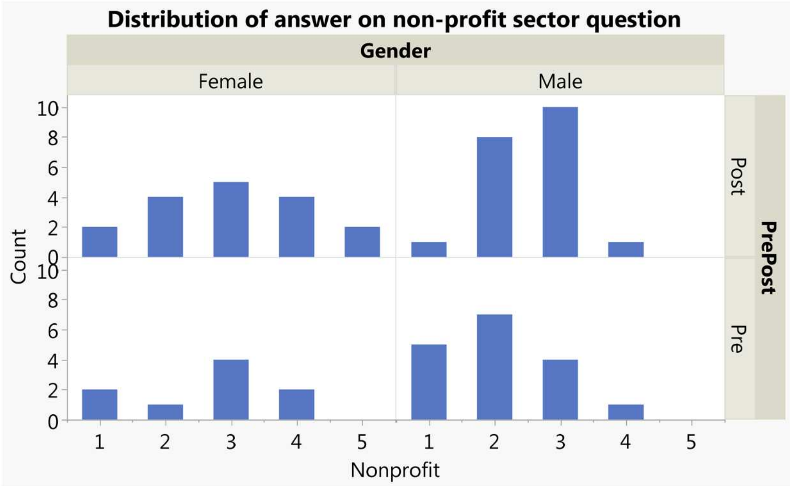

Figure 5. Distribution of answers by Gender and PrePost variables.

Indicator Function Parameterization

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	2.1876047	0.244319	8.95	<.0001*
Pre-Post	0.0552764	0.350421	0.16	0.8756
Gender[Female]	0.9606365	0.35705	2.69	0.0111*

Figure 6. Results from the analysis using multiple regression for the third course round.

Discussion

Emanating from the aim to develop and assess a small-scale live-case model from three perspectives – students, practitioners and universities – the SMILLA model offers a hands-on approach to integrating LLL and work-life examples in higher education. A key contribution, compared to most live-case models, is the short timeframe (Elam and Spotts 2004; Markulis 1985; Roth and Smith 2009). Moreover, challenges in accessing live-case problems from client organisations (Elam and Spotts 2004; Roth and Smith 2009) are overcome by embedding the case within the LLL course, where practitioners are required to identify and work on a problem from their own organisation. This embeddedness not only facilitates access but also ensures relevance and authenticity.

Operationalising transdisciplinary learning

The model developed also operationalised and exemplified transdisciplinary learning (Borrego and Newswander 2010; Klein 2010) by facilitating collaboration not only across academic disciplines but also between academia and professional practice. The integration of students' theoretical knowledge with practitioners' experiential insights reflects the dual knowledge domains described by Batalden and Stoltz (1993) – improvement knowledge and professional knowledge – both of which are argued to be essential for driving sustainable change in healthcare. This merging of perspectives goes beyond traditional multidisciplinarity, where disciplines contribute side by side, and instead fosters joint problem-solving and knowledge creation. Furthermore, the SMILLA model operationalises the typology of Kolmos et al. (2024) by situating the project within a system-level structure that includes multiple actors – students, practitioners, and faculty – working across disciplinary and institutional boundaries. This aligns with the concept of system projects and mixed micro projects (Kolmos et al. 2024), where collaboration occurs in networks rather than isolated teams. The model's dual impact – organisational benefits for the client and individual competence development for practitioners – extends the traditional scope of live-case models, which often focus solely on organisational outcomes (Roth and Smith 2009; Schonell and Macklin 2019).

Students' learning outcomes and transformative experiences

The students' initial anxiety about contributing to an unfamiliar healthcare context underscores the perceived distance between their disciplinary training and the lived realities of healthcare professionals. Having a real client also appeared to increase their commitment, as students expressed a strong desire to deliver results that the practitioners would value. Through the live-case experience, students gained confidence and developed long-term competencies such as time management, contextual communication and dealing with incomplete data – outcomes that are consistent with research on problem-based learning (Strobel and van Barneveld 2009). Their ability to contribute meaningfully by combining theoretical frameworks with practical insights illustrates the transformative potential of interdisciplinary collaboration. Furthermore, the survey results indicate that participation in the live cases is associated with an increased interest in non-profit sector employment among students. The analyses also suggest that gender may play a role in students' interest in non-profit sector work. In particular, female students tended to report a higher level of interest in non-profit sector employment than male students, on average, when controlling for participation in the live case. These findings should be interpreted with caution given the relatively small sample sizes and varying response rates, and are best understood as indicative patterns rather than definitive conclusions. Importantly, the model also addresses previously reported challenges in live-case pedagogy, such as transparency and access to data (Markulis 1985; Raman, Garg, and Thapliyal 2019), by leveraging the commitment of public sector employers and the non-competitive nature of the healthcare context. Ethical considerations were managed by selecting projects that did not directly involve patients, ensuring responsible engagement.

Having completed the live case, the students had experienced making a contribution by combining their 'theoretical' knowledge base with the experience-based knowledge base of the practitioners. In other words, experiencing in practice the merging of the two kinds of knowledge that are argued to drive healthcare improvements (Batalden and Stoltz 1993). Aligned with much of the research on PBL, the students' experienced learnings of a more long-term nature (see e.g. Strobel and van Barneveld 2009), such as time management, communication in a new context, and insufficient background data. Moreover, this article also provides an example of how to expose engineering students to the healthcare context, thus operationalising the framework of Batalden and Stoltz (1993) through the live case, which can be categorised as the mixed micro project as described by Kolmos et al. (2024) (see Figure 7). In line with Kolmos et al. (2024), the core of the mixed micro project live case is not primarily the success of the proposed solutions, but rather the collaborative learning it fosters. The opportunity for engineering students to engage with real-world problems and workplaces – through e.g. study visits and on-site data collection – is more important. Moreover, the learning objectives of both courses are based on their mutual dependence within the live case, which further strengthens motivation for knowledge-sharing and joint learning (Kolmos et al. 2024).

The findings suggest that the interdisciplinary set-up of the live case amplified several of the learning outcomes commonly associated with live-case pedagogy. In line with previous research, students developed skills related to communication, teamwork, and time management through interaction with a real client (Elam and Spotts 2004; Roth and Smith 2009; Schonell and Macklin 2019), but the presence of a second student group from a different professional context added an additional layer of learning. Specifically, students were required to explain, translate and adapt their knowledge to peers with different backgrounds, which supported a deeper understanding of both the problem context and their own disciplinary tools. This aligns with earlier findings that

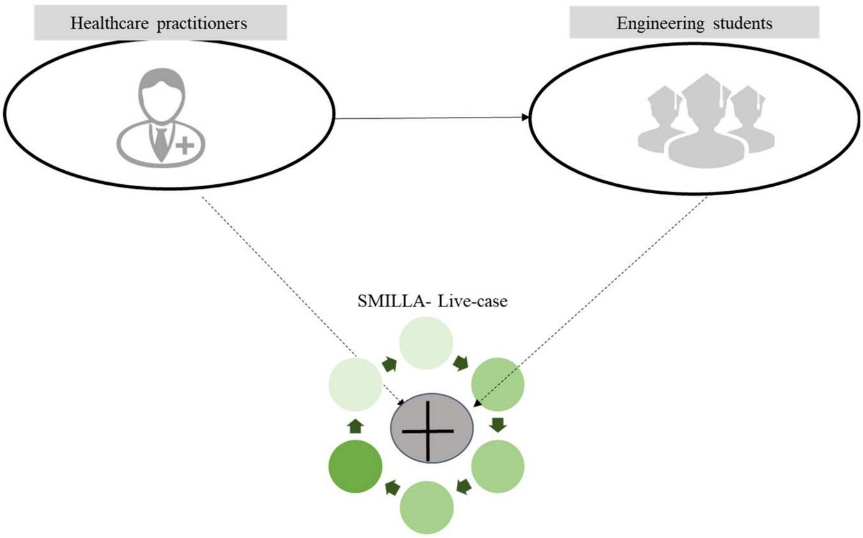

Figure 7. The SMILLA live case model as an operationalisation of merging two knowledge domains. (Inspired by Kolmos et al. (2024) and Batalden and Stoltz (1993)).

interaction with practitioners and access to organisational contexts enhance student learning (Markulis 1985; Raman, Garg, and Thapliyal 2019), while also extending these outcomes by emphasising mutual learning between student groups. As such, interdisciplinarity functioned not only as a contextual feature of the case, but also as an active driver of learning through dialogue, clarification, and perspective-taking.

Practitioner-centred benefits and organisational relevance

The present examples of live cases have mainly addressed benefits and challenges for the client organisation at an overall, organisational level. Here, benefits include operational assessments (Elam and Spotts 2004) and contact with potential employees (Roth and Smith 2009). In this study, as the practitioners also take part actively in the live cases as part of their own competence development, the benefits are at a more operational and individual level, where student input aids in the development of the case problem that will later be further developed by the practitioners themselves. Thus, the benefits perceived by the practitioners are more focused on hands-on help in moving forward with an improvement project. The SMILLA cases have not been perceived as challenging in terms of limitations in transparency from the client organisation (Markulis 1985; Raman, Garg, and Thapliyal 2019; Roth and Smith 2009) or having difficulty with assigning contact persons (Roth and Smith 2009). Overcoming these previously reported challenges is largely due to the practitioners' employers already having made a commitment by enrolling their employees in the LLL course, and perhaps also due to the problems coming from a public sector context with no competitive aspects to consider when sharing data. Naturally, ethical issues could be delicate, but in this case, the projects were chosen to avoid including sensitive patient data and other types of confidential or sensitive information that would be subject to secrecy regulations.

Implications for faculty and course design

For teachers and university faculty, one contribution is the description of a live-case model that facilitates co-creation and exchanges of knowledge between engineering students and practitioners. Another area of interest to explore in further investigations is that it was not only perceived that teachers' workloads increased (Elam and Spotts 2004; Schonell and Macklin 2019); it was also perceived that, upon further development, the model could lead to shared workloads among all parties involved. As argued for PBL that teachers become 'a guide to scaffold students' learning, particularly in the problem analysis and reporting' (Yew and Goh 2016, 76), in this type of case the role of being a guide extends to all parties: the teachers act as overall guides on a theoretical basis, process, and reporting, but the practitioners also guide the students in learning about their day-to-day context, and the students guide the practitioners (LLL students) in the theoretically based problem-solving models. Another benefit for teachers and faculty is, naturally, that the fragmentation of teaching assignments is avoided by working with integration between LLL courses and regular university courses, and that the continuous inflow of new problems for the live cases ensures teaching relevance.

Limitations and future research

While the SMILLA model demonstrates promising outcomes, its application in a single, favourable setting limits generalisability. It should be acknowledged that this specific setting has favourable characteristics, as the model is piloted in an existing LLL course, including case work for the practitioners. Thus, future research should explore its adaptability in other contexts and assess it quantitatively. Additionally, a further exploration of how the model supports transdisciplinary knowledge creation could enrich the theoretical understanding of interdisciplinary engineering education.

Conclusions

This article addresses two issues that are discussed extensively at universities: (1) how to provide – and find resources for – LLL courses, and (2) how to prepare students for complex, open-ended problems. The small-scale live-case model offers a resource-efficient learning activity for both traditional and LLL courses. In summary, the differences compared to standard live-case models are that it is strongly delineated in time, and that it focuses not only on the students' learning but also on the practitioners' learning. It can be argued that the practitioners' improvement knowledge has developed in parallel with improvements in the students' practical knowledge. One conclusion from the study is that it is possible to run a live case in a very short time (1 week in this case), but this requires support for the students in terms of managing expectations from all parties and providing 'scaffolding' in terms of report templates and supervision.

Beyond these practical considerations, the model also highlights the potential of interdisciplinary collaboration. By bringing together engineering students and healthcare practitioners, the live case enabled the integration of theoretical improvement knowledge with professional expertise from clinical settings. This interplay across disciplinary and sectoral boundaries not only enriched the learning experience for both groups, but also created new opportunities for transdisciplinary knowledge creation. The LLL students perceived the involvement of students as an eye-opener and as beneficial in providing an external perspective that supported their continued improvement project, especially in terms of lingering in the problem definition phase and being better prepared for continued improvement work. The study thus contributes to the ongoing discussion on how higher education can support both lifelong learning and interdisciplinary competence development in ways that are resource-efficient and relevant to contemporary work-life challenges.

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Appendix

Problem description template (as used by the healthcare practitioners)

As the first step in the improvement work to be carried out in this course, it is essential to understand and describe the current state. This description will serve as a foundation for the student group that will continue working on your problem within the framework of the Master's programme at Chalmers (SMILLA). During the second course session, you will present these descriptions to each other and provide and receive feedback in groups.

Use the headings below as guidance and feel free to expand upon them. If you have references or reports that may be useful, please include or attach them. Ensure that you describe your problem in a way that can be understood by external readers, i.e. without excessive abbreviations or technical jargon.

The project/description may be carried out together with colleagues in the course. Write down your project as far as you know it at this stage.

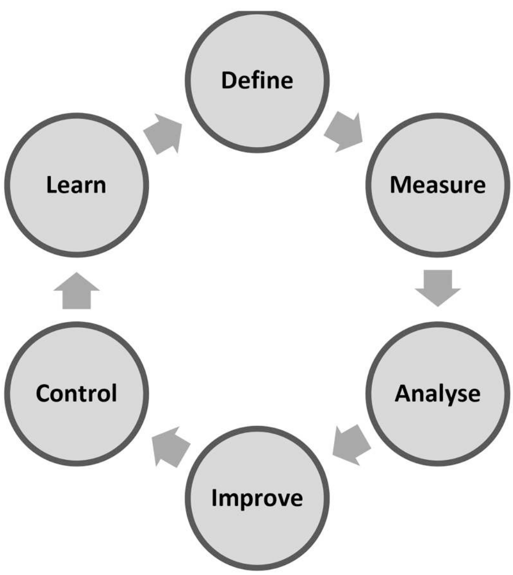

Figure A1. Steps followed in the DMAIC methodology.

DEFINE

Formulate the vision. *What overarching customer/patient problem can the project help address or manage? This may be a broader issue, where your local contribution constitutes part of the improvement.*

Formulate the problem you can influence. What goal or challenge will you tackle? How does it link to the overall vision? It is important to understand the problem even if your project is primarily of an implementation nature.

Describe the process in which the problem exists. What does the process/flow look like? Can you provide a graphical illustration? Which organisations are involved and affected? Which professional roles? How do you know there is a problem? What is not working or needs to be mapped?

Even if the problem is not directly patient-related, justify why the project is important for the customer/patient/relatives. What will improve for these groups if you identify and implement improvements? Can you involve these groups in defining the problem/process to ensure focus on those we serve and their perspective on the issue?