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Problem-Based Learning Approach Facilitating Sustainable Waste Management

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ABSTRACT

This work provides inspiration to foster Problem-Based Learning (PBL) in teaching practices related to waste management. Problem-Based Learning is about providing a learning environment where students can work practically and theoretically with problems of relevance for society. In this learning process, students themselves will define societally important problems and direct the problem identification, problem analysis, and problem-solving processes. The PBL approach at the engineering and technical faculties at Aalborg University acts as a case of inspiration to exemplify how the structure of a problem-based project can foster students' competencies and agency to contribute to a circular economy related to waste.

Keywords: PBL, problem design, process analysis, contextual learning, education for sustainability

INTRODUCTION

Exploring and developing sustainable solutions for future management of waste within a Problem-Based Learning (PBL) environment involves having a perspective both upon the general needs, being the overall goal of sustainability, and the more specific setting, being the actual context of waste management identified in a particular location.

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Education for sustainability (ESD) is characterised as strongly contextual, as illustrated by this quote about ESD "it should be applied and grounded in the local economic, social, and ecological context and community, followed by regional, national, international and global contexts" (Sterling, 1996, p. 22). For waste management, the complexity and the global aspects outlined in this quote are easy to spot. Let us just mention some of the aspects such as increased globalised product and waste chains, where multiple stakeholders are having an impact on the perceptions, strategies, and practices related to waste management.

In sustainable waste management and circular economy, we are facing several challenges including the amount of waste, diverse regulations of production and waste management as well as the increasing complexity of the way materials are combined in the products, which we eventually come to characterise as waste, and which adds to the complexity of reducing waste amounts through circular strategies (Bocken et al., 2016; Tisserant et al., 2017; Kristensen & Mosgaard, 2020). Added to these more structural issues, are serious concerns regarding health issues when formal and informal sectors are handling waste, notably in developing and transitional economies (Ezeah et al., 2013; Ferronato & Torretta, 2019). When identifying and opening for solutions addressing specific problems within waste management, PBL offers an approach that enables combining sustainability with contextual learning.

PBL is one of the pedagogical approaches which has been known for its emphasis on contextual learning (see for example Guerra, 2014; Guerra & Holgaard, 2019), as it rests on a constructivist and experiential learning perspective emphasising active and participant-directed learning. Kolmos et al define PBL learning principles from three approaches (Kolmos et al., 2009, p. 11) from a cognitive learning approach emphasising both the problem, the project, the experience, and the context; from a collaborative approach centred around working in teams through participant-directed learning; and finally, from a content approach focusing on inter-disciplinarity, exemplarity and the close relation between theory and practice.

The emphasis on exemplarity makes students able to transfer experiences from one situation to another and thereby be ready to cope with unexpected new challenges preparing them for solving real-life problems during their studies as well as in work life. All together this empowerment of student agency, this focus on contextual learning, and this call for exemplarity in the PBL approach is very much aligned with the change in paradigm in higher education including a strong emphasis on sustainability that Sterling (2014) argues for.

However, introducing problem-based learning calls for an experience-based approach to get inspiration from comparable cases and appropriate the learnings to the specific

context. In this chapter, we exemplify how the structure of a problem-based project can foster student's competencies and agency to contribute to sustainable waste management. The framework has been specifically developed in the context of waste management in developing and transition economies but is relevant also in the global north. We demonstrate the framework by drawing on the PBL approach used at the engineering and science faculties at Aalborg University (AAU), Denmark. AAU has a strong tradition for problem-based learning and has since its foundation in 1974 had a systematic approach to PBL, placing real-life problems in the core of the learning process throughout the curricula.

THE OVERALL STRUCTURE OF A PBL PROJECT

Working problem-based can be very challenging and therefore suitable educational framing and guidance should be provided. Working with real-life problems through students' semester projects or projects connected to courses is core to the PBL approach. Structuring the PBL project is the first essential step in the process of working problem-based, offering an overall framing of how a Problem-Based Learning project is designed.

In Figure 1, an overall structure for a PBL project is presented. The reflection-based feedback loops underline that students' reflections on their outcomes in a specific context can inform further analysis and offer inspiration to curriculum design. As in all cases, the learning objectives in the curricula provide both opportunities and boundaries for the learning process. If the learning objectives are defined in a very narrow and technical way, the following learning process will be shaped by this intention e.g., focusing on the redesign of a technology or a service. A subject or a theme to trigger the problem design process could for instance be waste sorting technology focusing upon narrow and technical learning objectives. If learning objectives are also focused on contextual learning, the trajectory will point towards more open problems and the output of the project will most likely be more inclusive, e.g., focusing on presenting action plans or different scenarios for change.

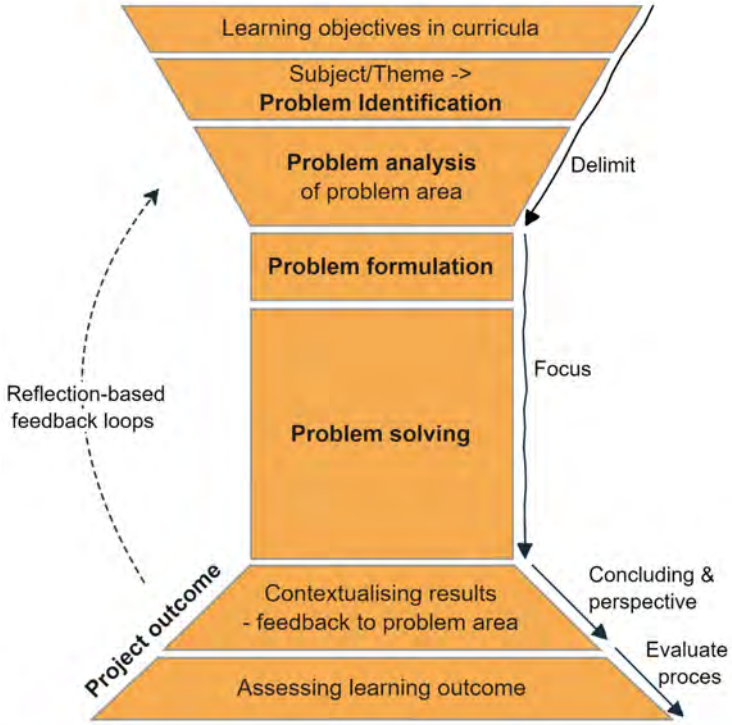

Figure 1. The different phases in a problem-based learning process (modified from Holgaard et al., 2014).

Students working with the process of delimiting and hereby designing the problem is one of the most distinct characteristics of the PBL approach at AAU. In this process, students are trained to identify problems and to balance creativity and analytical skills to target their problem-solving. For example, in designing a waste management system for a municipality, students must use their analytical skills to analyse the context of use, identifying stakeholder interests as well as state-of-art considering both current regulations and available technology. They also must engage their creative skills to appropriate state-of-art to the context of use – to combine existing solutions in new ways and maybe even contribute by a new approach to waste management.

When the problem is well-defined, the problem-solving process starts by presenting a question to direct the further inquiry process and introducing the methodology to solve the problem. As illustrated in Figure 1, the problem-solving process is narrower, whereas the students specialise in their chosen subject. The ambition in a PBL project is however that no project outcomes stand without being questioned and assessed more broadly considering the complexity of the societal context.

PHASES OF A PBL PROJECT

In the first part of a problem-based project, the problem is identified, analysed, and formulated as an outset for problem-solving. This phase has been characterised as a problem design process (Holgaard et al., 2017). In the problem design, students define

the important issues in a societal context. By using concrete theories and methods during this learning process, students engage in a problem-searching process of mapping reasons and explanations to complex issues. In this process, the problem area is explored and defined.

The aim is that learning moves beyond the purpose of acquiring knowledge of methods, tools, and theory and will include learnings to apply this knowledge to a society of complexity. In this sense, the 'exemplary principle' (Negt, 1981) comes into play by linking student's experiences to present societal problems, and in this process, students can learn to take a critical stand on the present status and use what Mills (2000) termed sociological imagination to explore alternative futures. Through the problem design process, the students identify and argue for an overall problem of relevance to society which is narrowed down to a manageable problem formulation, taking into consideration the time available for doing the project as well as the competence level and reach.

Figure 2 gives a detailed overview of how to approach and carry out the problem design process (steps 1 to 3) followed by the problem-solving process (step 4) and the project outcome (step 5).

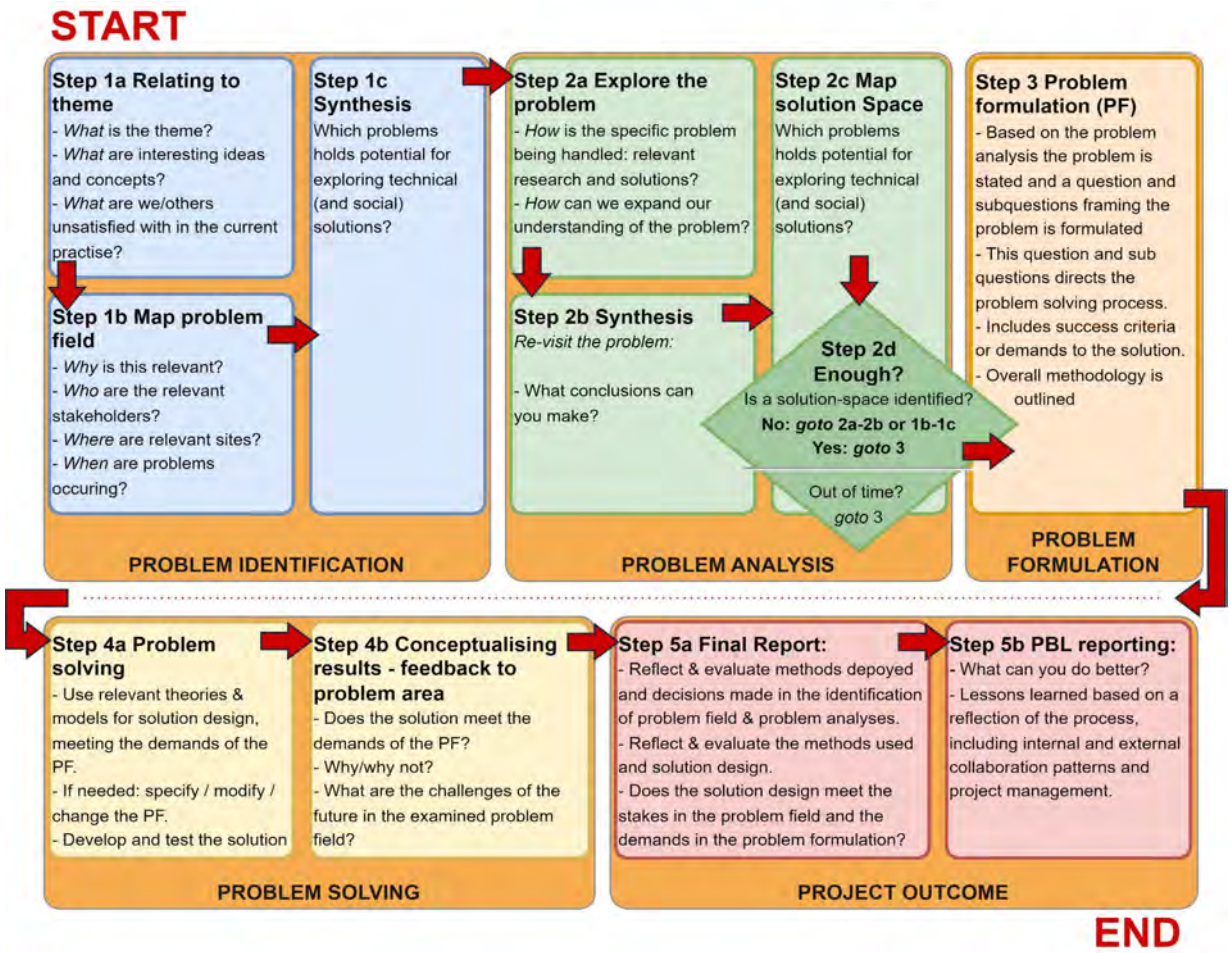

Figure 2. Steps of problem-based learning (developed based on Holgaard et al., 2017).

WHEN PROJECTS FOLLOW THE MISSION OF SUSTAINABLE WASTE MANAGEMENT

In exemplifying the problem design process, we use the process outlined in Figure 2 related to the area of sustainable waste management to illustrate how the PBL phases are used to address a specific mission.

To illustrate the process of designing a problem a project carried out in the second semester of undergraduate education "Cities, Energy and Environmental Planning" at the Technical Faculty of IT and Design at Aalborg University, Denmark will be introduced. The project group was involved in a pilot project regarding waste management on the Island of Bornholm in Denmark. The aim was to contribute with relevant studies on how to implement successful organic waste sorting in households on the island of Bornholm.

Step 1a Relating to theme

In the first part of the problem identification students will be "relating to a theme" to understand the underlying assumptions of addressing a given theme. In this case, the underlying assumption is that waste management is needed, and students validate this assumption.

From there, students study different overall aspects of the theme. For example: How is waste handled today? What are the challenges connected to the handling of waste? What different types of waste relate to which problems? What can be characterised as sustainable waste handling? What interesting ideas or examples from elsewhere are to be explored? The overall answer to such questions is: It depends. Therefore, students typically narrow down the theme guided by a particular context of study.

Step 1b Mapping the problem field

When the students have an overview of thematic discussions and choose a specific context of study, the inquiry becomes more specific. The basic tool for the mapping exercise, applied by the students, was the classic "Five Ws and one H" (5W1H), which is also recommended by Holgaard et al. (2017). This is the first step that directs the project engaging in W-questions like; 1) *What* are the concepts normally used for analysis of waste management problems? 2) *Why* is waste management in Bornholm relevant to address? 3) *Who* are the relevant stakeholders involved in the waste handling on Bornholm and what types of stakeholder relations can be mapped regarding waste management on Bornholm? 4) *Where* are the sites and/or flows of waste which may be problematic on Bornholm? Can we identify relevant sites and/or exact flows of waste which is problematic on Bornholm? 5) *When* do we see representations of state of the art, i.e., what interesting ideas or examples from elsewhere are to be explored? Often students have difficulties understanding the 'when' question in the 5W1H-method, and by

experience it is easier understood as a 'what' question. And finally: 6) *How* should the problems be addressed, taking notice of which problems are being handled in the current situation and which are not? The last question is especially important for the PBL approach, as it forces the students to maintain attention to both the working and non-working in the problem field, and thereby indirectly supports an understanding of the institutional context of the problem and a holistic problem-solving strategy.

It is however important to note that the mapping of the problem field provides "potential problems" and not validations of every of these problems in the specific context at the specific time – it is a phase of opening to different types of problems which can be considered in the following phase.

Step 1c Synthesis

In the case presented, mapping the problem field has thereby opened attention to a range of issues connected to waste management on Bornholm. Being able to handle the problem requires that it is narrowed down focusing on what could be interesting to analyse due to waste management and which problems are likely to hold a potential for introducing solutions within the frame of the study regulations, the curriculum, and the learning objectives.

This narrowing down the problem builds upon what has been investigated in steps 1 and 2 – pointing toward where to identify openings for working with current technical and/or societal issues. In the case of waste management topics which students can choose to work with could be technical solutions to sort different types of waste, the policy and safety procedures regarding this type of waste, or how to change people's routines and perceptions of waste. As the point of departure, students will choose an initiating problem to be further validated and defined.

In this case, the initiating problem is the implementation of effective sorting and collection of waste in households involving multiple stakeholders. The aim of students was thereby to contribute with relevant studies on how to implement successful organic waste sorting in households on the island of Bornholm. This choice was aligned with the curriculum framing having an extended focus upon how to motivate students by facilitating stronger collaborations between students and the local community.

Step 2a-d Problem analysis

Based upon the choices taken in the problem identification the process moves into an in-depth problem analysis which requires the use of scientific methods to address the narrowly defined problem considering how actors address the specific problem and state-of-art including relevant research and already existing solutions in the field to explore the

problem (4a). At this point in the process, this is done to expand the understanding of the chosen problem.

In the case of waste management on Bornholm, the group was characterized by having close collaboration with practice in the problem design phase. The group was in contact with the local waste management company, other students who had worked with similar topics, and researchers within the field. After exploring the problem, the different understandings of the problem were synthesised and prioritised to clarify the perspective taken in this specific project (2b). Together with a theoretical approach to sustainable waste management the input and discussions with stakeholders from practice students chose to work with concerns and perspectives from the waste company and the municipality having an agenda about optimizing waste sorting and collection on the island Bornholm being characterized by having small narrow streets.

From this point, students can map the solution space (2c), which might include different types of solutions from different perspectives e.g., political, technical, economic, social, or environmental. To identify solutions to these issues the students decided to bring forth a range of perspectives: Interviewing and working with the waste company, interviewing the municipality, interviewing the renovation company, providing surveys to citizens, carrying out citizen's focus group interviews, and interviewing renovation staff. Among the different perspectives identified, students narrowed down the solution space to collaboration between stakeholders to optimize the waste sorting and collection of waste on Bornholm.

Step 2d Attention to the link between the proposed solution and learning objectives
In this case, the students thereby were able to propose a relevant solution to the problem aligned with stakeholder interest, within the frame of the curriculum and learning objectives, and their engagement. If this is not the case, the problem analysis must be critically reviewed and revisited.

In a time-limited project, the students might be forced to address a less validated problem, if the path of the problem analysis has not been as beneficial as expected. However, the approach and the contextual insights in the problem analysis will by no means qualify the solution.

Step 3 Problem formulation
Based on the first 2 steps students are ready to state the problem to be addressed together with a question that will guide the problem-solving process. To address the problem of implementing effective sorting and collection of waste in households and thereby addressing a stakeholder group with a high degree of diversity, students formulated the following question based on their process analysis:

"How can the intentions of the waste management company regarding sorting and collection of organic household waste on Bornholm be implemented, with a particular focus on the narrow city centres and cooperation between actors?" (Olesen et al., 2016).

Step 4a-b Problem solving

After having designed and formulated the problem students have a guide to their problem-solving, even though the problem formulation may be altered during the problem-solving phase due to new insights. In the presented case, solving the problem of waste management in a narrow city (4a) a solution to the problem was developed building upon multiple experiences among relevant stakeholders. Concluding that when implementing sorting and collection of organic household waste on the island of Bornholm, three factors should be considered: 1) Inclusion of citizens, 2) Inclusion of urban structures 3) An increased and interdisciplinary cooperation between actors (Olesen et al., 2016).

The conceptualisation (4b), understood as ideas and understandings embedded in the solution, must be carefully re-aligned with the problem design and the problem formulation. Furthermore, the conceptualisation might also inform the ideas and understandings related to the current field of study. In this case, a conceptual model including the three aspects presented in the solution is a way to frame the experiences of the case in a way that opens for other contextual links.

Step 5a-5b Project outcome

Finally, the project outcome is reported (5a). In this case, the project outcome was documented in a two-step model, whereas one report addressed the outcome of the project related to the problem, and the other report (process analysis) related to the outcome in terms of student learning during the PBL process. This underlines that PBL is not only an educational means but also a means to have an impact on society – in this case, related to waste management on Bornholm, Denmark (5b).

To sum up, the problem-based project created a framing where students collaborated with local stakeholders concerning issues related to sustainable waste management by addressing; the anchoring of the new local recycling centre, citizen's participation in local climate protection solutions, and exploring new developments of businesses in the district. What characterized these collaborations was students' participation in enhancing relevant discussions and solutions to local challenges on waste collection.

FINAL REMARKS

Changes towards problem-based learning processes imply a curriculum including learning objectives that support the approach, and this means an open curriculum where learning processes are facilitated rather than instructed. Working explicitly with open-ended problem-solving provides students with incentives to interact with society. Instead

of instructions and pre-defined problems, students can be facilitated by a framing emphasising problem design as well as problem-solving. Problem-based learning seeks to transform students from passive listeners to agents of change, and outcomes from study projects can combine students learning with societal impact. This paper is a modest attempt to outline how this can happen on a project level in the case of sustainable waste management.

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