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Integrating the Integration: The Role and Challenges of Problem-Based Learning in Bringing Together Social Science and Humanities (SSH) and Science, Technology, Engineering and Mathematics (STEM)

Antonia Scholkmann, Nikolaj Stegeager, Richard K. Miller *

ABSTRACT

This paper provides a conceptual elaboration of the role of Problem-based Learning (PBL) in the integration of social sciences and humanities (SSH) with science, technology, engineering, and mathematics (STEM), and an analysis of the challenges this brings about. SSH-STEM integration is an endeavor that is timely, relevant, and urgent given the insufficient answers that higher education provides to the challenges social science and (especially) humanity faces. PBL can be argued as a pedagogical model to naturally cater to this demand. Based on two cases of integrated study programs from Aalborg University, Denmark, we analyze and discuss challenges and potential pitfalls in integrating SSH and STEM. As a result, we pinpoint learnings that can serve as timely guides in future iterations of problem-based, inter- and transdisciplinary endeavors in higher education.

Keywords: Interdisciplinarity, Academic integration, Problem-based learning

INTRODUCTION

> It is probably true quite generally that in the history of human thinking, the most fruitful developments frequently take place at those points where two different lines of thought meet.
>
> Werner Heisenberg

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* Antonia Scholkmann, Department of Culture and Learning, and Institute for Advanced Study in PBL, Aalborg University, Denmark
Email: ansc@ikl.aau.dk
Nikolaj Stegeager, Department of Culture and Learning, and Institute for Advanced Study in PBL, Aalborg University, Denmark
Email: nikolaj@ikl.aau.dk
Richard K. Miller, Olin College of Engineering, United States
Email: richard.miller@olin.edu

Over the last decade we have witnessed increased interest in breaking down the barriers between academic disciplines within higher education as part of inter- and transdisciplinary approaches to teaching and learning (Borrego & Newswander, 2010; Grant & Patterson, 2016; Pohl, 2011). Especially integrating social sciences and humanities (SSH) with science, technology, engineering and mathematics (STEM) programs has attracted interest from academic mangers, businesses and professional educators. In this respect, we have seen an increase in (case) studies that seek to investigate the dynamics, effects and value of such an integration, even though research in this area is still quite limited and suffering from methodological limitations (Committee on Integrating Higher Education in the Arts, Humanities, Sciences, Engineering, and Medicine et al., 2018).

Not least in the wake of disruptive change the COVID-19 pandemic triggered and the increased awareness of the massive and extremely complex challenges that our collective society faces, voices have been raised that SHH perspectives should play a vital part in teaching *any* subject or study program in order to prepare students to act upon the burning questions of the 21st century (Morgan Jones et al., 2020; Walker, 2009). However, it must be noted that there is a tendency to argue for SSH integration into STEM with what can be called an “add-on” perspective, i.e., adding “soft” competences to an overall “hard” curriculum. These include critical thinking, communications skills, the ability to work well in teams, content mastery, improved visuospatial skills, and improved motivation and enjoyment of learning (Committee on Integrating Higher Education in the Arts, Humanities, Sciences, Engineering, and Medicine et al., 2018). In contrast, problem-based learning (PBL), especially in its project-based form, has long been argued to be a pedagogical model deeply ingrained with the integration of different disciplinary approaches; PBL is considered to have the potential to re-think especially STEM subjects in totally new perspectives (e.g., Miller, 2021).

Problem-based Learning (PBL), specifically in its project-oriented version (Kolmos et al., 2019), can play a specific role in SSH-STEM integration beyond a competence-oriented add-on perspective. This can be attributed to PBL’s historical and conceptual entanglement with a critique of disciplinary thinking. However, also at universities and in programs practicing PBL, iterations of SSH-STEM integration have not been naturally successful in the past. Based on theory of organizational change and the role of disciplines in higher education it can be asked under which conditions PBL’s inherent quality of transcending disciplinary boundaries will unfold, and what can be done to allow this approach to unfold its potential in this respect.

To shed light on these questions, this paper analyzes two cases of study programs from Aalborg University, Denmark (AAU), which sought to integrate SSH and STEM a while go, although to various degrees of success. AAU has a long tradition of PBL and has thus always prided itself as an institution that values interdisciplinarity (Jensen, Stentoft, et al., 2019). When founded in 1974, the original idea was that groups of students should work together on authentic, societal problems across academic fields and disciplines. This Danish interpretation of the PBL idea was broadly based on John Dewey's theory of experiential learning (Dewey, 1938) and Oscar Negt's work on adult education and the development of a new European concept of solidarity (Negt & Kluge, 1990/1973). Over the years, AAU, like most other European entrepreneurial universities founded in the 1960s and 1970s, has gradually transformed its PBL practice to resemble teaching at more traditional (and powerful) universities (Collini, 2012). This has in part led to an abandonment of the idea of radical interdisciplinarity in favor of more discipline-oriented project work. However, coinciding with a general increase of interest in interdisciplinary teaching in the educational sector, Aalborg University has begun experimenting with new approaches toward the integration of academic disciplines in the educational programs. However, the university has had somewhat limited success in terms of sustainability and longevity of the respective programs.

In this paper we will explore the potentialities of empowering SSH-STEM integration in educational programs through a PBL-model. As a foundation for this, we initially discuss SSH-STEM integration in light of the well-elaborated concept of interdisciplinarity, and conceptualize the specific role of PBL for transgressing disciplinary boundaries. We will then illustrate potentialities and challenges regarding interdisciplinary integration by analyzing two recent cases from Aalborg University. This analysis will be based on publicly accessible material and studies and in this sense takes a synthesizing qualitative meta-analytical approach. In our final discussion we will elaborate how learnings from the two cases can be used as foundations for the design of new and more integrated pedagogical SSH-STEM approaches based on PBL principles. With this, we are seeking to answer the following question:

> *What are the potentialities and challenges for PBL-based interdisciplinary integration, based on an analysis of two cases from Aalborg University, and what conclusions can be drawn for future SSH-STEM integration at a PBL university?*

CONCEPTUAL UNDERPINNINGS

Academic disciplines and the call for interdisciplinarity

It is almost a banality to state that the academic world and hence also higher education pedagogies are heavily rooted in academic disciplines as categories of social order (for an elaboration, cf. e.g., Chettiparamb, 2007). Turner (2000, after Chettipramb 2007), tying disciplines to the profession and professional work, defines disciplines as:

> (…) collectivities that include a large proportion of persons holding degrees with the same differentiating specialization name, which are organized in part into degree-granting units that in part give degree-granting positions and powers to persons holding these degrees. (p.47).

Others argue that disciplines should be distinguished by the specific area of knowledge that they define, and be understood as "thought domains – quasi-stable, partially integrated, semi-autonomous intellectual conveniences – consisting of problems, theories, and methods of investigation" (Aram, 2004: 380). Both definitions state that academic disciplines are characterized by distinctive traits that render it possible to distinguish them from one another based on their specific practices and paradigms. Furthermore, the academic disciplines hold the capacity to distinguish and attract privileges. In this regard, disciplines are institutions of power and resources, and members of a specific discipline will often go to great length to protect the privileges and opportunities that belong to a certain discipline (Sarangapani, 2011). Such protectionary measures entail the use of a highly coded language that is non-accessible to outsiders, and scientific explanations of world phenomena that almost always rest on answers based on internal logic from within the discipline (cf. Fleck, 1980; Kuhn, 2012).

In opposition to the tendencies of academic disciplines to differentiate and distinguish, the programmatic call for interdisciplinarity has been heard frequently over at least the last 50 years, and in various iterations – often prioritizing the enactment of the concept in teaching over its enactment in research. In 1972, the OECD published the seminal report "Interdisciplinarity: Problems of Teaching and Research in Universities" (OECD, 1972), in which the authors, based on their extensive review of literature and practices in higher education, advocated for a more adventurous approach to interdisciplinary practice at universities. According to the authors, an interdisciplinary approach would increase innovation at the universities, reduce the gap between professional practice and university training and reduce the social costs of overspecialization.

Definitions and dimensions of interdisciplinarity and academic integration

Already in their 1972 report, the OECD distinguished between more loosely coupled and more interwoven forms of interdisciplinarity. Based on the OECD's (1972) original typology, Klein (2017) proposes using the terms *multidisciplinarity, interdisciplinarity* and *transdisciplinarity*. M*ultidisciplinarity* typically means that various disciplines contribute based on their specific paradigms to answer to a common problem, either at the same time or by sequentially applying ideas from multiple disciplines to the focal problem. A more binding way of collaborating is through *interdisciplinary* approaches in which scholars work jointly, albeit from each specific disciplinary stance to work on a common problem. The third mode of operating, *transdisciplinary* approaches, require

> (…) not only the integration of discipline-specific approaches, but also the extension of these approaches to generate fundamentally new conceptual frameworks, hypotheses, theories, models, and methodological applications that transcend their disciplinary origins, with the aim of accelerating innovation and advances in scientific knowledge. (Hall et al., 2012, p. 416)

Though by far not the only attempt to distinguish between different forms of interdisciplinarity, this tripartite taxonomy seems to be the most widely used. Other differentiations make distinctions based, for example, on whether representatives of different disciplines work together *parallelly at the* same time or *sequentially* after one another (Begg & Vaughan, 2011); if the collaboration is *punctual* or *permanent*; and what the *focus* of the collaboration is (Klein, 2017). In terms of the more recent term 'integration', it can be said that integration linguistically has been understood as "the process of combining two or more things into one" (Cambridge Dictionary, n.d.), with a specification that "integration across s.th." can entail also a "reduction of differences" (ibd.). A more scientific point has been provided by The Subcommittee on Interdisciplinary Teaching at Emory University, in which *pedagogical integration* is defined as:

> (1) the enrichment of one discipline by use of the language, methods, or canons of one or more other disciplines; or (2) the common inquiry into universal themes, such as health, justice, or violence, using the language, methods, and canons of two or more disciplines. (after Chettiparamb, 2007, pp. 31)

As inferred from these elaborations, (academic) integration can be understood as synonymous with interdisciplinarity, which we will therefore use from here on as the dominant wording.

Integration of various disciplinary approaches into teaching has been suggested to take place under various contingencies, such as the *level of implementation* (course or program), whether students come from *one or different academic programs*, how *far apart their specializations* are, how *long the pedagogical activity is scheduled to last* and if this activity is *part of the general curriculum or scheduled as an extra-curricular activity* (Ashby & Exter, 2019). Additionally, Jensen et al. (2019) have pointed out that the enactment of interdisciplinary approaches in higher education can be operationalized either so that various disciplinary approaches are *represented through different participants*, such as students from different academic programs; or so that the various disciplinary approaches are *represented through the provision of learning content*, which is selected under an interdisciplinary focus.

Problem-based Learning (PBL) as a "natural blueprint" for academic integration across the disciplines

As Klein (2017) points out, already in the initial OECD (1972) report, interdisciplinarity and academic integration were thought of as arising when knowledge creation is conceptualized in relation to working on real-world problems. It is precisely in this focus that the Aalborg PBL model in particular provides an almost "natural" blueprint to bringing this intention to life.

The Aalborg PBL model is just one of several variations of the problem-based learning approach (Scholkmann, 2020) and, together with Roskilde University, the AAU-model represents a Danish interpretation which, in its original form, was very much about modelling a democratic process (Milner & Scholkmann, forthcoming). Concretely, in the Aalborg PBL model students work in groups on a self-defined problem, often over the course of an entire semester. They "own" both the problem and the process and work with an academic facilitator. Their learning process is supported by more traditional forms of learning, such as attending lectures, workshops and seminars and self-study. The dominant form of assessment is a written project report that is defended orally in front of internal and external assessors (cf. e.g., Kolmos et al., 2004).

Considering the roots of PBL in the Deweyan notion of learning through engagement with authentic problems, the circularity of the process and the societal relevance attributed to learning outcomes, it becomes quite obvious that the problems addressed here lean towards interdisciplinarity (Thomassen & Stentoft, 2020). Also, gaining experience in collaborating in groups for the sake of learning can be considered a nucleus for exchange of thoughts about and across boundaries (personal, conceptual, disciplinary) that can be instrumental also in interdisciplinary project work (Jensen, Ravn, et al., 2019). Related to this, Ravn (2019) has pointed out that interdisciplinary project work is not about establishing the one right answer to a problem (in the positivistic sense). Instead, it must be considered as an ongoing establishment of a joint language:

> (…) Thus, interdisciplinary project work can be interpreted as a production of knowledge that is unique to a very specific and contextualized problem formulation [*i.e., a research question – annotation by the authors*], which means that it could be the only scientific approach with exactly this particular setup. (Ravn, 2019, p. 67).

In this sense, each PBL group process can be understood as the formation of a new community in which knowledge is constructed and reconstructed to fit the very specific and contingent project. Creatively expressed, each PBL group forms their own academic discipline, thus providing, in a nutshell, a call to understand disciplinarity as a human invention whose current form emerged contingent on somewhat arbitrary circumstances

(Collini, 2012). In this regard, PBL values the often-mentioned belief that breakthroughs in research more frequently occur at the boundaries of disciplines (e.g., Chettiparamb, 2007; Gibbons et al., 2015; Nowotny et al., 2003). Hence, parsing problems into a particular academic disciplinary framework, we simultaneously take them out of context and create limitations in the ability to see connections and approaches for solutions (cf. also Klein, 2021).

Interdisciplinarity: potentialities and challenges

Arguments for interdisciplinarity both in research and teaching have been predominantly based on normative and pragmatic demands (cf. Chettipramb 2007 for further elaborations). Empirical evidence on the learning outcomes of concrete integration of specifically SSH topics and methodology with STEM subjects is scarce and mostly inconclusive, as it often suffers the problem of independent variables (Graff, 2016). Despite these shortfalls, evidence from evaluative studies suggests that the integration of SSH with STEM can foster a range of beneficial learning outcomes such as critical thinking abilities, higher-order thinking and deeper learning, content mastery, problem solving, teamwork and communication skills, together with high motivation and preparedness for suitable jobs in respective industries (e.g., Committee on Integrating Higher Education in the Arts, Humanities, Sciences, Engineering, and Medicine et al., 2018; Ernest & Nemirovsky, 2016; Gurnon et al., 2013; Ghanbari, 2015; Scholl et al., 2014; Stolk & Martello, 205 C.E.) A strict focus on (measurable) gains in learning, motivation and competences can, however, cloud the fact that what lies at the heart of an interdisciplinary program should not (merely) be relatively short-term individual learning gains, but the ability to work collaboratively towards answering not yet well-elaborated, complex challenges.

As Weingart (2000, p. 26) states, it is quite paradoxical that so many reports, textbooks and public funding calls proclaim, demand and hail interdisciplinarity, supported by empirical evidence, while at the same time discipline-based education largely prevails. When the OECD, in the paper “Interdisciplinarity Revisited” (Levin and Lind, 1985), revisited the concept of interdisciplinarity a decade after the initial 1972 report, the conclusion was that university practice had remained mostly unchanged and the authors concluded that interdisciplinarity had lost its momentum.

Elaborations on challenges when integrating disciplines have been part of the literature on interdisciplinarity from the beginning. Already in 1972, OECD listed several challenges for universities striving for interdisciplinarity in research and teaching. These included: “the rigidity of institutional structures; the rigidity of people involved including resistance offered by disciplinary frameworks, and the lack of facilities” (Chettiparamb, p. 36; cf. also Telléus, 2019 for a more in-depth elaboration of the problems with disciplinary logics for PBL, specifically). Recent publications have taken this up and developed it further. For example, Braßler (2020) identifies challenges to the implementation of interdisciplinarity at the organizational level, team level and individual level. They mention, amongst other things, differences in discipline-based learning conceptions among teachers; incommensurable study regulations; and lack of institutional support as challenges to implement an interdisciplinary program involving both teachers and students from different academic fields. In the same line, Ashby & Exter (2019) have pointed out that "(…) designing an interdisciplinary learning experience requires close collaboration, team planning, and co-teaching of subjects by faculty from different disciplines." (p. 204), with precisely the creation of interdisciplinary exchange amongst co-teaching faculty being a major challenge to the enactment of interdisciplinarity (Richards, 1996, after Ashby & Exter, 2019).

In sum, interdisciplinarity in higher education is a contested field. While intentions are clearly in favor of an increased focus on interdisciplinarity, university practice has not really responded to the many voices calling for interdisciplinary research and teaching. The literature suggests that this dissonance between intentions and practice can at least partly be attributed to the regulating influence of the academic disciplines, which permeate the organization of higher education. However, when it comes to future iterations of academic integration, and the merging of SSH and STEM specifically, other factors can be seen as potentialities and challenges in designing interdisciplinary study programs, especially in consideration of the close entanglement between interdisciplinarity and PBL. Thus, in the following, two cases from Aalborg University is presented to examine potentialities and challenges of academic integration in a PBL-based educational system.

METHOD

Analytical approach

The cases analyzed in this paper are the AAU Megaprojects and the Techno-Anthropology (TAN) program. Both programs ambitiously and successfully integrated disciplines across SSH and STEM with different angles and approaches. However, both have recently experienced problems in terms of longevity and a sustainable interdisciplinary integration: the AAU Megaprojects are currently on hold; the TAN program faces a significant cut in student numbers, with education at AAU's Copenhagen campus being closed down altogether, and only the much smaller program in Aalborg continuing in upcoming years. The fact that neither program, although ambitious and forward-thinking in their PBL-based approach to interdisciplinary integration, could totally secure its existence invites a glance at the specific potentialities they were working with and the challenges they were facing in enacting interdisciplinarity.

Materials

The following analysis is based on publicly accessible information about the cases studied. Hence, an in-depth scrutiny of complex dynamics and micropolitics is not in the focus. We will instead rely on materials such as study program descriptions and self-presentation of the programs on their homepages as well as on academic writings in published books and journals elaborating the pedagogical design as well as on evaluation reports. The analysis of the AAU Megaprojects was based on the following material: The website and subsites of the Megaprojects (*Megaprojects*, n.d.; *What Is a Megaproject?*, n.d.; *For External Parties*, n.d.; *Simplyfing Sustainable Living. Fall 2019 - Spring 2021*, n.d.) and the academic evaluative papers by (Bertel et al., 2022) and Routhe et al. (2021). The analysis of the TAN program was based on the presentation of the program on AAU's website (*Bachelor Technoantropoligi*, n.d.); the presentation of the program's pedagogy and learning goals by Bruun (2019) as well as the program's competence profile in Karadechev et al. (2021); and the elaborations on the program in Børsen & Botin (2013). This will be supplemented with evaluation reports on the programs (Institut for Planlægning, n.d.-c), minutes from study board meetings (Institut for Planlægning, n.d.-a) and an evaluation report by the interest organization Danks Industri (Aziz, 2020). Moreover, we rely on press coverage regarding the partial closure of the program announced in 2022 by Baggersgaard (2022) and by Ravnsted-Larsen (2022).

Framework for the analysis

To shed light on potentialities and challenges within the program we will apply the framework by Braßler (2020) as a starting point. As elaborated above, Braßler (2020) distinguishes challenges to the enactment of interdisciplinarity in PBL-programs on the organizational, the team/group and the individual level. These also mirror some of the classical layers of organizational learning (Berson et al., 2006); however, we will supplement the taxonomy with an inter-organizational perspective (Ingram, 2017). For each of the two cases, we will also focus on potentialities as well as challenges for a more nuanced picture.

ANALYSIS

Presentation of the two cases

AAU Megaprojects

AAU Megaprojects were launched in 2019 as a new interdisciplinary initiative across the university. Megaprojects strive to bring together students from different faculties, disciplines and specializations. Each Megaproject centeres around a *central theme* which must be routed in one or several of the UN Sustainable Development Goals (SDGs; United Nations, 2015). To ensure that the Megaprojects were in fact interdisciplinary and to guarantee the authenticity of themes, an interdisciplinary group of faculty members assessed and developed each theme in collaboration with private and public stakeholders

(Bertel et al., 2022). The central theme is broken down in *sub themes* (focus areas) and further specified in *challenges*. Thus, in the first AAU Megaproject Simplifying Sustainable Living one focus area was “to reduce use of plastic” with one of the underlying challenges being “to avoid plastic in daily shopping” (*Simplyfing Sustainable Living. Fall 2019 - Spring 2021*, n.d.). Each challenge can contain several *cluster*s, each involving up to five student groups of four to seven students, coming from a specific academic field. As a result, a cluster could contain groups from sociology, engineering, business, computer science and philosophy, among others, all addressing the same challenge but from their specific academic perspective, while at the same time sharing knowledge and insights with the other groups within the cluster (cf. figure 1).

At the end of each semester, the university hosted a Megaproject conference for project participants, invited researchers and stakeholder representatives as well as potential future project participants and facilitators. At the conference participants presented the current state-of-the-art knowledge and proposed solutions from all project clusters in each Megaproject. Even though the ideas behind the Megaprojects were highly acclaimed by managers and academics, they were also subject for criticism (see below) and development of new Megaprojects was subsequently put on hold in 2021 while the team behind the projects evaluated the experiences and addressed some of the problems in the setup (Routhe et al., 2021). At present no announcement has been made as to the future of the Megaprojects.

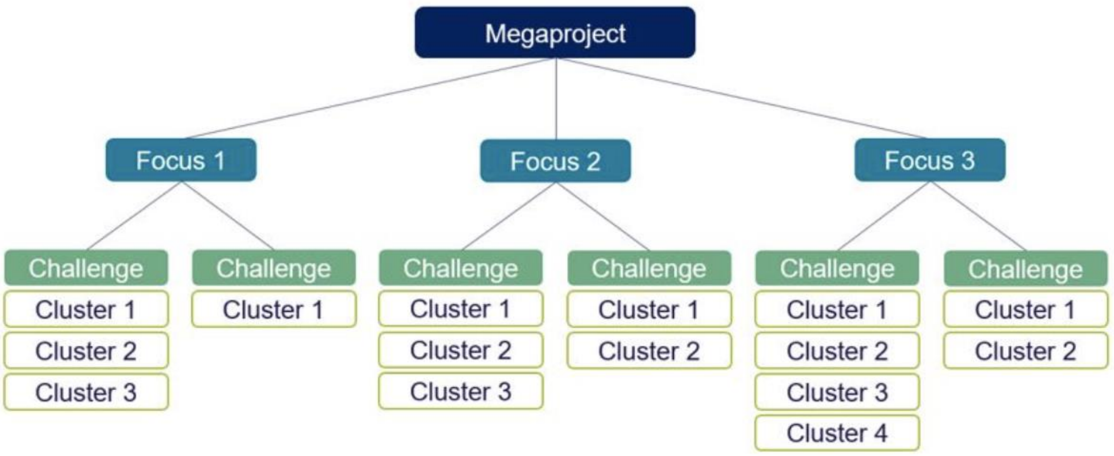

Figure 1. Structure of AAU Megaprojects (What is a Megaproject?, n.d.).

The Techno-Anthropology program (TAN)
Offering a bachelor and master’s degree, the TAN program runs at AAU’s campuses in Aalborg and Copenhagen, respectively. The program was established in 2011 (bachelor) and 2012 (master), and has, from its beginnings, prided itself on being a truly

interdisciplinary program. The trademark metaphor of the education is “the bridge”, since its aim is to bridge technical understanding with anthropological- and ethical analysis (Bruun, 2019). The program has always been very aware of the different forms of academic integration and its ambition is thus to achieve “transgressive interdisciplinarity” (Bruun, 2019: 38). With an explicit PBL approach, participation requires that students work on problems that address social challenges related to the human-technology interface, combining knowledge and methodology from the fields of technology, anthropology and ethics (Karadechev et al., 2021). Courses in the program are co-taught by teachers from different departments, and project groups are co-supervised by two supervisors from engineering and humanities, respectively (Bruun, 2019).

The program’s far-reaching transdisciplinary approach is intended to provide the students with competences to act as mediators between human actors and technology (*Bachelor Technoantropoligi*, n.d.). Notably, these competences have also been underpinned by a theoretical model (Børsen, 2013a) that defines three central competencies within the techno-anthropological field, which can only be acquired through an interdisciplinary education. The first is interactional expertise which is described as “the mastery of the language of a domain” (Collins & Evans, 2007, p. 30, after Børsen, 2013a). The second is social responsibility, i.e., individuals’ ability to orient themselves based on their own ethical orientation system (Børsen, 2013b). The final competence is anthropology-driven design, which is the ability to combine the Scandinavian model of participatory design with classic anthropological field research (Børsen, 2013a) (cf. figure 2).

Despite meeting high interest with students, AAU’s board and central leadership decided in the spring of 2021 to close the Copenhagen campus program and thus only continue with the much smaller program in Aalborg (Baggersgaard, 2022).

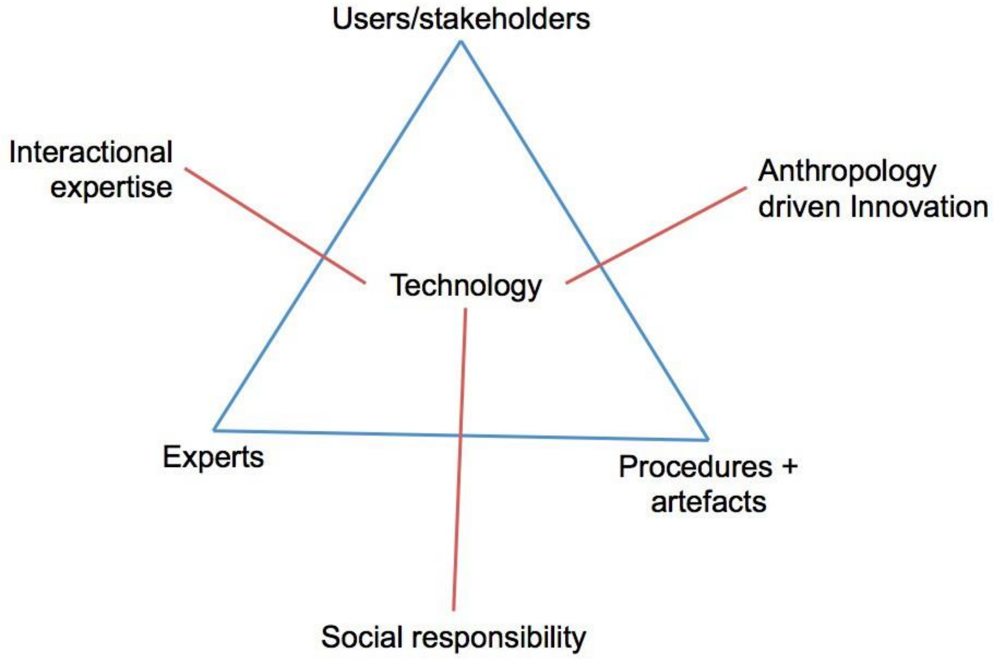

Figure 2. The techno-anthropological field (Botin, 2013).

Potentialities and challenges within the two cases

As evident in the two cases, integrating interdisciplinarity into academic education is no guarantee of success. Different potentialities and challenges seemed to foster and hinder the success of the two programs, sometimes detrimentally. Table 1 provides an overview of the outcome of our analysis.

	AAU Megaprojects		***The Techno-Anthropology program***	
Analytical level (after Braßler 2020; Ingman, 2017)	*Potentialities*	*Challenges*	*Potentialities*	*Challenges*
Individual/ student	Excitement about working with Sustainable Development Goals and interest in the interdisciplinary setup of the project	Declining appreciation for the interdisciplinary experience over the course of the program	High student interest, intake and good evaluations	Lack in feeling of cohesion within the program
Team/group	Increased understanding of other disciplinary perspectives through in-cluster communication by the students	Quality and intensity of collaborations depended on the engagement of individual teachers or student groups	Closely collaborating team of teachers	Power struggles amongst groups of teachers; additional time needed for coordinating and developing a joint practice

Organizational	Alignment of university teaching on a common goal; joint practice across disciplines	Differences in "project-logics" across the participating faculties and departments Tensions with the pre-set structure of the disciplinary programs	[no information retrievable from the documents]	Disputes on economy and authority between departments
Inter-organizational	Excitement about a new approach to PBL and interest in Sustainable Development Goals as a lever for university-industry collaboration	Difficulties in finding suitable partners due to the specific prerequistes of the program (collaboration with large private or public organizations)	Graduates as bridgebuilders between in-company departments and different professional perspectives	Low employment rate amongst graduates

Table 1. Potentialities and challenges for interdisciplinary integration in the two cases.

Potentialities and challenges within AAU Megaprojects

For the AAU Megaprojects, the material provided a rich source on the individual/student level, as especially the evaluations on the program dove deep into the student perspective. As a potentiality here, the students' excitement about engaging with SDGs in a project can be highlighted, hence an *interest in the interdisciplinary setup of the project* was evident across student evaluations (Bertel et al., 2022: 1182). However, as a challenge, students expressed *declining appreciation for the concrete interdisciplinary experience*, raising uncertainty on how to live up to the interdisciplinary demands stated in the program setup, and how to align engagement in the (extracurricular) Megaprojects with the disciplinary logics of their regular studies (Bertel et al., 2022: 1182f). As an effect, students, contrary to the intentions behind the program, chose to work in discipline-oriented groups and clusters, as coordinating with peers from other disciplines was experienced as difficult, time-consuming and with little relevance for their final grade (Routhe et al., 2021: 175f.).

The challenges experienced at the individual/student level seemed to be closely intertwined with challenges at the organizational level, as the resources integrated in the analysis showed. With this university-spanning interdisciplinary initiative the *differences in the "project logics" of the different faculties* required what (Routhe et al., 2021) have called "coordination in a decoupled system" (p. 179), being that students performatively worked in an interdisciplinary manner, whilst in fact reverting to working in disciplinary silos. This coincided with a feeling amongst teachers and local program coordinators that in order to hold the projects together an all too rigid structure was applied in terms of deciding on project topics and focuses, which were pre-set by faculty and stakeholders rather than defined by students themselves (Routhe et al., 2021). Bertel et al. (2022) here state that "the interdisciplinary collaboration was often driven by the structure of the megaproject rather than the nature of the problem." (p. 1183).

At the team level, students expressed appreciation for the opportunity to *learn about other disciplinary perspectives through in-cluster communication*. Talking to fellow students from other disciplinary fields allowed them to not just understand how other disciplines approached the problem that they themselves were trying to solve, but also brought them new perspectives on their own theoretical field. However, it seems that the spreading of the AAU Megaprojects across all faculties and departments also came with challenges in establishing interdisciplinary collaboration, and that the *quality and intensity of collaborations depended on the engagement of individual teachers involved* (Bertel et al., 2022). The same was true in a way for students, who felt that it was put as a requirement upon them to *self-organize towards interdisciplinary collaborations* (Bertel et al., 2022: 1182f).

At the organizational level the Megaprojects have helped to increase an organizational focus on sustainable education across disciplines and educational programs. Thus in 2022 The Times Higher Education Impact Rankings placed AAU as number one amongst all universities in the world on SDG 4 "Ensuring and disseminating quality education that supports global sustainable development". When the rankings were announced, AAU's Vice-Rector stated:

> Our unique pedagogical model of problem- and project-based learning, where student learning is based on real-life issues, directly addresses the UN's global goals. AAU focused on global sustainable development long before it was on everyone's lips. Most recently, our megaprojects involve students across semesters and programs working together to find sustainable solutions (Aalborg University, n.d.)

Although Megaprojects hold the potential for organizational alignment, it was also evident that *differences in 'project-logics' across the participating faculties* was a continuous obstacle. Vast differences in e.g., teaching practices, module setup, academic expectations, student credits amongst participating faculties made it hard to coordinate and create opportunities for actual interdisciplinary collaboration.

At the interorganizational level the AAU Megaprojects show more as a potentiality than as a challenge: based on the self-presenting material, they mainly present as surrounded by *goodwill, excitement about a new approach to PBL and massive interest in the SDGs as a lever for university-industry collaboration* (*Megaprojects*, n.d.; *For External Parties*, n.d.). A potential challenge that did not materialize due to the short life and relatively few realized Megaprojects, is that the scale at which Megaprojects operate requires interorganizational collaboration with quite large organizations (the first two were initiated with one of the biggest municipalities in Denmark). In this respect, one could speculate that it would become increasingly *difficult to find suitable partners* interested in participating in a project of such magnitude. In fact, the third and final megaproject Better Together which premiered in 2021 was without an external partner (*Megaproject: Better Together*, n.d.).

Potentialities and challenges within the TAN program

At the individual/student level, the TAN program was well received more or less from the opening in 2011. The responsible teachers succeeded in explaining the program rationale and intended learning outcomes as well as the interdisciplinary competence profile, resulting in *high interest, student intake and relatively good evaluations* (Børsen & Botin, 2013). However, some challenges at the individual/student level could be found in the student evaluations, in which we see that *students rate the cohesiveness of the education rather poorly*. Students (especially in the first semesters) seemed to find it hard to understand how the different academic fields can be integrated and quite a number feel that they do not get enough help with the integrative task they face (Institut for Planlægning, n.d.-c).

At the team/group level the program was run by a *closely collaborating team of teachers*, resulting in highly transdisciplinary teaching content and processes (Bruun, 2019, p. 36). However, these positive working relationships required massive effort to develop and maintain. Thus, teachers had to *spend more time than they normally would* on teacher meetings and seminars. Furthermore, as is evident in the minutes from the study board, the first years was also characterized by academic power struggles in which different academic groups argued for their academic specialty to play a more prominent role in the education (Institut for Planlægning, n.d.-a).

At the organizational level, the material does not give any information about possible potentialities. The challenges at the group level, however, seemed to carry over to the organizational level, resulting in *disputes on economy and authority between departments.* When initially establishing the program two departments (the Technical Department and the Anthropological Department) were to share academic and economic responsibility for the program. Due to the bureaucratic and economic structures of the university, it proved impossible to uphold this joint ownership and the Technical Department was made sole program owner. In 2019 seats on the study board were reallocated following these lines, resulting in only lecturers from the Technical Department holding seats with deciding votes (Institut for Planlægning, n.d.-b).

At the interorganizational level a report from 2021 describes graduates from TAN as *bridgebuilders between in-company departments and different professional perspectives* (Karadechev et al., 2021). Through their education, the graduates acquired competences that enabled them to "engage in dialogue on professional, disciplinary and interdisciplinary topics with stakeholders, and representatives of different professions and disciplines within selected technological domains" (Karadechev et al., 2021: 8). Furthermore, the report documents that graduates work in a variety of different fields both in the public and private sector, often involved in project management, user involvement and user experience or technology assessment, technology planning and technology design (ibid.: 16).

Even though the report emphasized their competences and the job opportunities, in a recent report from the interest organization Dansk Industri (DI, English: *Danish Industry*), TAN was rated amongst the ten technical education programs in Denmark scoring lowest in terms of employment rate among graduates (Aziz, 2020). This was subsequently the primary reason behind the managerial decision to close the program located in Copenhagen. Even though is seems fair to call TAN a success from a pedagogical point of view, the economic world and specifically employers have not shown the same kind of appreciation for the education as the students (Ravnsted-Larsen, 2022). Just as students and teachers can struggle to see the benefits of academic integration, so too can a labor market, where notions of traditional professional competences and professions are prevailing. In this sense it can be said that the biggest challenges that TAN has faced have been at the interorganizational level.

DISCUSSION: INTEGRATION AND DISCIPLINARITY – WHICH WAY FORWARD?

Even though the two cases in some ways draw a rather bleak picture of the potentialities of SSH-STEM integration, we believe that the challenges the programs encountered can serve as a starting point for an elaboration of new and sustainable practices of integration. In this final section we will jointly discuss lessons from the analysis of the AAU Megaprojects and from the TAN program. Although discussing these under three distinct aspects, we of course consider them as being highly intertwined and to be taken into consideration holistically in future endeavors of academic integration.

Balancing structure and freedom through internal alignment

As a first aspect, academic integration (whether SSH-STEM or otherwise) needs to find a balance between a clear structure and the freedom for students and teachers to explore relevant questions. As could be seen with the AAU Megaprojects as an extreme case, the need for providing a clear organizational structure (in this case: across faculties and departments) can sometimes compromise the problem-oriented nature of the interdisciplinary endeavors. The TAN program showed that this was better achieved on a smaller scale. However, a large or "mega" project interdisciplinary program should not per se be dismissed as unfeasible in this sense. By aligning project start dates, departmental expectations and assessment criteria across faculties, some gains could certainly be made here (cf. the recommendations by Bertel et al., 2022). Moreover, full academic interdisciplinarity as a regular part of the study program instead of an extracurricular activity would be beneficial, as suggested in a student project-expertise on the future of the AAU Megaprojects lately (Imre et al., 2021).

In this sense SSH-STEM integration must clearly be a topic at the top level of the university, where (vice) presidents and deans need to discuss how to provide spaces and study conditions under which students from various disciplines can be encouraged to work together in an interdisciplinary manner. However, as can be inferred from the TAN case, the potentially difficult task of practicing interdisciplinarity cannot be placed on students alone, while university teachers comfortably remain in their discipline's distinct department without much inclination for collaboration. Academic integration cannot come to life if only practiced in few places of relatively low prestige (as sadly still the case for teaching). An institution embracing interdisciplinarity in teaching must also walk the talk in other areas, by establishing a culture of integration also in research and knowledge dissemination (Klein, 2021). Also, for academic interdisciplinarity to flourish, research and teaching cannot be perceived as activities existing in separate spheres. Instead, activities in both areas must be co-designed to necessitate reciprocal dialog and foster long-term cooperation among academics and students.

External alignment as a long-term investment

As illustrated in the TAN-case, internal alignment is not necessarily enough in itself to ensure the longevity of an interdisciplinary program. If employers (and thereby society) do not understand the reasons for or see the value of such programs, chances are such initiatives will be short-lived. Of course, aligning teaching and learning with the surrounding world touches upon very fundamental questions about the nature of higher education, and the role that universities should play in it (Hearn, 2003) (Hearn, 2003). With the advent of mass university after World War II, the increased influx of students has changed the university from an elitist and isolated institution for the few, and the university of today must necessarily integrate and involve itself in society in completely different ways than ever before (Rasmussen, 2006).

Generally speaking, it seems fruitless to insist on the academic privilege of the pursuit of pure knowledge for the sake of knowledge itself. However, taking up on the idea of this paper again we want to argue that integration runs both ways, and universities can and should make use of the fact that today much tighter bonds between universities and society exists. We as teachers and scholars must engage in societally relevant discussions about the value of interdisciplinarity. We must argue for our choices and in this way initiate discourses that stress the necessity of interdisciplinarity in the years to come. As so overwhelmingly illustrated by the systemic nature of the SDGs, the most important problems that we face today are systemic and thus by nature interdisciplinary (Capra & Luisi, 2014). Even though businesses might still operate on the basis of a traditional linear logic, it is an academic obligation to argue for the competencies that will be needed in the future not to give in for the demands of today.

Reconfiguration of understandings of STEM and SSH

A third lesson to be inferred from the two cases is that the disciplinary expectancies especially toward STEM-educated professions could benefit from an overhaul when integrating them with SSH-perspectives. As Miller (2021) pointed out in his keynote to the PBL2021 International Conference, positioning excelling in mathematics as the primary signifier for becoming an outstanding engineer is no longer valid in the 21st century. Engineers of the future, so Miller states (2021), should be equally good, if not better, at analyzing the societal challenges they are addressing through their work, and understand the content of engineering subjects as processual rather than factual knowledge.

Integrating SSH aspects into the engineering curricula holds the potential for educating professionals that can envision futures that do not yet exist, thus shaping rather than reacting to the world. This calls for new forms of disciplinarily integrated courses, in which STEM, SSH and business education play a role on equal terms, to educate for a forward-thinking mindset. It also entails understanding emotional well-being and support as part of the educational process, ultimately leading to transformational education experiences. The global challenges humanity will face in just the next decade demand a broader "systems framing" that spans many current disciplines in order to even define the problems, e.g., accelerating global climate change; the re-emergence of global fascism, the Ukraine war, the continuing global pandemic, the expiration of dozens of antibiotics, the epidemic of youth suicide, growing widespread concern over mental health, the unintended consequences of AI, the emergence of a "surveillance economy", and the rapidly growing global economic recession. For all of these massive challenges it stands true that "no amount of emphasis on narrow specialized knowledge (or academic courses) will produce the innovators we need!" Miller (2021). This notion also calls for a reconfiguration of the roles of universities, who must think beyond their current position as providers of specialized knowledge for the next generation, and beyond academic parochialism. To continue to be relevant in an ever more complex world, the university of tomorrow must embrace the urgent need to shape the attitudes, behaviors and beliefs of the next generation. This is key to enabling them to understand the diverse and multi-faceted knowledge that universities produce, and to act upon this understanding.

CONCLUSION

To conclude on our discussion, we can state that, despite the somewhat sobering picture that can be drawn upon reflection of the two case studies elaborated earlier, it is pivotal not to lose faith in the fact that academic interdisciplinarity is a viable goal for the future of academic education. As mentioned above, there are no alternatives to a continued effort to integrate the knowledge and expertise of the academic disciplines if we are to respond to the challenges of today and tomorrow. Extrapolating from major academic change initiatives that one of the authors of this paper was involved in, we will end this paper with five key points that might increase the success of such endeavors:

- First, *keep experimenting.* Looking at innovations in the domain of engineering education, it becomes clear that none of these were perfect solutions in their first version. Iterations and refinement are pivotal to progress, so failing at one attempt should not discourage educational developers from continuing to experiment with what they believe in.
- Second, *start small.* The most successful examples of systemic change in learning models almost always begin as an experiment. This strategy has proven successful because it set low expectations and thus tend to avoid severe criticism at the beginning. While the stakes for a project rolled out at large scale are enormous, a smaller experiment can be enlarged subsequently in later iterations .
- Third, *provide a very clear picture of the problem or concern that you are addressing by integrating different disciplines.* The limitations of each discipline alone make it impossible for any single department to succeed in developing a comprehensive solution. Instead, the need to talk to each other to even frame the problem will lead to changes in behavior across the institution. While this does not always lead to breakthroughs in thinking, it seems to work more often than other approaches.
- Fourth, *engage external stakeholders from the beginning*. When employers are ambivalent about the capabilities of graduates from new non-traditional and highly integrative programs, this can be a sign that they were not engaged in the process of designing the content and pedagogies in the new program. Integrating external stakeholders is crucial, as they potentially will become invested and thus motivatied to contribute to the success of the program.

- Fifth and finally, *don't forget the important role of the students.* If students are invited to be partners in the design and iteration of new pedagogical models, they can become powerful advocates too. In a highly engaging educational environment, students are often willing to exceed requirements and continue their education beyond the end point for the degree to obtain a more comprehensive learning outcome. Experience shows that it is often hard for even the most traditional and conservative faculty member to deny their best students the opportunity to learn in new ways that they are passionate about.

On this note, we would like to close this paper with another quote – both as encouragement and inspiration for the continued efforts of academic developers to keep striving for urgently needed new ways of designing and conducting higher education:

> It ought to be remembered that there is nothing more difficult to take in hand, more perilous to conduct, or more uncertain in its success, than to take the lead in the introduction of a new order of things. Because the innovator has for enemies all those who have done well under the old conditions, and lukewarm defenders in those who may do well under the new. This coolness arises partly from fear of the opponents, who have the laws on their side, and partly from the incredulity of men, who do not readily believe in new things until they have had a long experience of them.
>
> Niccolò Machiavelli (1513)

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