Framing and facilitating complex problem-solving competences in interdisciplinary megaprojects

An institutional strategy to educate for sustainable development

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Framing and facilitating complex problem-solving competences in interdisciplinary megaprojects: An institutional strategy to educate for sustainable development

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Abstract

Purpose – Problem-based learning (PBL) has been suggested as an approach to education for sustainable development (ESD); however, the integration of interdisciplinarity is continuously challenged as it requires transfer and collaboration across disciplinary boundaries as well as integration into an often already-overflowing curriculum. Even in formalized PBL universities emphasizing student responsibility for defining relevant problems, envisioning sustainable solutions and developing transversal competences, interdisciplinary collaboration is still often "relocated" to extra-curricular activities. This paper's purpose is to explore *AAU Megaprojects* as a case for systematically integrating principles of ESD, and particularly interdisciplinarity, into PBL at scale.

Design/methodology/approach – The paper proposes a framework for analysing potentials and challenges concerning interdisciplinary framing and facilitation in large-scale projects based on PBL- and ESD-related research and presents findings from a case study on the first three rounds of megaprojects at Aalborg University in 2019 and 2020.

Findings – The findings indicate that interdisciplinary megaprojects have the potential to motivate students to engage in sustainable development; however, they require systematic framing and guided facilitation, particularly in the early stages, for students to take ownership, prioritize collaboration and see the contribution to and connection between disciplines. They also need prioritization at all institutional levels to succeed as an institutional strategy of education for sustainable development.

Originality – The paper provides insights into the potentials and challenges of framing and facilitating large-scale megaprojects as an approach to integrate the SDGs and interdisciplinary collaboration into higher education. Hence, it aims to provide new insights, concepts and practices for ESD and PBL for sustainability.

Introduction

For decades, the traditional discipline-specific approaches to research and education were considered sufficient for ensuring development and progress in society. Through distinct methodological, epistemological and ontological underpinnings, researchers identified and solved scientific problems without necessarily needing to question the approaches, the language or the nature of science itself. However, researchers and educators are increasingly challenging this approach, arguing that it is insufficient when addressing complex and highly contextual problems in practice. Particularly regarding sustainability

issues, rethinking of the scientific settings and interactions between disciplines is often required, combining ecological, economic and societal components to strengthen the shared understanding, create diverse knowledge and skills and develop suitable sustainable solutions (Stock and Burton, 2011).

Since the implementation of the UN's 17 Sustainable Development Goals (SDGs) in 2015, new visions, guidelines and common goals for a joint contribution to a better, more sustainable world have created a more complex setting for education, research and practice. Thus, higher education institutions across the world are currently taking action to support the development of students' complex problem-solving skills and competencies specifically related to sustainability. One such initiative is *Megaprojects*, a large-scale interdisciplinary project allowing students to work together across programmes and semesters to solve highly complex problems addressing one or more of the 17 SDGs while maintaining the time frame and discipline specific learning outcomes given within the formal curricula of specific semesters and programmes (Kolmos *et al*., 2020).

Through an expansion of students' contextual and interdisciplinary understanding, it is the aim of a megaproject to provide a platform for students to develop more complex and holistic approaches to problem solving for the future (Routhe *et al*., 2020). However, research has shown that the implementation of such large-scale interdisciplinary megaprojects also challenges the formal organizational structures within higher education and requires the facilitation of complex problem-solving skills, project management competencies and leadership (Routhe *et al*., 2020). Thus, to identify and analyse the potentials and challenges related to the implementation of interdisciplinary megaprojects as an institutional strategy in education for sustainable development (ESD), this paper explores and evaluates the processes and outputs from the first megaprojects implemented at Aalborg University (AAU) from the perspective of students, project supervisors and interdisciplinary facilitators.

In the following, an overview of related research on problem- and project-based learning (PBL) as an approach in education/engineering education for sustainable development (ESD/EESD) is provided and the intersection between PBL and ESD competences discussed, including complex problem solving and interdisciplinary collaboration. Following this, *AAU Megaprojects* is presented as the context and case for this study and a theoretical framework for identifying potentials and challenges in interdisciplinary approaches to PBL for sustainability. This will be followed by a section on research design and methods, providing an overview of the data collection from the first three rounds of megaprojects at AAU in 2019 and 2020. Based on this overview, the paper will analyse the potentials and challenges in interdisciplinary megaprojects in relation to the theoretical framework and discuss the needs and methods for better framing and facilitation of PBL and ESD competences within such projects. Finally, the paper will provide an initial assessment and propose future work to develop megaprojects further as an institutional strategy of education for sustainable development.

Problem-based learning in education for sustainable development

Education for sustainable development (ESD) specifically aims to prepare students to deal with (economic, social and environmental) problems threatening sustainability (Mulà *et al*., 2017; UNESCO, 2017). Educational institutions apply different strategies to embed sustainability in curricula and facilitate competences such as future thinking, critical and creative thinking, participation and participatory learning, partnerships and systemic thinking (Tilbury and Mulà, 2009; UNESCO, 2017). These strategies include, for example, using the 17 Sustainable Development Goals (SDGs) as a tool to link subjects and learning outcomes with sustainability (Rajabifard *et al*., 2021), contextualizing sustainability content within local, disciplinary and professional contexts related to students' experiences and surroundings (Guerra and Holgaard, 2019) and connecting capabilities within sustainability to careers and career paths (Thomas and Depasquale, 2016), among others. As sustainability capabilities extend beyond just knowledge and an understanding of environmental and social issues, ESD also aims to facilitate attitude and behaviour change and to promote competences through guiding principles such as self-directed learning, participation and collaboration, problem orientation, inter- and transdisciplinarity and the linking of formal and informal learning (UNESCO, 2017). As these principles share many similarities with those of problem-based learning (PBL), PBL has been suggested as a method for integrating sustainability into higher education and particularly engineering education (Lehmann *et al*., 2008; Mulder *et al*., 2012; Holgaard *et al*., 2015; Guerra, 2017; Quelhas *et al*., 2019).

Similar to ESD, the PBL research community, originating as far back as the late 1960s and 1970s (Kolmos and de Graff, 2014), argued for contextually embedded and authentic real-world problems as a point of departure for both single-discipline and interdisciplinary learning. However, designing appropriate problems, scenarios and problem-based projects suitable for ESD and EESD poses a challenge in and of itself as it requires researchers and educators to "integrate" and collaborate across disciplinary boundaries (Mulder *et al*., 2012). Even when PBL is implemented at the institutional level, the full integration of sustainability is continuously challenged by crowded and academic-centred curricula, the struggle to balance different contexts with professional, interdisciplinary and collaborative knowledge and the tacit presence of sustainability (Guerra, 2017), thus highlighting the need for educational institutions themselves to transform in the pursuit of transformational education (Dobson and Bland Tomkinson, 2012).

Integrating interdisciplinarity into PBL for sustainability

In the literature, different approaches and concepts have been used to describe the cross-disciplinary field or "integrated research", one key barrier being the lack of common language and an understanding of what the term means across disciplines, thus creating space where the term is used, and changed, differently depending on the discipline (Stock and Burton, 2011). Interdisciplinary approaches to research and education stem from the need to address the interface of problems from ever-evolving human and natural systems; hence, fields that were previously perceived as interdisciplinary may be considered as disciplinary today, each with its own epistemological and ontological foundation and methodological approaches (National Academy of Science, 2005). While interdisciplinarity is the most common term used to describe integrated research, other

terms have been adopted to embrace the diverse stages in interdisciplinary research, ranging from "borrowing" to "multidisciplinarity", "(narrow and broad) interdisciplinarity" and "transdisciplinarity" (Klein, 2010; Stock and Burton, 2011). A spectrum of interdisciplinary variation is integrated into PBL to varying degrees:

- *Borrowing* refers to the use of methods, theories and skills originating from other disciplines, often with no other interaction with that specific field; a natural part of many problem identification and analysis phases in PBL, particularly in engineering education, in which students "borrow" methods from the social sciences and humanities to analyse and include the problem field and its stakeholders (Guerra, 2017).

- *Multidisciplinarity* refers to one or more disciplines producing individual contributions or "expertise" through a thematic frame to an often project-driven common goal with no attempt to cross the disciplinary boundaries. In PBL, multidisciplinarity is often seen in bigger courses, or clusters of sub-disciplinary courses, as well as in particular product-oriented projects in which a number of student groups work in parallel on the same or complementary elements or work packages in product development (Kolmos *et al*., 2020; Graham, 2021).

- *Interdisciplinarity*, as opposed to multidisciplinarity, refers to settings that enable iterative processes of defining and redefining problems in more complex and often "real-world" settings, pushing the participating researchers to create new knowledge by crossing disciplines and paradigms and to examine the existing knowledge and approaches through a new lens. The participants must agree on a joint focus and common methodologies and tools, adding complexity to the collaborative processes from one researcher joining another discipline to large groups of disciplines learning to communicate and collaborate in a joint effort. In interdisciplinary projects, a distinction is often made between "big" and "small" settings (Stock and Burton, 2011) or "narrow" and "broad" interdisciplinarity (Klein, 2010), referring to the degree to which the collaborating disciplines are inherently distant from one another. In PBL, both narrow interdisciplinarity and broad interdisciplinarity occur, especially between courses; however, broad interdisciplinarity can be difficult to integrate while also achieving the learning outcomes defined in formal curricula, thus historically often being limited to extra-curricular events, like case competitions and hackathons or distinct limited programmes or capstone projects (MIT, 2017; UCL, 2015).

- Finally, *transdisciplinarity* refers to the integration of a variety of disciplines as well as participatory approaches including "non-academic participants" in real-world settings. It is also sometimes used to describe the emergence of entirely new interdisciplinary disciplines, such as new educational programmes or even entire educational institutions (London Interdisciplinary School, 2020).

Variation in PBL for sustainability: from single-discipline problems and "borrowing" to interdisciplinary complex problem solving and networked learning

A distinct feature of the Aalborg PBL model, a systematic approach to PBL practised at AAU since 1974 (Askehave *et al*., 2005), is that the students define problems to work on themselves. Students spend half their time (approximately 15 ECTS per semester) working in project groups of five to seven students and through this develop discipline-specific knowledge, collaborative skills and competences in defining, analysing and solving problems (Kolmos and de Graff, 2014). However, the majority of problems still tend to be discipline specific and simple in nature. According to Klein (2010), the drive for interdisciplinary projects is exogenous; that is, the complexity of the problem defines how to approach it. Thus, fully integrating inter- and transdisciplinary competences into PBL for sustainability at AAU calls for more diversity and complexity in both problem orientation and project constellations (Kolmos *et al*., 2020) to provide more opportunities to reflect on the variation in terms of complexity, scientific approach, project structure and team size (see Figure 1).

Based on the distinctions and definitions above, different project types have been developed and implemented at AAU, ranging from the most common single-discipline semester projects in smaller teams of four to seven people to large-scale interdisciplinary megaprojects in networks of clusters of up to five groups each, spanning a total duration of 2–3 years (see Figure 1). In megaprojects, the SDGs provide a contextual framework for networked collaborative learning, and as such they act as an umbrella project framing a thematic setting for a shared field of interest with varying degrees of interdisciplinarity, ranging from narrow interdisciplinary projects between closely related disciplines to large-scale projects spanning entire programmes and scientific paradigms.

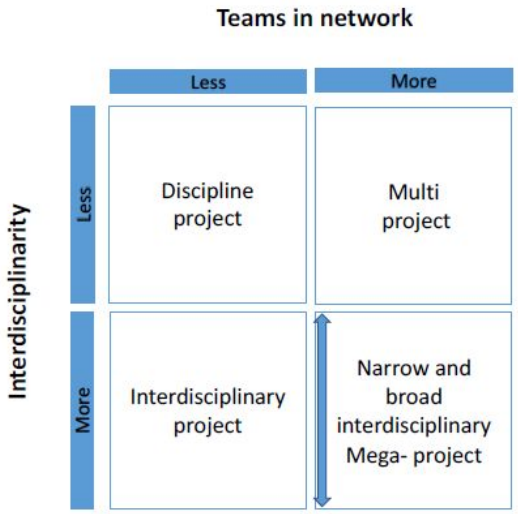

Figure 1. Variations in project types at AAU (Kolmos *et al*., 2020)

The vision for ESD at AAU is thus characterized by the addressing of sustainability as a complex broad inter- and transdisciplinary thematic frame branching into subsequent broad or narrow interrelated challenges that students can engage in while still achieving the learning outcomes and time frames outlined in the formal curriculum. By allowing students to work across disciplines and paradigms, the intention is to strengthen both discipline-specific knowledge and skills and PBL and ESD competences, such as self-directed

learning, participation and collaboration, problem orientation and interdisciplinarity, as they co-construct and integrate knowledge into a shared understanding of a common issue (Kolmos *et al*., 2020). However, the initial findings show that the interaction between groups and students within specific challenges in a megaproject is often categorized by multidisciplinary rather than interdisciplinary collaboration and that students' awareness of and engagement with diverse disciplines is still rather limited (Routhe *et al*., 2020). This points to a specific need to study practical experiences, processes, potentials and challenges related to the interdisciplinary framing and facilitation within the projects from the perspective of students, teachers and the institution as a whole.

AAU Megaprojects: a case study on PBL for sustainability in practice

The first AAU megaproject was launched in September 2019 and, so far, three megaprojects have been run: "Simplifying Sustainable Living" (2019–2021), "The Circular Region" (2019–2021) and "Better Together" (2020–2022).[1] To illustrate the internal, scalable structure of a megaproject (see Figure 2), "Simplifying Sustainable Living" was organized into three sub-themes (*focus areas*), further specified in up to two *challenges* each. Each challenge can contain a number of *clusters* (each involving up to five student groups of four to seven students). As an example, five challenges ran during the spring semester of 2020, divided between the two megaprojects (of these, three groups were single-student "teams" of master's students), and, in the autumn semester of 2020, six clusters were formed, five within the new megaproject "Better Together".

In the initial phase of the megaproject, each student group was required to choose a challenge of interest, and the student groups were distributed in clusters based on an initial project idea and description. Specifically, in autumn 2020, open pre-project workshops were organized to recruit students to the megaprojects and start-up seminars were facilitated in both autumn 2020 and spring 2021 to support collaboration in the early problem identification and analysis phases of the projects.

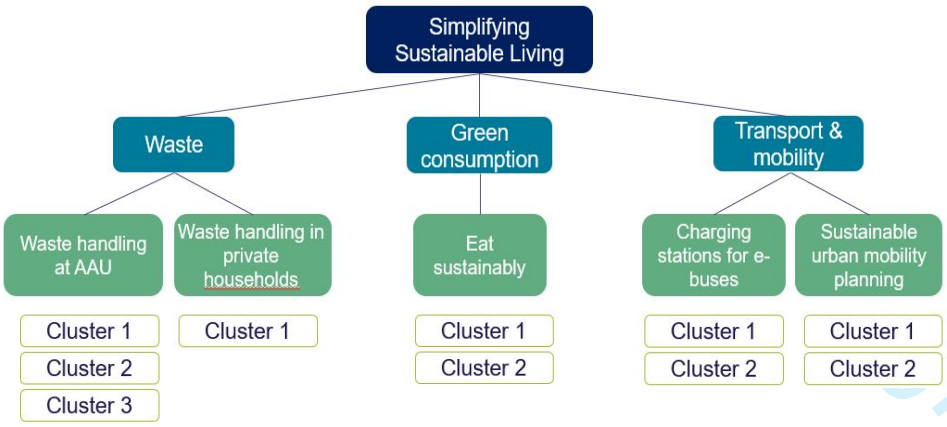

Figure 2. The structure of the AAU megaproject "Simplifying Sustainable Living"

To ensure that the megaprojects are in fact interdisciplinary and to guarantee the authenticity of themes, focus areas and challenges, an interdisciplinary group of faculty members assesses and further develops each theme in collaboration with private and public stakeholders. It is a requirement that a megaproject is relevant to at least four faculties, whereas focus areas must be relevant to at least three faculties and challenges must be relevant to at least two faculties, one in addition to the faculty hosting the particular megaproject. Joining a megaproject is currently not compulsory and thus to some extent is considered extra-curricular; however. the majority of megaproject activities work in tandem with program-specific activities and are fully credited in semester projects. Through this structure, it is possible for the students to take part in interdisciplinary and large-scale collaborative work and networked learning while adhering to the time frame and attaining the learning outcomes given within specific semesters and programmes (Routhe *et al*., 2020).

To promote interdisciplinary collaboration among the participating groups, the central megaproject administration organizes a number of joint products and collaborative activities throughout the semester (see Figure 3). In 2019 and spring 2020, these included a minimum of two seminars (midterm and end of term), four deliverables and participation in an online SDG module. In the autumn of 2020, a start-up seminar was added to this list. All the activities in the clusters are intentionally student led, that is, organized and coordinated by and for students, to facilitate self-directed learning, problem orientation and collaboration, concluding with a joint contribution to the final AAU Megaproject Conference at the end of each megaproject period. The aim of the seminars is to share and synthesize the preliminary findings and problem analyses, with deliverables contributing to ongoing reflection and knowledge sharing within the groups, while the online module provides a common framework for approaching the SDGs. At the Megaproject Conference, the participating clusters present their joint contribution to knowledge and solutions to stakeholders, invited researchers and potential future participants, serving as a kick-off for the next megaproject semester (AAU, 2019).

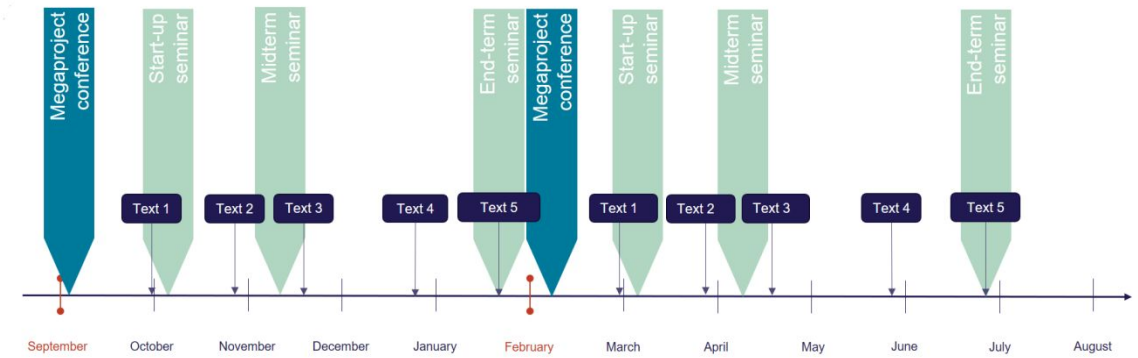

Figure 3. Timeline of collaborative activities in a megaproject

To provide each cluster with a platform for communication and information sharing, the administration offers a digital space for online collaboration before the cluster formation. In 2019, Moodle was used as a platform, but a transition to Microsoft Teams was initiated

by spring 2020. One group worked explicitly with an external stakeholder who also had access to this forum, providing the students with the knowledge required to identify and analyse the relevant problems collectively in this specific case. Still, initial research has shown that students request more feedback and facilitation (Routhe *et al*., 2020) and often experience the collaboration as parallel and multidisciplinary rather than integrated, questioning the purpose and effectiveness of the joint products and collaborative activities currently framing the projects (Routhe *et al*., 2020).

Framing and facilitating interdisciplinarity in PBL: a theoretical framework

Regardless of whether the context is sustainability or something else entirely, adopting an interdisciplinary approach to research and education requires framing and facilitation. Discipline-specific structures and understandings must be "broken down" to create space for meetings and interaction across disciplines (Klein, 2005).

A significant challenge in ESD and interdisciplinarity in a wider context is to foster adequate cohesion between disciplines through the transfer of knowledge (Klausen, 2014). Cohesion can be understood as an element serving multiple interests in different settings and transfer as referring to both the transfer of new knowledge between disciplines and the awareness of the existing knowledge, skills and understandings present in a discipline. Some of the most characteristic forms of transfer and boundary-crossing competences are the following (Klausen, 2014):

- Transfer of factual knowledge, theories, methods, models and skills
- Modes of collaboration and organization
- Meta-competence
- Disciplinary self-consciousness
- Problem selection
- Framework construction and motivation

In addition, systems thinking skills and mega-cognitive and interpersonal competences such as networking, critical thinking and team leadership are considered essential for future employees working in interdisciplinary teams to understand, navigate, manage and share knowledge in interdisciplinary settings (Lautamäki and Saarikoski, 2020). These "boundary-crossing competences" that facilitate collaboration by acknowledging differences in understanding across boundaries between disciplines, culture and university–society may even create new and transformative outcomes; however, they also require awareness and a change in discipline-specific "routine behaviours" as a starting point for creating new ideas, products and solutions (Fortuin *et al*., 2020).

Elements that are often emphasized as crucial for facilitating interdisciplinary teamwork include considerations regarding the size and stability of the team, the degree to which a common understanding is established through shared information, quality in communication and articulation of language, methods and approaches to bridging disciplines and motivation and willingness to succeed (National Academy of Science, 2005). Interdisciplinary teams should be result driven and work towards achieving challenging goals with clear roles and strong leadership, creating mutuality and

interdependence and an atmosphere in which feedback is part of the process (Klein, 2005).

In traditional PBL, problems are often somewhat scattered, tailored to fit a specific study programme or learning outcome. In an interdisciplinary setting, the problem must serve as a point of departure in and of itself and encourage students to discover links and connections between a complex problem setting and their professional competences and skills (Lautamäki and Saarikoski, 2020) and accordingly manage and create cohesion between disciplines, becoming proper "boundary crossers" (Fortuin *et al*., 2020; Klausen, 2014). However, this requires a learning environment that facilitates the setting for students to explicate and explore boundaries across disciplines and university–society as a way to secure and develop new hybrid or transformed practices of co-creation and reflection (Fortuin *et al*., 2020). Thus, interdisciplinary teamwork moves beyond ordinary coordination and delegation of tasks, creating new interchanges between disciplines. When relating these understandings of the organization of interdisciplinary teamwork, cohesion and transfer to the understanding of interdisciplinarity as more than just "borrowing", often something new emerges from this interplay between disciplines. Transfer is therefore more than just the exchange of information and knowledge but a distinctive contribution from different disciplines, creating a holistic and broad understanding of problem solving.

Combining these perspectives with PBL and ESD principles creates a theoretical framework, enabling the analysis of the ways in which and the extent to which megaprojects manage to frame and facilitate transfer and boundary-crossing competences (Table I):

Table I. Theoretical framework and guiding questions

Transfer of factual knowledge/skills	To what extent do megaprojects facilitate cohesion and transfer of knowledge and skills that extend beyond "borrowing"?
Modes of collaboration and organization	To what extent do megaprojects facilitate new hybrid and transformed practices of co-creation and networking with clear roles and strong leadership, creating the interdependency, quality in communication and articulation of language, methods and approaches needed to navigate and bridge disciplines?
Meta-competence	To what extent do megaprojects facilitate critical thinking, reflection and the discovery of links and connections between complex problem-solving and professional competences?
Disciplinary self-consciousness	To what extent do megaprojects facilitate the "breakdown" of discipline-specific structures, understandings and "routine behaviours" to create space for interaction across disciplines?
Problem selection	To what extent do complex, interdisciplinary problems serve as a point of departure in megaprojects?
Framework construction and motivation	To what extent do megaprojects facilitate systems thinking and the motivation and willingness to succeed in a new, holistic and broad understanding of problem solving for sustainability?

Case study design and methods

To identify the potentials and challenges related to the interdisciplinary framing and

facilitation of megaprojects at AAU, a case study on the practical experiences, processes and outputs from the first three rounds of AAU Megaprojects was conducted and evaluated from the perspective of students, teachers and the megaproject administrative management and working group. The empirical data for the study were collected through observations and follow-up interviews with students, supervisors and interdisciplinary facilitators across different megaprojects and project periods between January and December 2020. A total of 92 students, 5 supervisors and 3 interdisciplinary facilitators (or "challenge proposers") participated in the study, providing nuanced perspectives on the processes of participating in and facilitating interdisciplinary PBL for sustainability.

From September 2019 to January 2021, three megaprojects ran in parallel. The two megaprojects "Simplifying Sustainable Living" (SSL) and "The Circular Region" (CR) ran throughout the entire period, whereas "Better Together" (BT) was launched in September 2020. A total of 24 clusters of student groups were formed in the three megaprojects throughout this time period. Table II provides an overview of the data collected in the case study through observation and individual and focus group interviews with students (st), supervisors (su) and facilitators (fa). Additional data include documents such as project deliverables, syntheses and conference posters as well as recurring meetings with the megaproject administrative management and working group.

Table II. Overview of the data collection

	Project: challenge	*Event*	*Time*	*Type of data*	*Participants*
1	SSL: Eat locally	End of term	Jan. 2020	Observation	17
2	SSL: Waste handling	End of term	Jan. 2020	Observation	10
3	SSL: Eat sustainably	Midterm	April 2020	Observation	17
4	CR: Govern. of circularity	Midterm	April 2020	Observation	6
5	SSL: Urban mob. planning	Midterm	April 2020	Observation	2
6	SSL: Eat locally	-	May 2020	Interview (st)	1
7	SSL: Eat locally	-	May 2020	Interview (st)	1
8	SSL: Eat locally	-	May 2020	Interview (st)	1
9	CR: Waste handling	-	June 2020	Interview (st)	1
10	CR: Govern. of circularity	-	June 2020	Focus group (st)	3
11	CR: Govern of circularity	-	June 2020	Interview (st)	1
12	SSL: Eat sustainably	End of term	June 2020	Focus group (st)	4
13	SSL: Eat sustainably	End of term	June 2020	Focus group (st)	9
14	SSL + CR	-	June 2020	Focus group (su)	5
15	SSL + CR	-	June 2020	Focus group (fa)	3
16	BT: Integrating vulnerable unemployed	Midterm	Oct. 2020	Observation	9
17	BT: Practised inclusiveness	Midterm	Oct. 2020	Observation	11

Due to restrictions related to COVID-19, observations and interviews were conducted physically in the first round in January 2020 and online through MS Teams during the

second and third rounds in the spring/autumn of 2020. As the clusters were forced to meet and interact online only for the majority of 2020, it was possible to observe most interactions within the clusters and with challenge proposers and organizers, albeit with limited means of observing interactions within individual student groups or conducting in situ interviews in these settings. The observations focused on elements such as interaction and interdependency, project management and decision-making processes, leadership and mutual understandings of concepts such as sustainability, complexity and collaboration. In the autumn and spring of 2020, some student groups resigned from the megaprojects halfway through the semester to continue their discipline-specific projects alone. Interviews were conducted with both students who had completed the megaproject period and students who had decided to leave, providing important insights into their expectations and experiences related to their participation as well as challenges in facilitating ongoing motivation and a sense of purpose within the megaprojects. Interviews with supervisors and facilitators/challenge proposers were conducted as focus group interviews providing teachers' perspectives on framing and facilitation across the megaprojects. Here, the focus was on general experiences as well as readiness in relation to the role as an interdisciplinary facilitator, time spent preparing and differences from supervision and facilitation in ordinary semester projects.

While the three megaproject periods were similar in structure and comparable in terms of goals and purpose of activities, they were fundamentally different in nature and not necessarily directly comparable. Thus, the intention of this paper is not to compare or evaluate the success of the three megaprojects but to elaborate on the experiences and perspectives related to the framing of, participation in and facilitation of interdisciplinary PBL for sustainability from a student, teacher and institutional perspective.

Findings

In this section, empirical data from the observations and interviews inform the analysis of megaprojects as a case for systematically integrating principles of ESD and particularly interdisciplinarity into PBL at scale. The analysis focuses on the present interdisciplinary setting of AAU megaprojects as it is currently experienced by students, supervisors and facilitators as well as the potentials and challenges related to the ways in which the megaprojects frame and facilitate transfer and boundary-crossing competences as elaborated in the theoretical framework.

Framework construction and motivation

When asked about their motivation to join the megaprojects, the majority of students pointed particularly to sustainability and the SDGs as key motivators as well as the opportunity to collaborate with students from other disciplines. Furthermore, working with real-life problems, engaging with external stakeholders and participating in something "bigger" were described as motivating factors, with the added complexity of interdisciplinarity and sustainability distinguishing megaprojects from regular discipline-specific semester projects. In this sense, students' initial expectations and goals aligned with the overall intention and framework construction, and the megaproject setting was sufficient for communicating its purpose and recruiting students to the projects. Students also expressed a high degree of willingness to succeed in the projects; however, early in

the process, it became less clear for the students how the structure of the megaproject was supposed to facilitate their collaboration with other disciplines. This was in part due to the fact that clusters and problems were defined and administered centrally and were not sufficiently transparent for the students, who requested more communication and involvement in the process of defining challenges and forming clusters. Similarly, supervisors and challenge proposers questioned the seemingly hierarchical and rigid structure of a megaproject, particularly the secondary "focus area" level, arguing the need for more flexibility within clusters and challenges and better visualization of the interconnectedness of challenges and related SDGs to facilitate systems thinking and reflect better the holistic approach to sustainability issues addressed in the megaprojects.

Problem selection

Though the megaproject themes were initially assessed by an interdisciplinary group of faculty members in collaboration with private and public stakeholders to ensure the authenticity of the challenges and relevance across faculties, the group projects still had to align with the learning outcomes in the formal curriculum developed outside the framing of the megaproject and not necessarily aligned within a cluster. Thus, the interdisciplinary collaboration was often driven by the structure of the megaproject rather than the nature of the problem. Clusters were formed administratively based on students' initial problem statements and their connection to relevant challenges, and, while start-up workshops were organized in the second and third rounds of megaprojects to create space for collective problem analysis and mutual adjustment, these were not sufficient to facilitate the desired interdependency within the clusters and challenges. Thus, groups often tended to work in parallel on related problems rather than developing a shared understanding of a common issue and negotiating relevant solutions. However, in clusters in which the interdisciplinary challenge proposer had a more active role in facilitating a collaborative process of defining and analysing the challenge and related problems, students found it easier to see where their projects interlinked and how they could contribute to each other.

Transfer of knowledge, theories, methods, models and skills

In addition to the start-up workshops, the megaproject administration required different joint products and collaborative activities to enhance the interdisciplinary setting for the students. The purpose of the megaproject conference and the midterm and end-of-term seminars as well as the deliverables between them was to help the students in framing and connecting their group projects to the megaproject challenge and to facilitate the transfer of knowledge, theories and methods between groups in the clusters. When asked about their experiences with these products and activities, students from all three rounds of megaprojects pointed out the challenges and frustration related to the fulfilment of their expectations. For instance, whereas the midterm seminars were put in place to help students to align problem analyses and define common goals and contributions, students experienced these as more of a "status seminar" for reporting only, with little integration of shared knowledge for the future. Both students and supervisors also requested a better alignment with the formal curriculum and semester timelines and clearer communication from the administration about the requirements and assessment criteria. One student suggested a seminar focusing on the creation of a common understanding of sustainability

in general and an alignment of expectations within the megaproject, similar to a group and supervisor agreement.

Several groups expressed difficulties in linking project findings and transferring knowledge between groups in the clusters, and the midterm observations support this. Whereas the students were capable of presenting state-of-the-art knowledge and preliminary findings to each other, they seemed unsure of the overall aim of the sessions and how to integrate the presented knowledge into their own projects. Several students requested more supervision, particularly in relation to integrating discipline-specific knowledge into the overall topic of the megaproject and sustainability in general, more feedback on deliverables and more help with adjusting projects to shared findings and outcomes. In clusters in which the "challenge proposer" took a more active role in this process, for example participating in initial meetings with stakeholders and attending the midterm seminar to give feedback on individual projects and joint deliverables, this helped to facilitate more discussions about how disciplines and sub-projects within the cluster were interconnected. However, it also pointed to the need for clarification of the role of "challenge proposer" and a balance between instruction and facilitation as some students tended to address this role as somewhat of a "project owner", shifting the initiative from the students to the teacher and thus challenging the principle of self-directed learning.

Modes of collaboration and organization

Since communication mostly happened online through Microsoft Teams, it was possible to observe how and to what extent communication and interaction occurred among the groups outside the seminars as well and to what extent peer feedback was utilized within the clusters. Here, this space was observed to be particularly useful for communication and planning immediately before and just after the midterm seminars. In this period, most clusters scheduled meetings and shared documents and relevant literature across groups and disciplines. However, after the midterm seminar, the interaction decreased considerably in all the clusters. Some groups requested a joint follow-up meeting, often with little or no response from the other groups in the cluster. It is difficult to determine whether this was due to COVID-19 restrictions and the general pressure from isolation and emergency remote teaching; however, it highlights the need for ongoing facilitation to ensure communication and peer feedback throughout the project period.

Some clusters decided that the purpose of the midterm seminar was too complex to achieve in one meeting, thus dividing it into two sessions (a "knowledge-sharing" meeting and a "working meeting"), with some days for reflection between them. This approach enabled the students to elaborate and reflect on the information received in the first meeting before making suggestions for integration in the second meeting. One cluster in particular utilized this structure to find common ground in its problem statements and seemed more motivated to work on the joint deliverables, which the members explained helped to bridge the disciplinary boundaries further and guide the meetings. However, most other groups and clusters found deliverables to have a weak or no impact on their own projects or to be too loosely structured to generate precise enough input. One group explained that being slightly ahead of deadlines turned deliverables into extra documentation and a "control mechanism" rather than a tool for facilitating collaboration and the integration of new

knowledge. This points to a need to redefine the purpose and nature of meetings, activities and joint products designed to frame and facilitate transfer, collaboration and cohesion as well as to reflect on products and processes as part of the development of ESD and PBL competences related to collaboration. This need extends to the supervisors as well, who experienced little to no communication among themselves or with challenge proposers within the same cluster, thus limiting the knowledge exchange and feedback on their approach and skills as interdisciplinary facilitators.

Disciplinary self-consciousness and meta-competence

As student participation was voluntary and still quite limited, student groups in clusters were often from the same or similar scientific paradigms, particularly in the first round of megaprojects. In the second and third rounds of megaprojects, substantial effort went into recruiting students from all five faculties at AAU and creating diverse clusters with broad interdisciplinary representation across different semesters. Whereas this approach ensured that megaprojects adhered to the initial definition as broad interdisciplinary projects, one could argue that it also compromised the principle of the problem as the point of departure and boundary object throughout the process. Similarly, disciplinary self-consciousness was not particularly prevalent, except when the clusters spent extra time on midterm seminars or explicitly challenged the composition of their cluster. In these cases, the clusters were to a greater extent aware of and articulated knowledge gaps or "missing disciplines", arguing that specific disciplines outside their own could have contributed to the challenge or critically assessing the overrepresentation of a specific discipline within a cluster, creating competition or a comparison of competence levels rather than collaboration. However, this aspect highlighted the potential for developing meta-competence regardless of the success of the interdisciplinary boundary crossing, as students were able to reflect on why collaboration was difficult and articulate expectations and learning goals for themselves regarding their future professional work. The observations and interviews supported this conclusion, particularly pointing to the potential for facilitating meta-competence through progression in interdisciplinarity (i.e. from narrow to broad interdisciplinary collaboration) as older, more experienced students often acted as facilitators in discussions and generally expressed a higher level of disciplinary distinctiveness and self-consciousness and thus a greater ability to identify and challenge disciplinary "routine behaviours".

Summary and discussion

This section summarizes and discusses the empirical findings in relation to the theoretical framework to illustrate the different needs, potentials and challenges related to the framing and facilitation of interdisciplinary and integrated learning and makes suggestions for experiments to develop the megaproject concept further as an institutional strategy to educate for sustainable development at AAU (see Table III).

Framework construction and problem selection

Sustainability and the SDGs provide a highly motivating framework for students; however, one major challenge in the current megaproject concept is the evident difference between the authentic process of identifying and analysing real-world sustainability issues and responses and the way in which groups and clusters are currently formed. Whereas

interdisciplinary collaboration for sustainable development is usually based on naturally emerging problems and incorporates iterative processes for aligning theoretical, methodological and epistemological approaches and perspectives, this is not currently the case in megaprojects. Interdisciplinary groups of faculty members predefine the focus areas and challenges within the megaprojects, and students themselves do not play much of a role in the processes of identifying and negotiating the overall goals, clusters and collaborative products. The one cluster that did implement steps to align problem statements and workflows by distinguishing between the "knowledge-sharing" and the "work" phase of their project seemed to achieve greater success in aligning problems and projects and was thus more motivated to collaborate to reach its goals. Thus, involving students more at all levels, that is, defining megaproject themes and challenges, project management and administration as well as facilitation and supervision through peer feedback and mentoring, could increase participation, improve motivation and retention and facilitate self-directed learning within megaprojects.

Collaboration, organization and transfer

Most students, supervisors and facilitators agree that interdisciplinary collaboration is a critical professional competence, often explicitly stated in the professional competence profiles in the formal curriculum. However, students find it difficult to transfer their experiences and competences from regular single-group and discipline-specific semester projects to large-scale interdisciplinary megaprojects and networked learning. The nature of megaprojects requires students to coordinate and manage much of the collaboration in the clusters themselves and through this to establish and agree on the guidelines needed, which is a challenging task simply because it is new to the students. One student mentioned that "self-directed facilitation" was possible only if the students had the right tools and methods for it, for example team roles, leadership skills and communication tools. These are all competences that these students learn and express in regular semester projects but seem particularly challenging or missing in this new interdisciplinary setting. Even though a semester project supervisor is assigned to all the student groups and an interdisciplinary facilitator to all the clusters, these roles are not clearly defined in this new interdisciplinary setting and are thus confusing for both students and supervisors. Furthermore, supervisors and facilitators were not initially awarded additional hours to supervise megaprojects and, in some cases, the focus of the megaproject was not sufficiently aligned with the formal learning goals within the existing curricula, further challenging the facilitation and assessment. This points to a need to align expectations not only between students and supervisors but also at the department, faculty and university levels to ensure institutional anchoring and the allocation of extra resources to the supervision and facilitation of ESD competences and particularly the interdisciplinary collaboration necessary to manage problem-based and networked learning at scale. In addition, some students and supervisors experienced the organizational structures of the megaprojects as inhibiting collaboration, emphasizing overlapping dates, timelines and deadlines across programmes as being particularly challenging for cross-faculty collaboration. This highlights a need for greater flexibility within both megaprojects and study regulations to allow projects that cross boundaries between disciplines and programmes to varying degrees as well as more coordination to ensure that megaproject activities and structures do not conflict or compete with local structures and activities in individual departments and programmes.

Disciplinary reflection and meta-competence

Finally, whereas many clusters were similar in terms of scientific paradigms and research epistemology in the first three rounds of megaprojects, the few clusters that did include groups of students with diverse backgrounds (e.g. engineering and humanities) experienced challenges related to culture, academic language and the alignment of problems. This shows the need to implement measures to articulate the background, approaches and methods as well as facilitating awareness of disciplinary language and "routine behaviours" to ensure common ground early on in the problem analysis and encourage reflection throughout the project period. Thus, in addition to the allocation of additional resources related to supervision and facilitation, there is a need for reflective tools to support meta-competence, such as online resources and learning modules for complex problem-solving competences, agile project management and interdisciplinary communication and leadership as well as new practices and methods for assessing and awarding these competences. Slowly scaling up interdisciplinary collaboration through progression from multidisciplinary or narrow interdisciplinary clusters and "meso" projects (e.g. within one semester, one programme or one faculty) to broad interdisciplinary megaprojects across faculties may also be a way to facilitate ongoing reflection and meta-competence and support students by providing varied and diverse project experiences and gradually increasing their complexity.

Table III. Summary of the potentials, challenges and suggestions for further developing the megaproject concept at AAU

Framework construction and problem selection	*Potential*	Students are highly motivated by sustainability issues and the SDGs, interdisciplinary collaboration, real-world problem solving and stakeholder involvement
	Challenges	A rigid megaproject structure and conflicting goals in the formal curriculum challenge interdisciplinary collaboration and result in students working in parallel with little boundary crossing and integration
	Suggestions and experiments	- The problem as the driving force for creating clusters - Involving students in defining megaproject themes, challenges and clusters - Flexibility within the structure of projects and the curriculum, opening up the possibility of fully integrating megaprojects, that is, as accredited electives
Collaboration, organization and transfer	*Potential*	Interdisciplinary collaboration is considered a crucial professional competence, and the megaproject setting provides a complex interdisciplinary setting that is not otherwise available in regular PBL
	Challenges	Students find it difficult to transfer experiences, knowledge and methods from regular semester projects to large-scale interdisciplinary and networked learning

	Suggestions and experiments	- More supervision and feedback, particularly in the early stages of the megaproject, including supervisor networks for knowledge sharing and collaboration - Digital tools to support collaborative learning and the visualization of the megaproject as a network of interlinked challenges and projects - Experiments with interdisciplinary project groups, for example in combination with disciplinary "expert" groups
Disciplinary reflection and meta-competence	*Potential*	Students become aware of and reflect on disciplinary "routine behaviours" and limitations
	Challenges	Students lack the language and tools to articulate and bridge culture, background, approaches and methods
	Suggestions	- Integrating learning goals specifically related to PBL and ESD competences - Reflective tools and online resources to support meta-competence and assessment - Implementing progression in interdisciplinary collaboration through project variation

Conclusions and future work

This paper explores large-scale interdisciplinary megaprojects as a case for systematically integrating the principles of ESD into PBL at scale and presents potentials and challenges related to interdisciplinary framing and facilitation from student, teacher and institutional perspectives based on a case study of the first three rounds of *AAU Megaprojects* in 2019 and 2020. The findings indicate that interdisciplinary megaprojects have the potential to motivate students to engage in sustainability issues and develop important professional competences related to interdisciplinary collaboration; however, challenges particularly related to self-directed and student-organized boundary-crossing collaboration created uncertainty and a wish for more structural guidance that is otherwise usually undertaken by students themselves in regular single-discipline semester projects. With the present megaproject structure, students lack the means and competences to manage complex and collaborative problem solving confidently in an interdisciplinary setting, resulting in reduced interaction and limited interdisciplinary collaboration (leaning towards multidisciplinarity or "borrowing" rather than interdisciplinary integrated research) as well as experiencing issues with student retention within the megaprojects. Furthermore, the preliminary findings indicate that the current rigid structure of megaprojects influences students' experiences of interdisciplinarity, supervisors' and challenge proposers' engagement with the clusters and the overall success of the megaprojects. Thus, whereas the megaproject concept has the potential to facilitate new practices in PBL for ESD, more flexibility is needed in both megaprojects and formal curricula to allow fully for broad interdisciplinary collaboration and further prioritize student involvement, self-directed learning and the development of collaborative and reflective competences related to problem-based and networked learning for sustainable development.

This research is ongoing, and the next steps include evaluating the adjustments made in the fourth and fifth rounds of megaprojects in 2021 along with integrating the experiences and suggestions of students, supervisors and interdisciplinary facilitators into cross-faculty scenario development and participatory workshops to develop and improve further the megaproject concept and implementation at Aalborg University. Future work includes evaluating experiments by integrating progression in interdisciplinary collaboration through variation in problem and project complexity, increasing the collaboration with companies and international universities and the provision of AI-supported qualitative feedback and assessment of ESD and PBL competences. Finally, for higher education and society in general to be able to adopt new practices, policies and procedures, prioritization at all institutional levels and the bridging of disciplinary boundaries in society are necessary. Funding is required to create new research infrastructure and collaborative practices as well as the time and resources needed for new cultures, language and boundary-crossing competences to emerge and evolve. In real-world settings, interdisciplinary teams materialize and dissolve in response to emerging problems in an open system that is fluid over time. Thus, when designing for interdisciplinarity in a learning outcome-based educational setting, even with the inherent fluidity of problem-based and contextual learning, flexibility and facilitation are needed as well as continuing examination of potentials for and barriers to interdisciplinary collaboration within and between systems. In this way, framing and facilitating interdisciplinary megaprojects as an institutional (and global) strategy to educate for sustainable development is an interdisciplinary and complex (mega)-project in and of itself.

References

AAU (2019), "Megaprojects", available at https://www.megaprojects.aau.dk/ (accessed 31 October 2020).

Askehave, I., Prehn, H.L., Pedersen, J. and Pedersen, M.T. (Eds.) (2005), *PBL: Problem-Based Learning*, Aalborg University, Aalborg.

Dobson, H.E. and Bland Tomkinson, C. (2012), "Creating sustainable development change agents through problem-based learning: designing appropriate student PBL projects", *International Journal of Sustainability in Higher Education*, Vol. 13 No. 3, pp. 263–278. https://doi.org/10.1108/14676371211242571

Fortuin, K.P.J., Post Uiterweer, N.C., Gulikers, J.T.M., Oonk, C. and Tho, C.W.S. (2020), "Training students to cross boundaries between disciplines, cultures and between university and society: developing a boundary crossing learning trajectory", paper presented at the SEFI Annual Conference, 20–24 September, Enschede, the Netherlands. In press.

Graham, R. (2021), "Giraf Project. Collaborative Engineering Education in the Digital Age (CEEDA)", available at https://www.ceeda.org/case-studies/giraf-project/2021-03 (accessed 9 July 2021).

Guerra, A. (2017), "Integration of sustainability in engineering education: why is PBL an answer?" *International Journal of Sustainability in Higher Education (Print Edition)*, Vol. 18 No. 3, pp. 436–454. https://doi.org/10.1108/IJSHE-02-2016-0022

Guerra, A.O.P.D.C. and Holgaard, J.E. (2019), "Contextual learning for sustainability", Leal Filho, W. (Ed.), *Encyclopedia of Sustainability in Higher Education Springer*. https://doi.org/10.1007/978-3-319-63951-2_340-1

Holgaard, J. E., Hadgraft, R., Kolmos, A., & Guerra, A. (2015), "Strategies for education for sustainable development – Danish and Australian perspectives", *Journal of Cleaner Production*, Vol. 112, pp. 3479–3491.

Klausen, S.H. (2014), "Transfer and cohesion in interdisciplinary education", *Nordidactica – Journal of Humanities and Social Science Education*, No. 1, pp. 1–20.

Klein, J.T. (2010), "A taxonomy of interdisciplinarity", Klein J.T. and Mitcham, C. (Eds.), *The Oxford Handbook of Interdisciplinarity*, Oxford University Press, Oxford, pp. 15–29.

Klein, J.T. (2005), "Interdisciplinary teamwork: the dynamics of collaboration and integration", In Derry, S.J., Schunn, C. D. and Gernsbacher, M. A. (Eds.), *Interdisciplinary Collaboration, An Emerging Cognitive Science*, Psychology Press, New York, pp. 23–50.

Kolmos, A., Brogaard Bertel, L., Egelund Holgaard, J. and Routhe, H.W. (2020), "Project types and complex problem-solving competencies: towards a conceptual framework", in Guerra, A., Chen, J., Winther, M. and Kolmos, A. (Eds.), *Educate for the Future: PBL, Sustainability and Digitalisation 2020*, Aalborg University Press, Aalborg University, Denmark, pp. 56–66.

Kolmos, A. and de Graff, E. (2014), "Problem-based and project-based learning in engineering education", Johri, A. and Olds, B.M. (Eds.), *Cambridge Handbook of Engineering Education Research*, Cambridge University Press, Cambridge, pp. 141–161.

Lautamäki, S. and Saarikoski, L. (2020), "Interdisciplinary teamwork as basis for innovation competences development", paper presented at the SEFI Annual Conference, 20–24 September, Enschede, the Netherlands. In press.

Lehmann, M., Christensen, P., Du, X. and Thrane, M. (2008), "Problem-oriented and project-based learning (POPBL) as an innovative learning strategy for sustainable development in engineering education", *European Journal of Engineering Education*, Vol. 33 No. 3, pp. 283–295.

London Interdisciplinary School (2020), "A new undergraduate degree", available at: https://www.londoninterdisciplinaryschool.org/ (accessed 9 July 2021).

MIT (2017), "New engineering education transformation (NEET)", available at: https://neet.mit.edu/

Mulà, I., Tilbury, D., Ryan, A., Mader, M., Dlouhá, J., Mader, C., Benayas, J., Dlouhý, J. and Alba, D. (2017), "Catalysing change in higher education for sustainable development: a review of professional development initiatives for university educators", *International Journal of Sustainability in Higher Education*, Vol. 18 No. 5, pp. 798–820. https://doi.org/10.1108/IJSHE-03-2017-0043

Mulder, K. F., Segalas, J., & Ferrer-Balas, D. (2012), "How to educate engineers for/in sustainable development", *International Journal of Sustainability in Higher Education*, Vol. 13 No. 3, pp. 211–218.

National Academy of Science (2005), *Facilitating Interdisciplinary Research*, The National Academies Press, Washington, USA.

Quelhas, O.L.G., Lima, G.B.A., Ludolf, N.V.-E., Meiriño, M.J., Abreu, C., Anholon, R., Vieira Neto, J. and Rodrigues, L.S.G. (2019), "Engineering education and the development of competencies for sustainability", *International Journal of*

Sustainability in Higher Education, Vol. 20 No. 4, pp. 614–629. https://doi.org/10.1108/IJSHE-07-2018-0125

Rajabifard, A., Kahalimoghadam, M., Lumantarna, E., Herath, N., Hui, F.K.P. and Assarkhaniki, Z. (2021), "Applying SDGs as a systematic approach for incorporating sustainability in higher education", *International Journal of Sustainability in Higher Education*. https://doi.org/10.1108/IJSHE-10-2020-0418

Routhe, H.W., Brogaard Bertel, L., Winther, M., Kolmos, A., Münzberger, P. and Andersen, J. (2020), "Interdisciplinary megaprojects in blended problem-based learning environments: student perspectives", paper presented at the 9th International Conference on Interactive, Collaborative and Blended Learning (ICBL2020), 14–16 October, MC Master University, Hamilton, Canada.

Stock, P. and Burton, R.J. (2011), "Defining terms for integrated (multi-inter-trans-disciplinary) sustainability research", *Sustainability*, Vol. 3, pp. 1090–1113. ISSN 2071-1050.

Thomas, I. and Depasquale, J. (2016), "Connecting curriculum, capabilities and careers", *International Journal of Sustainability in Higher Education*, Vol. 17 No. 6, pp. 738–755. https://doi.org/10.1108/IJSHE-03-2015-0049

Tilbury, D. and Mulà, I. (2009), *Review of Education for Sustainable Development Policies from a Cultural Diversity and Intercultural Dialogue: Gaps and Opportunities for Future Action*, UNESCO, Paris.

UCL (2015, 5 August), "The Integrated Engineering Programme (IEP) and how it works. Teaching & learning", available at: https://www.ucl.ac.uk/teaching-learning/case-studies/2015/aug/integrated-engineering-programme-iep-and-how-it-works (accessed July 2021).

UNESCO (2017), "Education for sustainable development: learning objectives", UNESCO Representation in Brazil, Brasília, available at: https://unesdoc.unesco.org/ark:/48223/pf0000247444_eng (accessed 9 July 2021).

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[1] https://www.megaprojects.aau.dk/