Enabling problem-based education in collaboration with manufacturing companies

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Abstract

A focus on problem-based education is crucial as students need to complement academic knowledge with real-life projects. Several concepts in problem-based education have been tried over the years with focus on preparing students for working life. This paper aims at creating a list of recommendation on how to enable learning in problem-based education. To do so, we collect data in a problem-based course at Mälardalen University in Sweden. The resulting list of recommendations contributes with guidelines on what to do, and what to avid to successfully enable learning in problem-based education.

Keywords: Problem-based Learning, Production System Development, Education

Introduction

Problem-based courses has been on the agenda as an opportunity for real-life situated learning for many years (Brown Sr. and Brown Jr., 1997). Literature claims that problem-based learning is an important enabler of the way Operation Management (OM) students transition to working life, yet executing this type of courses places strains on actors compared to traditional courses at universities (Brown Sr. and Brown Jr., 1997; Nielsen, 2004; Bennis and O'Toole, 2005; Bak and Boulocher-Passet, 2013; Gorman, 2018). Therefore, *the purpose of this paper is to present a list of recommendation to enable learning in problem-based education with real-life manufacturing company student projects.* This paper analyses problem-based education from the perspective of three actors, students, companies and facilitators in an OM university course for engineering students. To reach this, we formulate the following research question: *how can challenges in problem-based education be approached to enable learning in OM course?* For the purpose of this paper, problem-based education means that students gain professional experience in a real-life setting to improve abilities to solve complex interdisciplinary problems and to learn how to communicate and collaborate with companies (Brown Sr. and Brown Jr., 1997; Nielsen, 2004). Teachers in problem-based courses has a facilitating role rather than exclusively giving lectures (Gorman, 2018), subsequently teachers are referred to as facilitators in this paper.

In problem-based courses, facilitators and companies experience challenges in time-consuming preparations starting months before the course starts, including the demanding phase of defining and scoping student projects, and setting up schedules (Gorman, 2010,

2011; Bak and Boulocher-Passet, 2013; Gorman, 2018). The actors, having intense interactions throughout the student project, are interdependent which requires the facilitator to manage the collaboration between companies and during the course (Nielsen, 2004; Bak and Boulocher-Passet, 2013; Gorman, 2018). Assessing the problems and challenges associated with problem-based leaning is an open issue in preparing students for working life (Bak and Boulocher-Passet, 2013). Contributing to existing problem-based literature, this paper presents three novel contributions by a list of recommendations providing, firstly approaches to managing problem-based courses, secondly present what to avoid in problem-based courses. Finally, the contributions are based on data collected from a course in OM.

Problem-based education in literature

In the review of problem-based education by Gorman (2018) indicate that the facilitators require a longer period of preparations for the course, for instance by undertaking a solicitation phase. Finding challenging and new student projects requires redoing the solicitation phase each year which is time-consuming compared to standardised lectures in other courses (Gorman, 2018; Konrad, 2018). Several contacts with companies need to be established, especially as the rate of accepted student projects from companies can be as low as 60% (Gorman, 2018). However, well-established industrial contacts are likely to come back for several years with new student projects easing up the workload for the facilitator. The student projects are scoped to include both the industrial partner's criteria, academic requirements and to make sure that the student projects are attainable for the time given in the course. Preparations are also made to ensure that student groups are formed and assigned to a case (Bak and Boulocher-Passet, 2013; Gorman, 2018).

According to Gorman (2018), the actors involved in a field-based course, students, company and facilitators experience challenges and benefits from participating in courses with real-life student projects. Companies that are unable to sustain the level of involvement and support required for the student project is risking the student project to miss the intended project or learning goals (Bak and Boulocher-Passet, 2013). Nevertheless, the learning experience from a student and academic perspective is still valuable (Gorman, 2018). The student projects ambiguity is considered to be a risk in that students can experience that the project is overwhelming and require more time than the course stipulates (Bak and Boulocher-Passet, 2013). A rigours project selection process done by the facilitator give the students direction on how to approach the student project. With further guidance on standardised documentation, grading and continuous facilitation, these risks can be limited. Facilitation can include supporting student groups to narrow the scope and clarify goals of the project (Gorman, 2018).

In problem-based education, the facilitator experience a risk in student projects as course ambiguity can results in an intense level of student group supervision, resulting in time-consuming activates (Bak and Boulocher-Passet, 2013). A release of time and resource of the facilitator can be achieved when student projects are self-managed and supported by the facilitator. Thereby being a learning opportunity in project management (Gorman, 2018). Furthermore, facilitators perform a tedious company solicitation and promotion, which requires business area acquaintance and contacts (Bak and Boulocher-Passet, 2013). Approaching companies on-site and creating groups of industrial partners as a long-term strategy can minimise the risks involved with solicitation. Indeed, resource shortage in the course can be addressed by increasing the credit scope of the course (Gorman, 2018). Finally, from a company perspective, there are risks associated with course participation as the resources required are challenging to estimate, especially in regards to the requirements of academic courses and expectations of student skills (Bak

and Boulocher-Passet, 2013). Generating a schedule and assigning supervisors, often experts, is challenging in a problem-based student project. The facilitator carefully communicating expectations to the company, such as course outline and schedule, can limit the aforementioned risks (Gorman, 2018).

Methodology

The purpose of this paper was fulfilled by analysing course evaluations and performing observations before, during and after a problem-based course. Initially, a literature review was conducted by searching databases such as Scopus and Emerald Insight with keywords like; 'teachings and learnings AND organisational management', 'Field-based education' and 'problem-based education AND organisational management'. Data was collected from problem-based course industrial excellence at Mälardalen University (MDH) in Sweden from year 2018 by observations, investigating course evaluations, facilitator's self-evaluation as well as conducting field studies by writing notes when visiting companies. The data was analysed in a seven-step process including both individual analysis as well as joint analysis sessions, see Figure 1. The purpose of step one through three was for the authors to individually analyse the data in terms of categories, perceived course dynamic based on the categories and to identify interrelationships of the aforementioned. Finally, in step four through six the authors compared results, presented an initial set of recommendation and supported findings with literature. The analysis was scrutinised iteratively to ensure reliability in the list of recommendation.

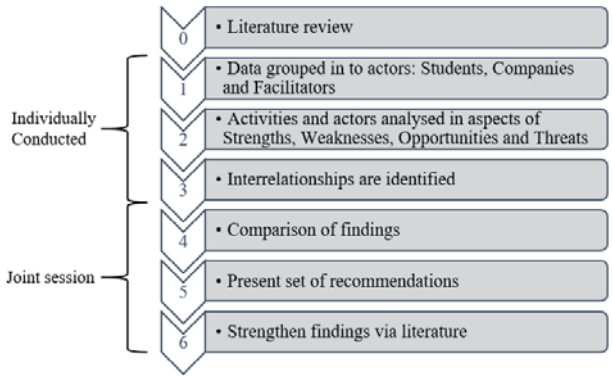

Figure 1 - Analysis Process

Mälardalen University

MDH is a public university college in Sweden, located in the cities of Eskilstuna and Västerås. MDH has a student body of 16 000 students in undergraduate programs ranging from two to five years of education. In the field of OM, MDH is concerned with education and research necessary for developing new products, services and production systems in a technically leading, economically viable, and environmentally sustainable way. MDH offers its production engineering students problem-base courses related to the development of production systems. In addition, students of this program take OM courses that help contextualise the development of production systems during their education. This program requires all production engineering students to pass the problem-based course industrial excellence. In this course, students meet twice a week for three-hour sessions during 16 weeks. On average 20 students, in their fourth or fifth year of education, attend the course every year. Student composition includes diverse nationalities with about a third of students from abroad and students with different background (product or production specialisation). Course industrial excellence has been

offered for five years in its current form.

Problem-based education at Mälardalen University

The problem-based course industrial excellence includes collaboration with five to six companies ranging in size from small to large manufacturing companies. The aim of this course is to give students a deeper understanding of how to apply knowledge from the field of OM and improve industrial processes. The course includes three tasks: understanding the competitive priorities reflected in a production system, analysing the steps involved in the development of a production system, and proposing an improvement to a production system based on Discrete Event Simulation. In addition, students analyse literature in areas manufacturing strategy, production system development and discrete event simulation in OM individually, and participate in a four student project during the course. Company representatives and course facilitators select and define a project and a schedule of at least three on-site student meetings is decided. In this project, student teams visit a company on at least three occasions to understand the problem, collect data and clarify or present partial results.

During the execution of the course, course facilitators provide lectures, supervisions, and feedback supporting students in their project. Students visit the company continuously and the companies are expected to support the students throughout the course. Furthermore, the facilitator require the students to present project status in set milestones as well as facilitating the projects and company collaboration.

At the end of the course, student teams submit an academic report to course facilitators and companies, and present their results to other student teams and companies. Collaboration with companies occurs in three phases including preparation, execution, and follow up. These phases occur prior, during, and after course industrial excellence respectively, and include different activities for each of the actors involved in the course (i.e. students, companies, and facilitators).

Analysis of problem-based education

This section describes the activities of the three actors in course industrial excellence (i.e. students, course facilitators, and companies) during the preparation, execution, and follow-up phases. In addition, this section presents a classification of strengths, weaknesses, opportunities, and strengths as perceived by students, course facilitators, and company representatives according to Osita et al. (2014). Correspondingly, strengths are characteristics of the course that gives it advantages over other courses to prepare engineering students for real life problems. Weaknesses are characteristics of the course that places the course at a disadvantage relative in preparing engineering students for real life problems. Opportunities means elements in the environment that the course could exploit to its advantage in preparing engineering students for real life problems. Finally, Threats are elements in the environment that the course could cause trouble in preparing engineering students for real life problems. In Table 1 - 3, the SWOT's are presented by abbreviations, thus only S, W, O and T are seen in the table. Each activity can contain one or all of the SWOT's depending on its analysed impact on the course.

Preparation phase

For the facilitators, the preparation phase consumes a generous amount of time and effort, similar to that of companies. Initially, visiting companies to find projects entails several meetings with company representatives that are either known by the facilitator, or new companies. As some visits ends without a project being formulated, this activity requires several iterations. However, time spent on visits ensure that the students projects are

tailored to the course and that the projects are indeed a real issue for the companies. Facilitators and company representatives analyze that these projects may be achieved within the duration of the course. Evaluation of student projects is a time-consuming, but the benefits are front-loaded activates and, the companies are able to see the project from a new angle by iterating cooperatively with the facilitator. The activities in the preparation phase are on the other hand, experienced as demanding and time-consuming. For instance, taking time off daily operations to define a student project, collect data, and later supervise students and evaluate results of the student project. Time spent on the preparation activities ensure clearer problem definition, purposefulness of visits and a manageable student project as well as student in-depth problem solving. Additionally, the iterative approach of defining the problem together with the facilitators is a learning experience regarding the company's ability to form student projects, see Table 1.

Table 1 – analysis of Preparation phase in problem-based education

	Activity (Preperation)	***SWOT***
Facilitators	Visit companies	S – Tailored project, that is a real issue for the company (also Gorman, 2018) W – Time consuming task (also Gorman, 2018) O – Allow students to experience real life situation, continuous collaboration opportunity T – Problem to find the right fit between company and student needs (knock on many doors before getting a yes) (also Gorman, 2018)
	Evaluate student project	S – Introduces an academic perspective to projects (also Gorman, 2018), (PSD, MS, DES) T – Scoping student project can be time-consuming and require several iterations (also Gorman, 2018)
	Help company collect data	S – Ensures that correct data is collected W – Defining suitable data can be challenging and companies may not know how to do it or may not have the resources O – To get to know the company for future editions of the same course T – Company can be reluctant to give data
	Manage company drop-outs	T – Drop-outs can cause last-minute projects that are not fully defined
	Define problem of interest by iteration	S - Front load activities and allow students to focus on learning and not scoping W – Time consuming O – Gain awareness of the type of competence required by industry T – As a result of a lack of time, facilitators may not be able to help companies scope problems to the right fit
	Divide students into homogenous groups	S – Groups are evenly distributed based on background, grades, and gender; Provides a diverse work environment W – Limited information on student skills O – Evaluation of students is simplified T – The respective problem-based projects requires well performing groups
	Define subjects of individual assignments	S – Make sure that there is a synergy between academic knowledge and a practical problem W – Time needed to collect relevant articles O – Give student groups insight on various topics
Companies	Find suitable student project	S – Tailored project, that is a real issue for the company (also Gorman, 2018) W – Time-consuming task (also Gorman, 2018) O – Allow students to experience real life project (also Gorman, 2018) , gain outside perspective on production issues, continuous collaboration opportunity (also Gorman, 2018) T – Can be challenging to find a project that meets the competence of students, time frame for the course, and not overly complex (also Gorman, 2018)
	Assign a supervisor	S – An assigned supervisor can support student projects (also Gorman, 2018) W – Time needed to put in to project (also Gorman, 2018) O – Evaluate and meet students as candidates for thesis and future work T – May not have sufficient time to supervise (also Gorman, 2018)
	Initial data collection	S – Support to get better end results and reduces the time students may otherwise spend collecting data O – Ensure usability of results and help scope the project T - Can be time-consuming
	Define problem of interest	S – Company can revise project with facilitator to find appropriate level W – The companies may oversimplify the problem O – New insights gained on own project T – In dynamic environments and highly dynamic projects there is a threat that the problem scoped in the beginning is no longer relevant, and therefore under-prioritized
	Develop a schedule for student visits	S – Companies have control of time spent and ability to schedule activates (also Gorman, 2018) W –Might vary between companies to a large extent in terms of accessibility O – Visits by students are planned and purposeful
Students	Ask for course references from former students	S – Former students with positive experience support new student to apply for course T - Student experience might be negative (due to high workload in course) thus projecting a negative view of course.

Execution phase

The role of the facilitator comes with challenges in managing the diversity in student

projects as well as addressing company-student collaboration issues. Time spent on this effort have benefits in academic results, solution fit to companies as well as in evaluating students. A set of course milestones support facilitating the student projects in a structured and controlled manner. Preparing students for the project creates a common view of the project, and how to approach the problem but also how to communicate with companies. Preparation by lectures and, especially, the individual assignment give the student a preconception of the topic at hand. The individual assignment, being a literature review on a topic related to the project, is demanding but the knowledge is useful for both project execution and report writing, see Table 2.

Students report that course industrial excellence is challenging and time-consuming when compared to courses that do not include a problem-based approach. For instance, *"the workload was very high"*, and *"[the course is] tough, but the experience could not be provided anywhere else"*. In addition, students report that the course is worthwhile as it leads insights about problems faced by manufacturing companies, and collaboration with companies in solving problems. Working closely with the companies is identified as an opportunity to learn about problem-based projects and how to manage, re-define, and execute the projects at companies. However, contact persons at the companies can be difficult to contact due to hectic schedules Presenting results to a company provide students with communications skills and students "*have learned how to communicate results directly to a company […]"*. Companies can however, fail to attend the university presentations and focus on on-site presentation at the company. Student report benefits in learning self-management and group work, *"You learned to plan and work on your own and in a group"* and to manage project setbacks, *"I learned how to make the best out of a situation"*. Furthermore, defining and adjusting the problem is a challenging task for students, but it is nonetheless an opportunity to learn about how production system-related problems are managed in real-life. Additionally, the opportunity to meet and learn about future employers is expressed as a strengths of the course, for instance, *"I would recommend it [the course] for learning about simulation and get company contacts"*, as one student said. Finally, students express that "*the teachers [facilitators] helpt us a lot*" and *"the course was structured and planned"* giving the students an opportunity to focus on project delivery.

From an academic perspective, students found that the assignments in the course add to the demand and time limitations of the course. However, improvement in writing and presenting complex problems in an academic way are identified as important learnings from the course. For instance, *"I learned a lot about manufacturing strategy, production system development and discrete event simulation. […] I learned to manage my time better and where my flaws are when delivering and finishing assignments, that is very valuable to me"*. Additionally, thesis preparation and managing a project are perceived as major learning outcomes. Student's experiences show that there is *"a lot of time spent on writing"* in the course, but the assignments contributed to the student's *"improvement on writing a literature review and connecting it to analysis"* and to "*learn how to write a report and prepare for thesis*". The assignments furthermore contributed to learning by *"[…] discussions among the group and teachers [facilitators] to get insight and perspective"*. For details, see Table 2.

The company's participation is planned to minimise the companies time in the course by only having three mandatory student meetings. This does however require the companies to make preparations prior to the meetings. Companies experience that the planned meetings are controllable, but some projects require adjustments and, the supervisor need to add more time to the project. On the other hand, the opportunity to evaluate students as future employees or potential thesis workers is seen as a major benefit

when collaborating continuously with students in several course activates. As a result, master theses can be developed as a continuum on the student's project, allowing the company to continue working with the students that performed satisfactorily. Finally, the execution phase provide the company with insights on student ability to understand and solve complex production system problems, see Table 2 for details.

Table 2 – Analysis of Execution phase in problem-based education

	Activity	***SWOT***
Facilitators	Confirm student projects with companies	S – Securing final projects and ensure that resources are in place W – Time-consuming task due to many projects O - Increase collaboration with companies, companies learn about academic viewpoint in project (also Gorman, 2018)
	Act as student project facilitator	S – Quality in student project execution is increased W – Many issues have to be addressed in project groups (also Gorman, 2018) O – Gain insight on student project management and ability to adjust projects that are off-track (also Gorman, 2018) T – Time-consuming task
	Supervision for individual and group assignments	S – Set deadlines facilitates report and assignment deliveries, progress can be monitored O – Support students in project execution T- Due to many project, each student project have specific challenges and prerequisites that need consideration/support.
	Solve student project group dynamic issues	S – Ability to combat issues hands-on as they arise W – Time-consuming, each student project is different O – Learn from issues to develop course/project outline
	Solve issues related to company-student collaboration	S – Issues can be manages instantly – adjusting project etc. W – Time-consuming (also Gorman, 2018) O – Show companies and students that they are supported T – Issues can be difficult to manage
	Grading of individual assignment and student project	S – Teach students how to write and read articles – preparation for report and thesis W – Each project is unique, hence a common grading system is not entirely possible O – Identify good students for future thesis or PhD positions
Companies	Meet students 3 times for: Workshop, interviews and complementary data collection	S – Time spent is limited and controlled, little time needed for supervision W – In some projects, more time is needed to form and support student project O – To get to know students and evaluate them T – Supervisor might become unavailable on predetermined times due to daily operations
	Provide feedback to students • Support students • Provide feedback on progress • Provide feedback on findings	S - To follow student project and address issues, gain insight on student project O - Learn how students work and perform, gain insight on novel student project solutions T - Might be considered time-consuming (also Gorman, 2018)
	Adjust problem for student project	S – Collaboration with students, self-evaluation of project W – Academic requirements can be challenging to interpret O – Gain insight on student ability to understand complex projects T – Active participation required, not just handing over a project (also Gorman, 2018)
	Provide additional data for student project	S – Support project for better execution and results W – Can be time-consuming, expertise might be needed T- Time and experienced personnel might not be available for a one-case problem-based courses
	Participate in final presentation of student project	S – Gain insight on project results, gain novel knowledge on current issues W – Can be challenging to interpret academic results O – Find potential candidates for employment – based in project execution T – results might not reach expectations, or be too far from initial problem statement
Students	Active participation in student project	S – Effective groups, collaborative learning experience, learn self-management W – Can be time-consuming due to group meetings and company visits O – Learn how to work with problem-based project on academic and company approach (also Gorman, 2018)
	Deliverables for Supervision and milestones	S – Deliverables ensure that sub-targets are met, and finally the report W – Students feel pressured to deliver continuously throughout the course O – Learn about problem-based project, and managing deadlines T – Students might skip supervisions due to high workload, thus lose learning opportunities
	Write an individual assignment on provided subject (in PSD)	S – Learn about topics relevant for project W – A lot of reading and writing is expected O – Become a better academic writer, preparation for full report T – Students can experience high demands for a passing grade (also Gorman 2018)
	Adjust problem for student project	S – Opportunity to collaborate with companies and gain insight on how to limit and adjust projects (also Gorman, 2018) W – Challenging to balance academic and industry expectations (also Gorman, 2018) O – Learn much about production system projects and problem-based projects in production companies T – Overwhelming amount of information can complicate this task
	Deliver individual assignment and student project	S – Learn to present results in a scientific way, preparation for thesis W – Companies can view report to be "too academic". O – Learn from feedback from company and facilitator on how to improve on writing and problem-based investigation T -Students can experience these tasks to be demanding and time-consuming
	Present findings to class and company	S – Learn how to present, and communicate, complex project results to both companies and academia (also Gorman, 2018) W –Academic presentations can be considered too stiff and complicated for companies O – To get feedback from both academia and companies on project management T - Students can experience company presentation as a daunting undertaking

Follow-up phase

Taking time in the follow-up phase to speak with participating companies give valuable feedback to the facilitator in regards to updating the course curriculum as well as to form closer relationships with the companies in both research opportunities and in preparation for next year's edition of the course. Feedback from companies is a valuable contribution on how to manage the partnering companies, student-company relationships and future versions of the course structure. Corse evaluation from companies and students are indeed of high value in problem-based courses, as the learning environment need to be improved each year to enable students to focus on learning and collaboration rather than surrounding issues. Companies add current industrial issues to the curriculum, but also gain up-to date knowledge on ongoing research in related areas. The final report and results contributes to the company with an outside perspective on the defined problem. However, as there are only a few points in time for collaboration, the companies might experience that the results does not match the initial student project. Nevertheless, continuous collaboration with the university and learnings from earlier student's projects can increase the possibility of valuable end-results from the project when planning for next year's student project. Additionally, student theses can spring from close collaboration. Details of the analysis can be seen in Table 3.

Table 3 – analysis of Follow-up phase in problem-based education

	Activity	***SWOT***
Facilitator	Contact companies to gain feedback on student projects	S – Continuous contact emphasises collaboration W – Can be time-consuming O – Increase collaboration and gain insight on student project execution T – Companies might be difficult to get in to contact with
	Re-evaluate/update course based on course evaluations	S – Insights from students and companies emphasise continuous improvement of course
	Submit grades	O – Teach students how to write thesis and work with company projects
	Grade re-examinations	W – No opportunity to change project outline for re-examination due to the nature of the project
Companies	Provide feedback to facilitators	S – Companies can contribute to course, thus adjusting course to company needs. O – To present concerns and improvement suggestions on student project and course
	Provide feedback to students	S - Can support students as future employees in self-development and project skills
	Evaluate findings from case	S – Gain insight on students approach to solve problems, learn about state-of-the-art in academia. W – Some project may not have come to the expected results O – Insights on own production from an outside perspective T – Report can be highly academic
	Consider participating in next year's course	S – Able to identify projects in advance and adjust well in time O – Continuous collaboration with university in research and student projects
	Follow-up on case contributions	S – Students can continue their project as employees or thesis workers. O – Can be an opportunity for an in-depth project based on student project
Students	Evaluate course	O – To express concerns about course structure and to give improvement suggestions for future versions of course
	Receive grade	S – Gain knowledge and feedback on what is expected from thesis work

Contributions and Discussion

This study contributes to previous research by providing a list of recommendations on how to enable a problem-based course, to do so we focus on three distinct points in time, preparation, execution and follow-up. This paper provide insight on outstanding challenges that hinders problem-based education. Furthermore, actions have been identified that can be taken to avoid the aforementioned challenges.

A novel contribution presented in the paper shows that the preparation phase in general is a prerequisite for successfully enable learning in problem-based education (Bak and Boulocher-Passet, 2013; Gorman, 2018). Efforts in this phase ensure that students can focus on problem solving, problem solving and achieving academic goals. Gorman (2018) suggested that this phase should be in focus, however, we present the novel finding

that company data collection is necessary to ensure that the student projects can get a short start-up and focus on problem solving. We presented that the individual assignment in course industrial excellence support the students in learning about subjects related to OM in general, but manufacturing strategy, production system development and discrete event simulation specifically. Additionally, the individual assignment prepare the students understanding of the company's context, which contribute to their ability to understand the current challenges. This paper suggest that the companies should be presented with a clear understanding of the course schedule and curriculum (Nielsen, 2004; Bak and Boulocher-Passet, 2013; Gorman, 2018) but going further, we suggest that a predefined set of student company visits should be decided. Three company visits during the course have been proven as a success factor for enabling students to focus on learning and problem solving and the companies to be able to manage the timeframe for the project. Finally, we contribute with a course structure consisting of a set of milestones throughout the course. The milestones gives the facilitator an opportunity to determine student project status and address issues in student group or student-company collaboration, whereas students have clear deadlines and can get support from the facilitator. In Table 4, a complete list of recommendations and what to avoid is presented, thereby answering the RQ; *how can challenges in problem-based education be approached to enable learning in OM course?*. The list contains all actors, but the focus is on what approaches are required from a facilitator's perspective in relation to the course actors.

Table 4 – List of recommendations on how to manage challenges in problem-based education

Challenges	**Recommendations**
Focus on long-term collaboration with companies	Keeping the company satisfied with student group performance, in delivered results and overall student and facilitator collaboration experience
Iterative project scoping process	Ensure project fit to company and academic requirements
Homogenous groups	Ensure student groups are multidisciplinary and group performance is higher as student levels are harmonised.
Data collection in the preparation phase	Students can focus on learning and project execution
Scheduled company visits	Students can focus on project, easy to manage by companies
Course milestones	Enables learning and student project execution
Student project iterations	Allow students to focus on student project execution
Individual assignment	Preparing students for project by gaining knowledge on subjects related to student project
	What to Avoid
Giving companies leeway on timeframe	Companies can ignore students and prioritise daily operations
One time company projects	Companies on long-term collaboration learn how to scope projects and knows how to priorities project and reap benefits, simplifying the solicitation process.
Using last-minute project	Usually ill-defined, poorly scoped and companies have not realised the required time needed for project execution
Company secrecy	Students cannot use or present results in the course
Letting students create groups	Can have a negative effect on company-university collaboration due to low performing groups

Conclusions

The purpose of this paper was to present a list of recommendation to enable learning in problem-based education with real-life student projects. This have been achieved by a list of recommendations and what to avoid in problem-based education stemming from a thorough analysis of course industrial excellence at MDH. Indeed, the preparation phase was identified as the most challenging for company and facilitator, but the reword in learning outcome and manageable student projects for all actors is worth the time of preparations. This paper would have benefited additionally by collecting data on how companies prepare the student project to understand the underlying reasons for engaging

in problem-based education. Additionally, an investigation of other courses in problem-based education, outside the production system development area, would have given an opportunity to compare data and verify results to strengthen our findings. For future research, we recommend additional courses in problem-based education to be investigate, and that companies should be more thoroughly investigated in order to understand how to engage them in problem-based education.

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