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Holgaard, Jette Egelund; Kolmos, Anette; Winther, Maiken

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Designing Progressive Intended Learning Outcomes for PBL: A Workshop Format for Curriculum Redesign

Jette Egelund Holgaard
Aalborg University, Denmark, jeh@plan.aau.dk

Anette Kolmos
Aalborg University, Denmark, ak@plan.aau.dk

Maiken Winther
Aalborg University, Denmark, maikenw@plan.aau.dk

Abstract

Generic competences such as teamwork, communication and system thinking have gained increasing attention in engineering education, and problem-based learning (PBL) models have been highlighted as effective in fostering such competences. Aalborg University (AAU), Denmark, has had a systemic approach to PBL since its foundation in 1974, and in 2018 a process was initiated to make the progression of PBL competences more explicit in the curricula. Consequently, all study programmes had to redesign their curriculum and integrate progressive intended learning outcomes (PILOs) for PBL. In the engineering and science faculties, a project was initiated with the purpose of supporting all study programmes in the process of designing such learning outcomes. The outcome was a guide for staff to develop PILOs for PBL, presenting a participatory process design and a complementary workshop format. This paper outlines the process for educational design, the workshop format, and reflections on the project carried out at AAU as a best practice example of integrating PBL throughout the curricula in an inclusive and participatory way.

Keywords: progression, problem-based learning competences, curriculum development

Type of contribution: Practice paper

1   Introduction

Generic competences such as teamwork, communication and system thinking have gained increasing attention in engineering education to cope with the ever-changing and increasingly complex societal challenges. As noted by Graham (2018, p. 39), based on a study of leaders in engineering education, future engineering curricula will "emphasise student choice, multi-disciplinary learning and societal impact, as well as expose students to a breadth of experiences outside the classroom, outside the traditional engineering discipline and across the world".

Problem-based learning (PBL) models have been highlighted as effective to foster generic competences alongside domain-specific competences (Kolmos & Koretke, 2017), and PBL models in different shades have been implemented worldwide. However, where there is not much doubt that PBL is seen as an effective means to foster domain-specific engineering competences, it is more questionable whether PBL competences are acknowledged as an end in themselves that are worth emphasising in the explicit curriculum. Aalborg University (AAU), Denmark, has had a systemic approach to PBL since its foundation in 1974, and PBL has been an integrated part of the curriculum from the very beginning. In the first year, students are assessed in their achievement of certain PBL competences; after the first year, however, there is no further focus on this (Kolmos, Bøgelund, & Spliid, 2019).

In 2018, as a part of the institutional strategy, AAU management initiated a process to highlight the progression of PBL competences in the written curriculum. Consequently, all study programmes had to redesign their curriculum and integrate so-called progressive intended learning outcomes (PPILOs) for PBL throughout the curriculum for PBL, with a clear progression and employability perspective appropriate to the specific educational profile.

At the Technical Faculty of IT and Design (TECH) and the faculty of Engineering and Science (ENG), a project was initiated with the purpose of supporting all study programmes in the process of designing such PILOs. However, for many of the programmes, the progression of learning objectives was far from explicit after the first semester, and even though students saw a progression in PBL competences, it was more implicit than explicit in the curricula (Holgaard & Kolmos, 2019).

The ambition was to frame the process, but to leave the sensemaking and formulation of PILOs to the staff actively involved in the programmes and responsible for supporting students' learning in the specific educational context. The outcome was a guide for staff to develop intended learning outcomes (PILOs) for PBL in a participatory design and workshop format. The workshop format is based on a card game, where the cards have the sole purpose of initiating dialogue in a workshop setting.

This paper outlines the process for educational design, the workshop format, and reflections on the project carried out at AAU as a best practice for inclusive and participatory educational design of progressive learning outcomes for PBL.

2   Sources of inspiration—theoretical as well as experience-based

Holgaard and Kolmos (2019) characterise different types of PBL competence in four types: problem-oriented, interpersonal, structural and metacognitive. These four types of competence cover the intentions in the AAU PBL principles (see AAU, 2015). As illustrated in Figure 1, metacognitive competences are cross-cutting. Metacognitive competences raise the other competences above the level of application in Bloom's taxonomy (Bloom, 1956), enabling students to analyse, evaluate and synthesise their approach to learning to address new modes of application. As such, without this cross-cutting competence, the other competences are reduced to skills.

In the TECH and ENG faculties, all students have a course of five European Credits (according to the European Credit Transfer and Accumulation System - ECTS) in the first semester on problem-based learning in science, technology and society (Kolmos et al., 2019). This course creates the basis for students to practise PBL, and supplements the problem-based project work supported by facilitators from the disciplines. The problem-based project work is organised in teams and is somewhat extensive, as it takes up half of the study time in each semester. Furthermore, PBL consultants from PBL research environments scaffold the students to ensure that the students develop metacognitive competences.

The students document their metacognitive competences through a process analysis, three times in the first year, and with increased depth. The process analysis concept was developed in the late 1990s (Kolmos & Kofoed, 2002) based on the experiential learning theory, primarily with inspiration from Kolb (1984). However, systematic development of metacognitive PBL competences only takes place during the first year of study.

Figure 1: PBL competences as outlined in Holgaard and Kolmos (2019:1645)

The long-term experience of building students' PBL competences in the first semester has created the foundation for exemplifying the PBL competences in Figure 1. At the same time, it has formed the approach to develop PILOs for PBL throughout the curricula.

3 Implementation: process overview

Although ongoing curriculum development is common at Aalborg University, explicit focus on the implementation of progressive PILOs for generic competences like PBL has been rare, and therefore the implementation process design had to be developed. At the faculty of Engineering and Science and the Technical Faculty of IT and Design, deputy deans managed the implementation process in close collaboration with the Aalborg Centre for Problem-Based Learning in Engineering Science and Sustainability under the auspices of UNESCO (UCPBL). The pro-deans clarified that the overall framework should rely on a participatory process, while the programme managers and practitioners were the ones to outline the learning objectives based on the overall AAU framework for PBL competences (see section 2). UCPBL was not therefore the designer of a set of PILOs for PBL to be integrated into the curricula of all programmes. On the contrary, they served as process facilitators to frame the process, as well as to inspire and support local research communities to take ownership of the design process of new PILOs for the curricula.

For the local educational communities, the presence of PBL in the curricula was not totally new—for one thing, due to the learning objectives in the PBL course in the first semester. Therefore, the process first of all included consideration of the PILOs for PBL that were already included in the curricula. Secondly—and as research has shown that after the first semester the progression of PBL competences is far from explicit—it is important to capture these tacit competences by considering activities in the programme with an implicit ambition of developing PBL competences, and to question whether this should be made more explicit in the curricula. Finally, staff should also consider prescriptive perspectives of the curricula in terms of emphasising PILOs pointing to new directions in future engineering and science education.

3.1 A five-phasemodel

To capture creative ideas to rethink PBL practices and to consider existing PBL practices being more or less explicit, the one-year process of implementing PILOs for PBL was designed in five stages (see Figure 2).
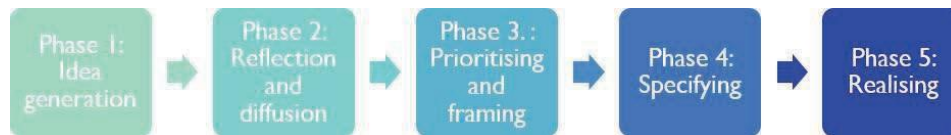

Figure 2: Outline of the process of implementing PILOs for the progression of PBL competences

Phase 1: Idea generation

To ensure that the discourse of PBL does not close around current ways of integrating PBL in the curricula or current practices, the process of designing PILOs is initiated by a phase of idea generation. The framing is made by a short introduction and a three-hour workshop for programme designers and practitioners. In the workshop, pre-prepared dialogue cards with aspects related to the four areas of PBL competences, as defined by the AAU PBL Academy, are used to point out important aspects of PBL within the particular programme (see more about the workshop material in section 4). Furthermore, staff are asked to structure the ideas in relation to the semester structure, having four semesters on the Bachelor programmes and four semesters on the Master programmes.

Phase 2: Reflection and diffusion

After the idea generation workshop, the PBL aspects mapped in relation to different semesters are used as what Wenger (1998) would call a boundary object for further reflection and discussion. It is recommended that the visualisations from the idea generation workshop are placed in the lunchroom, making space for an informal dialogue and offering easy access to add more post-it notes with more ideas. Furthermore, it is recommended that the results of the idea generation workshop be reported online, with the possibility for further additions.

Phase 3: Prioritising and framing

In phase 3, the ideas from phases 1 and 2 are gathered and the study boards (including both staff and students) have the important task of selecting the aspects of PBL which are to be stressed in the PILOs of the particular programme. Each programme has its own disciplinary scope, and it is the intention that the PILOs for PBL be aligned with this scope and integrated into relevant modules. Furthermore, and on a quantitative note, the number of PILOs for PBL should be balanced with the total number of PILOs in order to remain a strong core profile of the specific programme. Last but not least, the study board considers covering the four types of PBL competence.

Phase 4: Realising—from ideas to learning objectives

After key PBL aspects and derived ideas are selected for further development in phase 3, phase 4 supports the transformation from aspects/ideas to PILOs. Like in phase 1, a three-hour workshop format can be used to scaffold this process for programme managers and teaching staff, and again predesigned dialogue cards support the participants in the explication process. Besides supporting the formulation of PILOs for PBL, the workshop also helps faculties to prepare an outline for the corresponding teaching and assessment activities (see section 4 for further information).

Phase 5: Specifying
In the final phase, the study board refines the learning objectives developed in the workshop in phase 4 to ensure both horizontal and vertical alignment in the curricula. The study boards are advised to get an overview of the PILOs for PBL for each module and for each semester. In this way, it is also possible for teachers in different semesters to know who to coordinate with to ensure clear progression and coherence in the support students get to develop PBL competences progressively throughout their study.

3.2   Reflections on the overall process

The five phases presented in the previous section were prepared as an implementation guideline. The decision to guide and not direct proved to be beneficial for creating ownership—not only for integrating PILOs for PBL, but for the co-creation process beforehand. The local study communities were, however, obliged to report on their progress twice in the process. Even though the implementation of PILOs for PBL throughout the curricula is obligatory, the experiences from the facilitator of several workshops in phase 1 was that trust in the research environments taking responsibility for the process of implementing meaningful and aligned PILOs for PBL (instead of generic add-ons) created a clear motivation for change. Likewise, the pedagogical unit, UCPBL, supported the process with online resources and, on request, facilitating workshops and attending meetings. By no means did the pedagogical unit try to interfere with decision-making processes and the actual defining of the PILOs for PBL.

Another important reflection concerns the time management of the process. For some programmes, idea generation came rather late in the process due to other urgent matters, which put considerable pressure on the last phases of the process. We saw on some occasions that phases 2–5 merged, and the focus on delivering PILOs as requested to some extent overpowered considerations of progression and coverage. Therefore, progression and coverage should be properly considered in the subsequent process of evaluating and eventually qualifying the implemented PILOs for PBL. At AAU, this process is set up as a cross-university activity, where study boards receive feedback from the PBL Academy on the result of the implementation as it presents itself in the revised curricula.

4   A workshop kit for initiating PILOs for PBL competence

To scaffold the process of implementing PILOs for PBL throughout the curricula, the UCPBL developed a so-called workshop kit for staff (related to phases 1 and 4). The workshops could be facilitated by UCPBL on request, but it was also possible for local faculties, through the use of online resources, to facilitate the process themselves. The workshop setting was considered important to benefit from the group creativity taking place in face-to-face discussions. As noted in the previous section, the workshops at AAU were structured in two sessions as a part of an overall implementation plan, but the overall aim was to get people together and facilitate them to address the following five questions:

- What are the core PBL aspects in the particular programme?
- When should we (re)visit these PBL aspects in the curriculum?
- How do we transfer aspects of PBL into qualifications?
- How can we support students in reaching the intended PBL qualifications?
- How do we assess the PBL qualifications?

The core of the toolkit is dialogue cards, which are developed with the sole purpose of initiating dialogue. The purpose is therefore not to present a complete overview of aspects related to the PBL competence; on the contrary, ideas can emerge by noticing what is not present. To stress this, sets of dialogue cards are always in pairs of 12, this number being chosen as cards can easily be divided into subgroups of two, three or four, according to preference.

In the following, we elaborate on the reasons for asking these particular questions in designing PILOs for PBL, and the toolkit provided to support staff to address these questions.

4.1   What are the core PBL aspects in the particular programme?

The process was initiated by referring to aspects of PBL instead of PBL qualifications, to detach the first line of thinking from the learning situation itself. Instead, the intention was that staff would start to consider what it is valuable for candidates within a given engineering or science profession to know about and bring into practice. Four sets of 12 PBL aspects were presented on dialogue cards, respectively related to the problem-oriented, interpersonal, structural and metacognitive competences. The aspects chosen to initiate dialogue in the AAU case are shown in Figure 3.

PBL aspects

12 aspects related to metacognitive competences:

1. Personal learning objectives
2. Intended learning outcomes (formal)
3. Learning style
4. Resilience
5. Motivation
6. Self-efficacy
7. PBL principles
8. Individual learning theory
9. Social learning theory
10. Process analysis
11. Competence profile
12. Personal learning paths

12 aspects related to problem-oriented competences:

1. Problem types
2. Problem identification
3. Problem analysis
4. Problem formulation
5. Problem solving
6. Creativity
7. User involvement
8. Cultural contexts
9. Sustainability
10. Ethics
11. Technology assessment
12. Scenario planning

12 aspects related to interpersonal competences:

1. Teambuilding
2. Team culture
3. Team roles
4. Team collaboration
5. Communication strategies
6. Conflict management
7. Active listening
8. Constructive feedback
9. Decision-making processes
10. Diffusion of project results
11. Professional codes of conduct
12. Collaboration with supervisors and external partners

12 aspects related to structural competences:

1. Distributed project management
2. Situational project management
3. Agile management systems
4. Setting objectives
5. Managing time and activities
6. Delegation of work
7. Collaboration agreements
8. Types of meeting
9. Managing meetings
10. Information gathering structures
11. Knowledge exchange structures
12. Diffusion of project results

Figure 3: PBL aspects used to initiate dialogue in relation to the four types of PBL competence

The cards were of different colours; for each colour, the assigned group was handed post-it notes in corresponding colours. The idea was that the group, whenever possible, should specify the generic concepts on the dialogue cards by considering the given educational context. For example, the card drawing attention to problem analysis could generate three blue post-its, including actor network analysis, state-of-the-art analysis, and user needs in context study. In other cases—for example, for process analysis—a yellow note could specify that an analysis of project management, collaboration and learning processes is expected.

In the workshop sessions, groups worked with one colour at a time: thinking blue, thinking pink, thinking green and thinking yellow. Approximately 45 minutes to one hour per area is recommended for this brainstorming session. In most workshops, the competence areas were divided between workshop participants, so that everyone could contribute to the following phase 2.

4.2 When should we (re)visit these PBL aspects in the curriculum?

The identified and specified core PBL aspects of the programme are then related to semesters, focusing on vertical alignment in the curriculum and competence development. For this purpose, a pre-printed outline of semesters was handed to the participants to fill in their ideas/post-its, considering the alignment between the PBL aspect and overall semester aims, as well as patterns of progression.

A hypothetical example could be that agile management is related to SCRUM in the software engineering programme. Participants relate the development of SCRUM competences to semesters 1, 4 and 5. They have in mind that students in the first semester are taught and use selected techniques from SCRUM; in the fourth semester, they have an extended course on SCRUM to build up conceptual knowledge and skills; and in the fifth semester, they document their competence in project management of software development projects by using SCRUM.

Figure 4: Verbs to initiate formulation of PILOs

4.3 How do we transfer PBL aspects to qualifications?

In the next phase, the chosen PBL aspects are transferred into the mindset of the european qualifications framework for lifelong learning (European Communities, 2008), classifying the knowledge, skills and competences related to a given aspect. Among others, Grün et al. (2009) highlight the strength of using active verbs as descriptors of knowledge, skills and competences. To initiate dialogue about the qualifications based on the PBL aspects, the 12 verbs in Figure 4 were proposed and transferred to dialogue cards.

As an example, if team culture is stressed as an important PBL aspect, it makes a difference whether students are required to conceptualise a team culture, to exemplify a team culture by use of personal experiences, or to optimise the team culture they are a part of in their group work. For the latter, the use of 'optimise' also indicates that the student can elaborate and argue his/her understanding of what an optimal team culture is.

4.4 How can we support students in reaching the PBL qualifications?

Along with the formulation of PILOs for PBL, staff have to consider how to support students in achieving the intended PBL qualifications. In other words, there has to be alignment between the PILOs and the pedagogical approach, including the planned teaching activities. In order to stimulate this discussion, 12 potential activities to support PILOs for PBL were pre-printed on dialogue cards to be discussed in relation to specific learning objectives (see figure 5).

For example, let us use an example where the ILO is that students can plan and manage problem-based project work

12 potential activities to support PILOs for PBL:

1. Facilitation of projects
2. Facilitating of casework
3. Online 'just-in-time' lectures
4. Inspirational speeches
5. Thematic workshops
6. Status seminars
7. Targeted feedback based on exercises
8. Excursions
9. Facilitation of cross-team collaboration
10. Facilitation of interdisciplinary collaboration
11. Facilitation of external collaboration
12. Ad-hoc individual coaching sessions

Figure 5: Activities to support PILOs

taking into consideration the given problem type, the team constellation and the duration of the project. In this situation, staff could, for example, consider a mix of:

- Inspirational talks on the diversity of real-life problems and ways to cope with this in project design
- Targeted feedback on students' project designs
- Ongoing attention to project design in the facilitation of projects
- Peer feedback in status seminars

4.5   How do we assess the PBL qualifications?

Last but not least, the PILOs for PBL and the pedagogical activities to support these have to be in alignment with the assessment methods. Yet again, 12 potential assessment approaches are noted on dialogue cards to open up a discussion of the appropriate assessment method in relation to a specific set of PILOs for PBL (see figure 6). First of all, the cards initiate a discussion of both summative and formative assessment methods. Secondly, they are designed to initiate a discussion about the type of documentation needed (individual or group-based) and, in line with this, whether the exam should be written (based on individual documentation) or oral (which might be based on documentation prepared in a group setting). Last but not least, they are designed to initiate a discussion of who the assessors should be.

12 potential activities to assess sets of PILOs for PBL:

1. Written exams documenting individual reflections on PBL processes
2. Written exams documenting individual casework
3. Oral exam where students are questioned based on shared process analysis
4. Oral exam where students are questioned based on shared casework
5. Pass/no-pass assessed by a certain extent of active participation
6. Integration of PBL in project exams
7. External examiners present at the assessment
8. Formative assessment in the group
9. Formative assessment of peer groups
10. Formative assessment across semesters
11. Formative assessment across educations
12. Self-assessment

Figure 6: Activities to support PILOs

4.6   Reflections on the use of the workshop kit

The workshop kit was made accessible to all studies across all faculties by establishing online resources with materials that could easily be adjusted to local needs—e.g. by changing the wording on the dialogue cards. There were only a few examples of revision of the dialogue cards, however. As an example, some included entrepreneurship as a problem-oriented aspect of PBL. However, faculties overall reported that the PBL aspects covered the intention to embrace different types of PBL competence in a way that worked across disciplines and educational programmes.

As noted in the following section, the idea generation workshop in the first phase was the most thorough, and therefore there is a lack of experience with the dialogue cards in the fourth phase. The experience from the idea generation workshop was that the dialogue cards worked well to initiate an engaged dialogue about generic competences, which for some seemed rather abstract at the outset. In the workshops facilitated by UCPBL, we as facilitators experienced that cards could also be characterised by the way the discussion was triggered, as different types of card within the same themes initiated different types of response.

The following types of card were distinguished:

- Cards creating a sense of familiarity—e.g. problem analysis, process analysis and teamwork are all embedded in the PBL way of AAU.
- Cards initiating a discussion about different perspectives on the same subject—e.g. the difference between distributed, situated and agile project management or different types of assessment.
- Cards creating curiosity—e.g. questions like what is metacognition, what is active listening, what can be considered as different problem types, types of meeting, etc.
- Cards stressing the need for selective thinking when approaching a multi-directional concept—e.g. what line of thinking should we take to include sustainability, social learning theory or problem solving?

In changing the wording on the cards to fit local needs, it is recommended to pay attention to the need for diverse types of trigger to engage staff in co-constructing PILOs for PBL.

5   Final remarks

In this paper, we present a process of implementing progressive learning objectives for PBL, which can be adopted and adapted to local contexts. Furthermore, a workshop kit is presented in order to facilitate divergent thinking and open discussion of the content and prospects of PILOs for PBL. First of all, a comprehensive set of PBL competences were transferred into keywords on qualification cards. Different types of qualification card were presented, relating to four types of PBL competence: problem-oriented, structural, interpersonal and metacognitive. Secondly, activity cards were developed for staff to discuss the expectations of the taxonomic level of learning. Finally, evaluation cards were designed to consider the alignment between the PILOs for PBL and the assessment format. Last but not least, pre-printed overviews of semesters were designed to get an overview and ensure progression of PBL competences throughout the curriculum.

The process and workshop materials were developed for the Faculty of Engineering and Science and the Technical Faculty of IT and Design at Aalborg University, but made accessible for all faculties. The process has been designed with the aim of guiding and not directing the implementation of PILOs for PBL to create ownership and engagement for change. The next step is to evaluate, to disseminate experiences and outcomes, and to provide an opportunity to qualify the PILOs for PBL in the next round of revisions.
In this paper, the aim has been to disseminate the material even further to other university contexts, with the broader ambition of transforming engineering and science education to a stage of increased awareness, explication and enforcement of generic competences for PBL throughout the study, as well as on the subsequent professional path.

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