Designing successful and sustainable interdisciplinary PBL in engineering education: A cross-case analysis of System Projects in practice

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Abstract

Interdisciplinary collaboration is considered a key competence for engineers and necessary to solve society's wicked problems in environmentally and socially sustainable ways. However, designing and developing successful and sustainable interdisciplinary PBL-projects that provide students with opportunities to engage in interdisciplinary learning, is no easy task. It requires cross-cutting collaboration, not only between students themselves but also between supervisors and facilitators, study management and administration. This paper provides indicative and explorative insights into potentials and challenges related to designing interdisciplinary PBL, exemplified through an empirical cross-case analysis of the "System Projects" initiative at the Technical Faculty of IT and Design at Aalborg University. Through in-depth interviews with project coordinators, we identify eight dimensions of system project integration and develop a curricular model for mapping variation within system projects: the System Project curricular spiderweb. We discuss key drivers for success and typical challenges, finding that successful interdisciplinary PBL can be achieved when the definition of the type of project is not too rigid, when we provide space for prototyping, experimentation and co-creation between staff, students and stakeholders, and when the objectives are perceived by all involved as engaging and important with purpose extending beyond just academic goals.

Keywords: system projects, interdisciplinarity, engineering education, problem-based learning, curriculum design

1 Introduction

In the face of escalating global challenges such as climate change and rapid technological advancement, the role of engineers is shifting. Contemporary engineering problems are increasingly characterized by their complexity and multifaceted nature, often transcending traditional disciplinary boundaries. Consequently, there is a growing need for engineers to not only provide technical expertise, but to possess interdisciplinary skills that enable effective collaboration across various fields, integrating diverse perspectives to design and develop sustainable solutions (Royal Academy of Engineering, 2025; UNESCO, 2021a). Engineering education is responding to this demand by increasingly integrating sustainability competences into curricula and providing students opportunities to engage in cross- and interdisciplinary learning, for instance, through problem- and project-based learning (PBL), recognizing that real-world problems seldom adhere to a single domain (Habbal et al., 2024; Guerra, Jiang & Du, 2022; Guerra & Rodriguez-Mesa, 2021; Lantada, 2020).

Previous research has categorized these into different project types, each varying in team composition and the breadth of disciplines involved (Kolmos et al., 2024). Among these project types, system projects hold particular significance in bridging the gap between theoretical knowledge and practical application as teams from related engineering disciplines engage to address components of a larger system (Kolmos et al., 2025). However, designing and developing successful and sustainable cross-disciplinary educational projects is no easy task and requires cross-cutting collaboration not only between students but also between supervisors and facilitators, study management, and administration (Routhe et al., 2024; Bertel et al., 2022).

In this paper, we explore the 'System Projects' initiative at the Technical Faculty of IT & Design at Aalborg University (AAU), which was initiated to provide students with opportunities to work across disciplines in PBL projects that strive to make a tangible difference in the world. Through an empirical cross-case analysis, the paper outlines potentials and challenges when integrating interdisciplinary collaboration into PBL curricula and proposes a curriculum model, inspired by the curricular spider web, to map variations herein.

1.1 System projects

While interdisciplinary collaboration is increasingly considered essential for addressing complex, real-world challenges, implementing such collaboration in engineering education presents several difficulties. One major challenge identified in the literature is resource allocation, as effective interdisciplinary teaching demands significant funding, materials, and trained personnel (Christiansen et al., 2023). Limited budgets and institutional priorities can restrict the availability of these resources, making it difficult to support collaborative efforts across diverse disciplines (Bertel et al., 2022). Additionally, collaboration issues arise due to differences in teaching philosophies, communication styles, and levels of commitment among educators, and coordinating across departments thus often involves overcoming organizational silos and aligning varied goals and expectations, which can be time-consuming and complex (Routhe et al., 2024).

Another significant barrier is difficulty in establishing effective communication among students from different disciplines. Different terminologies and perspectives between fields can create misunderstandings and social distance, requiring enhanced efforts to build mutual trust and understanding (Routhe et al., 2021). Furthermore, classical curricula often prioritize disciplinary depth over interdisciplinary integration, making it challenging to overcome institutional barriers and academic silos and align interdisciplinary projects with existing study regulations while ensuring they meet diverse learning objectives (Bertel et al., 2022; d'Escoffier, Guerra & Braga, 2024).

To navigate these challenges, different models of interdisciplinary projects have been proposed, notably system projects and mega/mission projects (M-projects) (Kolmos et al., 2024; 2020). M-projects are large-scale, long-term, and highly complex interdisciplinary projects that require substantial investments and involve multiple disciplines, including both STEM (Science, Technology, Engineering, Mathematics) and SSH (Social Sciences and Humanities). Examples include infrastructure projects, space technologies, and renewable energy systems. The vast complexity and scale of megaprojects pose significant challenges in coordination, resource allocation, and integration of diverse disciplinary perspectives, making them difficult to implement within educational frameworks (Routhe et al., 2021; Bertel et al., 2022). While system projects, too, address and develop complex systems, they typically focus on collaboration among *related* engineering disciplines, such as electronics, material science, production, and civil engineering, illustrating the interdependencies within specific technological systems while maintaining distinct learning objectives for each engineering team (Routhe et al., 2024). This may result in looser coupling between projects, allowing for students to develop discipline-specific knowledge and skills while understanding how different engineering fields contribute to a cohesive whole (Routhe et al., 2024; 2021).

System projects might offer a feasible approach to interdisciplinary collaboration in educational settings due to their manageable scope. Unlike megaprojects, which demand extensive coordination and resources, system projects focus on narrower interdisciplinary collaboration within related engineering fields, making them more practical in terms of implementation, alignment with existing curricula, and engagement in interdisciplinary learning without the need for extensive curricular restructuring. Additionally, system projects provide focused learning objectives by concentrating on the interdependencies within technological systems, offering students a structured yet flexible environment to engage with real-world engineering challenges (Routhe et al., 2024; Kolmos et al., 2024).

To understand the variations, potentials and challenges of integrating system projects in practice in engineering education environments, this paper presents and analyses different and current aspects of system projects in the context of PBL at Aalborg University and develops a curriculum model for system projects visualizing these variations: the System Project curricular spiderweb.

2 Methodology

In this paper, we apply cross-case analysis of five different cases of system project integration at The Technical Faculty of IT and Design. As part of the case selection process, the deputy heads of departments of education at the faculty identified different relevant system projects to be considered relevant as cases for the analysis. The final selection was based on the following two criteria: 1) All selected cases align with the definition of system projects, meaning at least two or more student groups from two or more engineering disciplines are involved in the project, which includes a shared boundary object (Kolmos et al., 2024), and 2) the selected cases reflect the variation of implemented system projects within the faculty, showcasing similarities and differences in the practical implementation of this particular project type.

The final case selection includes five system projects, one from the Department of Computer Science, one from the Department of Sustainability and Planning, and three from the Department of Electronic Systems.

In the data collection process, we focus on project coordinators, i.e. faculty members who initiate, develop and facilitate system projects across programs. We conducted in-depth semi-structured interviews with each of the five project coordinators (one for each of the cases), ranging from 63 to 79 minutes in length. The interviews covered themes such as the history and development of the system project, its structure and institutional framing, distribution of roles within the project (e.g. as facilitator, stakeholder representative, expert, supervisor etc.), progression within the project and expansion across programs, and finally perspectives on the potentials and challenges of system projects at Aalborg University, now and in the future. The full interview guide can be found in Appendix A. The interviews were conducted, recorded and transcribed online through Teams, upon which automated transcriptions were read through and minor corrections made by one of the two interviewers.

Focusing solely on project coordinators presents certain limitations to this study, i.e. prioritizing organizational perspectives on the part of the faculty, and the potentials and challenges related to the implementation of system projects in formal engineering curricula at the involved departments. Thus, the perspectives of students, domain-experts and supervisors, as well as external stakeholders involved in the system projects, that could have provided important additional insights into the potentials and challenges of system projects in engineering education as it relates e.g. to student experiences, learning and collaboration, external outreach and employability, is not included in this study.

The analysis was conducted in three phases including an inductive thematic analysis within each of the five cases, a cross-case comparison (a synthesis overview can be found in Appendix B), and a deductive exploration of cross-case patterns pertaining to specific aspects of system project implementation, which was synthesized into an eight-dimensional curriculum model, allowing for the mapping and visualization of variations in system project implementation.

3 Modelling System Project Dimensions

From the thematic analysis and cross-case synthesis, we identified the following eight dimensions of which each system project represents a particular variation: Curricular integration, system-level orientation, size/scale, interdisciplinarity, vertical integration, sustainability focus, student autonomy and external partnership. Based on these eight dimensions, we have developed a curriculum model for the design and implementation of interdisciplinary system project in engineering education (see figure 1).

This model is inspired by van den Akker’s curricular spiderweb (van den Akker 2003; 2013). However, it is important to note that while Akker’s model, as well as its recent appropriations within interdisciplinary engineering education (Beldad & Miedema, 2025) and Challenge-Based Learning (CBL) (Doulougeri et al., 2024) do indeed reflection curricular variation, the purpose of the original model and previous applications has been to assess curricula and identify “weak links” for improvement. This is not the intention with the System Project curricular spiderweb. Rather, it is to make visible the versatility and diversity of system project design, organisation and implementation and to inspire practice for further development.

In the following, we present this synthesized model (see figure 1) and provide a description of each dimension followed by the results of the cross-case analysis of the five system projects at the Technical Faculty of IT and Design as it relates to specific aspects of the system project variation.

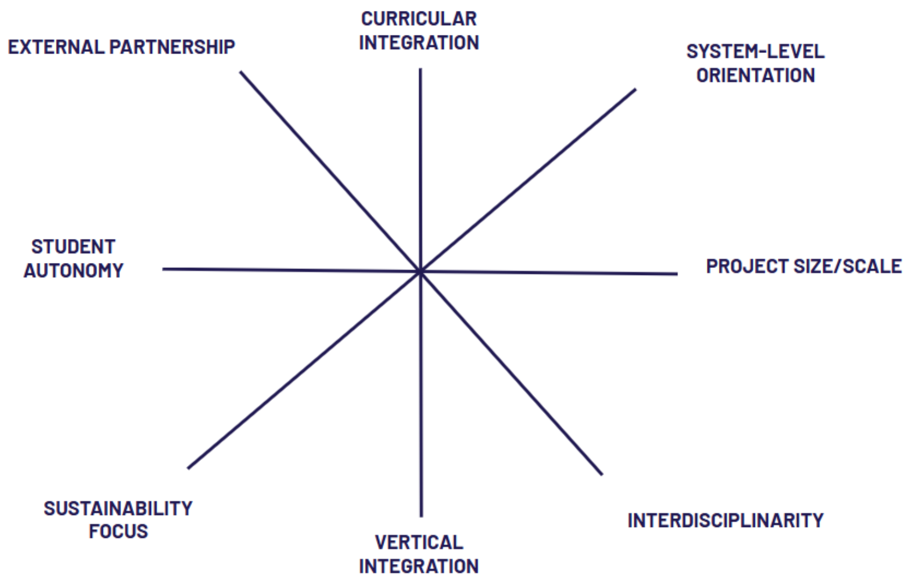

Figure 1. The System Project Curricular Spiderweb

Size/scale refers to the number of students and/or teams involved in the project, typically at least two or more different, but related, discipline-specific teams (Kolmos et al., 2024).

External partnership is the degree to which external stakeholders (e.g. companies, public organisations etc.) are involved in the project and in what role, e.g. either as informant or case on the one end, or as client or even partner at the other end of the spectrum (Holgaard et al., 2020).

Curricular integration refers to whether the project is integrated into the formal curriculum or considered extra-curricular, i.e. whether formal courses and structures support the project and explicit intended learning outcomes for the project are defined and assessed formally through study regulations and exam.

System-level orientation refers to the system perspective within the project. All system projects involve some engineered (non-natural/artificial) system, but the extent to which aspects of system integration and interaction with other boundary (technical, natural or socio-technical) systems are included, varies.

Interdisciplinarity refers to the range of disciplines in the project. In some cases, interdisciplinary collaboration is limited to programs within the same department, whereas other system projects include collaboration across departments and even faculties.

Vertical Integration refers to the extent to which projects are long-term and passed over from one semester to the next to build on lessons from others and strengthen continuity (Strachan et al., 2019). Especially projects that deal with functional solutions or technologies that are to be implemented in real-world environments are rarely completed within a semester. Thus, vertical integration or 'transfer' of knowledge from the previous project is crucial.

Sustainability focus refers to the extent to which sustainability is a focus of the project. In some cases, sustainability issues are key driving forces, while in other cases sustainability is less present or can be integrated as an add-on.

Student autonomy refers to the extent to which students can define the project scope, its problems and solutions, themselves. In some system projects, both problem and solution are pre-defined, and the students produce the best version of said solution through incremental innovation. In other cases, only the problem is defined, and students need to ideate to come up with ideal solutions, and in yet other projects students need to first identify and structure the problem.

4 Case analysis

In the following, we present each of the five cases and the results of the initial inductive thematic analysis, as well as the synthesis and cross-case comparison according to the System Project curricular spiderweb.

4.1 Graphic Interface foR Autistic Folks (GIRAF)

This system project at the Department of Computer Science focuses on ongoing software development of an app designed to support children with autism (Aalborg University, n.d.). The project has been ongoing since 2011. Initially, only students from Software participated, but since 2023 more education programmes at the department, including Interaction Design and Bachelor of IT, have joined and increased its interdisciplinary scope. As such, the project has progressed from a single 'inter-team' or multi-project to a more complex and cross-disciplinary system project that involves both horizontal (cross-disciplinary) and vertical integration, meaning students must describe and 'hand over' their work to the next student cohort to take over. This is explicitly stated and assessed as part of the formal learning goals, to be able to work asynchronously across semesters similarly to a 'real' software development unit, thereby training important competences needed at the labour market. While the project does involve long-term partnership with a special needs school, the system-level orientation is on the digital artefact and its sub-systems (rather than e.g. integration with other socio-technical systems) and the stakeholder acts more as informant or case, with the project coordinator as domain expert and primary point of contact.

4.2 AAU SAT

Satellite-related initiatives at Aalborg University (AAU) commenced as early as 2003, building upon the university's involvement in "The Ørsted Project," which led to the successful launch of Denmark's first exclusively national research satellite in 1999. AAU Student Space emerged, where students at the Department of Electronic Systems have since developed and launched 5 student-built CubeSats during the last two decades (AAU Space, n.d.). These projects are highly student-driven, vertically integrated and extra-curricular, although students can choose to integrate aspects of AAU SAT as a case into their semester project to be formally assessed as well. The overarching objective of AAU's satellite development activities is to cultivate advanced engineering competencies among students, surpassing the conventional learning outcomes of a typical master's degree program. Participants in these complex system-oriented projects include students from academic disciplines such as e.g. Electronic Systems, Antenna Technology and Automation. Throughout the years, over 200 students are estimated to have been part of the project. In AAU SAT, the role of the project coordinator has mainly been to ensure a physical space and infrastructure is available to students (i.e. lab settings and funding) as well as provide expertise in the form of informal and formative feedback during student-organized project meetings.

4.3 AAU SPACE ROBOTICS

Similarly, the AAU Space Robotics project is an equally highly student-driven, vertically integrated and extracurricular initiative where participants design and build robots capable of operating in space environments. Since 2023, students from various disciplines (and faculties) have participated, such as Materials and Production, Industrial Technology, Energy, Robotics, Media, and Design. Student teams compete in The European Rover Challenge (ERC), an international competition where university students from all over the world compete to build the most optimal rover, fostering both academic growth and practical experience (AAU Space Robotics Team, n.d.). Similarly to AAU SAT, the project exemplifies interdisciplinary collaboration and high student autonomy, as students balance this voluntary effort alongside their formal studies, although students have the option to incorporate elements of the initiative into their semester projects. The role of the project coordinator has been to initiate the project and ensure lab facilities as well as support students with fundraising. In some cases, the project coordinator has also supervised semester projects that integrate the system project as a case in their formal education.

4.4 Sustainable Development Lab

This curricular system project initiated in 2023 (IAS PBL, n.d.) with the first mixed-micro group of students participating from Information Studies (Department of Communication and Psychology), Sustainable Cities and Techno-Anthropology (Department of Sustainability and Planning), respectively. Six education programs are currently involved (as supervisors and/or teachers) and all students are invited to join. It is aimed at addressing complex sustainability challenges through collaboration among students, supervisors, and public and private organizations, taking point of departure in the UN's Sustainable Development Goals at a system level. The lab focuses particularly on green transition, encouraging all semester projects to integrate this perspective. It provides a learning framework to develop competences such as adaptability, interdisciplinarity, and systemic thinking, and creates opportunities for hands-on experience in addressing sustainability challenges in systemic ways. The semester projects and scope are made in cooperation with external partners, for example a local amusement park or recycle station. Participation is voluntary but integrated into the curriculum (if students choose the project) and the role of the coordinator has been to align the project with formal learning goals and develop suitable assessment methods (i.e. interdisciplinary exams) as well as act as censor at the exam. At this exam, an examinator and censor is present from each of the participating educational program to ensure the fulfillment of discipline-specific learning goals.

4.5 BRASILIA RECYCLE PROJECT

In 2018, Latin America's largest open landfill in Brasília, Brasil, was closed. This marked a difficult transition for the more than 1,000 children and adults who survived by scavenging for food and items in the garbage. A support program was organized to help waste pickers adjust to the new reality, and this recycle-focused system project emerged in this context, starting as a collaboration between students from AAU and students from the University of Brasília. Today the system project has been extended as part of an Erasmus program. Four countries are involved, with students from the Netherlands, Portugal, Brasilia and Denmark. The students have differentiated learning goals depending on their specific curriculum (or extracurricular activities) and involved education programs but cooperate across countries and educations. In the system project the collaboration across countries is organized deliberately on low dependencies on deliveries and working both synchronously and asynchronously with each other as it fits their specific educational programmes and semester projects.

4.6 Cross-Case comparison

While all five cases share some similarities, e.g. with regard to their focus on the development of a (socio)-technical system and (complex) problems that require interdisciplinary collaboration, they also vary significantly across the eight identified dimensions, as we will elaborate below.

As for the ***size and scale***, some projects are stille quite new, such as the Sustainable Development Lab and Space Robotics, while other projects such as GIRAF and AAU SAT have years or even decades of student cohorts participating. With regard to scale, most of the cases could be scaled up to mega- og mission (M) projects i.e. larger-scale multi-team projects with broad interdisciplinary, and potentially transdisciplinary, collaboration (Bertel et al., 2023; Kolmos et al., 2024), depending on the scope. In particular, projects that deal with contextual implementation and multiple stakeholders, such as the Sustainable Development Lab and the Brasilia Recycle project, however these cases currently focus on specific problems and solutions within the overall system, thus adhering to the system project definition.

As for ***external partnership***, in some projects (such as GIRAF), the role of the external stakeholder is to provide or offer access to specific domain knowledge, data or processes without active involvement in the research or project development, although potentially benefitting from the resulting analyses and solutions. In other projects, the external stakeholder acts more as a ‘client’, defining project scope and objectives, or particular criteria for the solution. This is the case for AAUSAT and AAU Space Robotics, although the external stakeholder in these particular projects (such as ERC) does not necessarily have a specific ‘stake’ in the project and whether it succeeds. In some system projects, external partners and students engage in somewhat of a joint research initiative, both contributing resources and expertise and working together towards shared goals and long-term strategic alliances, through which new system projects can emerge. This has been the case with the Brasilia project, as is the intention with Sustainable Development Lab. These projects share an inherent ***sustainability focus*** (e.g. on green transition and social sustainability), while in other cases sustainability is less present or can be integrated as an add-on (e.g. thinking about sustainable power supplies in space). It could be argued, that while system projects do not always centre on sustainability issues, any project that *do* in fact address sustainability issues must always approach these from a systemic perspective.

For ***curricular integration***, the cases also present different end points of a spectrum. For instance, projects such as AAU SAT and Space Robotic are not explicitly part of the formal curriculum, but students can choose to use a specific aspect of the project (e.g. developing a prototype of a system component) as a case study for their semester project, which is then formally assessed according to study regulations, while other projects such as GIRAF and Brasilia are fully integrated into the curriculum and somewhat mandatory. Although ***student autonomy*** and curricular integration can be related, they are not necessarily interdependent. Formal PBL-curriculum models often will allow for high student autonomy with regards to choice and scoping of problem and project design even though they are formally assessed (as is the case with Sustainable Development Lab), whereas extra-curricular projects such AAUSAT and AAU Space Robotics, despite their very nature as entirely voluntary, might have very specific goals or requirements and thus in principle lower student autonomy with regards to problem definition and solution.

While all projects are concerned with engineered (artificial/technological) systems of some sort, the ***system level orientation*** is somewhat flexible and a matter of 'zooming in or out'. For instance, in the GIRAF project, the focus is on a specific digital artifact (an app) and its integration within one particular context and target group (a special needs school). The project is further divided into sub-systems (e.g. frontend, backend, etc.), thus there is a 'zooming in' and division of work based on system components within this one artifact. This is the case for AAU SAT and Space Robotics too. However, hypothetically, students could eventually 'zoom out' too and look at relevant boundary systems such as the education system, health system, transportation system, energy system, planetary system or any other relevant natural or socio-technical systems that the system of interest could interact with. At the other end of this spectrum are projects such as Sustainable Development Lab and the Brasilia, that take point of departure in overarching and emergent issues or change processes within larger, interconnected and socio-technical system, with multiple stakeholders, technologies and potential target groups, and through this explore ideas for engineered solutions, of which some can be digital artifacts (and thus potentially subject to a subsequent process of 'zooming in'). This aspect thus highlights the need for students to develop systems thinking to understand the interconnectedness of problems, systems and disciplines and to define the boundaries of a given problem and system before designing and developing suitable and sustainable solutions.

This too raises questions about the definition of narrow and broad ***interdisciplinary collaboration,*** and whether it is defined by somewhat artificial institutional boundaries, or whether it relates more to e.g. scientific paradigms and students' experiences of differences in expertise and problem-solving approaches. However, in all cases, the project coordinators were able to identify disciplines outside their domain that could be included in meaningful ways (e.g. social workers or psychologists for GIRAF, or energy engineers for AAU SAT), thus there seems to be a potential to use a system project as a leverage point for 'zooming out' and scaling up to M-projects with broader interdisciplinary participation.

Vertical integration can occur somewhat naturally in system projects that deal with functional solutions or technologies that are to be implemented in real-world environments and thus rarely accomplishable within one semester (such as AAU SAT or Brasilia), or it can be purposefully designed this way as a formal requirement to practice this particular skill (GIRAF). In either case, project coordinator emphasized having a knowledge-sharing platform (such as GitHub) as important to facilitate the transfer of knowledge, solutions, and documentation across student 'generations' and leadership. In some cases, multiple semesters are involved simultaneously, working on different aspects of the solutions, such as the AAU Space Robotics project. However, according to the coordinator, the educational level in and of itself did not entail a certain hierarchy or specify level of leadership or management responsibilities. Rather, this was established based on personal interest or skill. Thus, a younger student could take on the role as project manager and lead their senior peers. The project coordinators all generally reflected on managerial roles and when to share this responsibility with (or leaving it entirely up to) students to support their motivation and their development of leadership skills.Below (figure 2) is a synthesized mapping of the five system projects according to the System Project curricular spiderweb. A mapping of each individual case can be found in Appendix C.

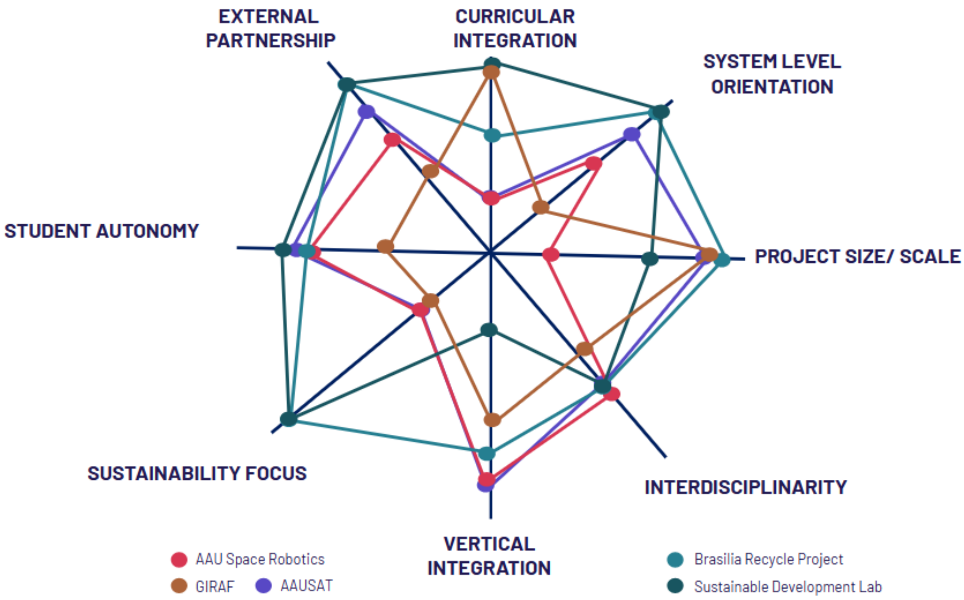

Figure 2. Variation in System Project implementation at TECH

5 Discussion

While such a mapping provides insights into decisions and priorities to be considered when implementing system projects, it is important to note that this mapping only represents a "snapshot" of each case. Projects can grow in scale over time or shift in system-level focus and new external collaboration might emerge between semesters. Similarly, changes can be made with regards to curriculum integration, both vertically and horizontally (e.g. expanding from narrow to broad interdisciplinarity) and formal assessment can be implemented later on with changes in study regulations. In this cross-case analysis, it should also be noted that the particular "snapshots" presented in this paper specifically represents project coordinators' perspective. Thus, supervisors, students and external partners might experience e.g. levels of partnership, autonomy and interdisciplinary collaboration differently, just as other dimensions might emerge when exploring system projects from the perspectives of other stakeholders.

Furthermore, the model should not be considered 'normative', i.e. the scaling up or expansion of a system project is not a goal in and of itself. Rather, different project purposes call for different system project constellations, and while broadening the scope of a project will naturally increase its complexity, and thus the opportunity to develop transversal competences associated with complex problem-solving, it is variation that is key (Kolmos et al., 2025). Ideally, students should be able to experience different kinds of interdisciplinary PBL projects, and even, different kinds of system projects, as they progress through their education. Here, the awareness of this variation, of the shifts in system-level orientation, requires systems thinking abilities on the part of both students and facilitators.

Systems thinking is a higher order thinking skill that enables students to identify, understand, predict, and suggest improvements of every aspect of a technological system, including the way these aspects inter-relate within the system and with other socio-technical systems on its boundary (Lavi et al., 2023; Bertel et al., 2025). All technologies can be considered systems, and these systems both consists of sub-systems and are themselves sub-systems within a larger technical or socio-technical system. As such, it could be argued that any discipline-specific or domain project could become a system project by ‘zooming out’, and likewise any mega- og mission (M) project could be split into multiple system projects by ‘zooming in’. Thus, rather than a distinct and rigid system project definition, it might be beneficial to consider different project types as potentially related to or even embedded within one another.

Following this, it could be considered whether the definition of system projects should be extended to not only include criteria related to team constellation and presence of a specific boundary object (i.e. an artifact embedded in a technological system) but to also include intended learning outcomes related to systems thinking as well as engagement with boundary systems e.g. through the simulation of ‘real-life’ work conditions.

Finally, it is noteworthy that all project coordinators highlighted the fact that most successful system projects are student-driven or initiated by highly motivated staff through a bottom-up process, and with goals that are shared and co-created between students and external stakeholders and thus extend beyond merely academic interests. Project coordinators take on the responsibility of ‘creating space’ for collaboration, either by literally ensuring a physical (and sometimes digital) space for collaboration and experimentation, or by contributing to and facilitating the infrastructure (e.g. funding) necessary for the project to continue and evolve, often investing their free time in the project as well. Thus, for system projects, or other interdisciplinary project types, to be implemented at a curriculum level, acknowledging this investment at an institutional level is likely crucial.

6 Conclusions and future work

The aim of this paper was to provide indicative and explorative insights into the implementation and integration of system projects within engineering education at Aalborg University. Through a cross-case analysis of five distinct system projects, we identified key dimensions that influence the success and sustainability of interdisciplinary PBL initiatives. These dimensions include curricular integration, system-level orientation, size/scale, interdisciplinarity, vertical integration, sustainability focus, student autonomy, and external partnership. Our findings highlight that successful system projects are characterized by flexible project definitions, opportunities for prototyping and experimentation, and objectives that resonate with both academic and broader societal goals. The role of project coordinators is crucial in creating and maintaining the infrastructure and support necessary for these projects to thrive as well as student-driven initiatives and the co-creation of goals with external stakeholders.

The eight-dimensional System Project curricular spiderweb model developed in this study offers a valuable framework for understanding and visualizing the variations in system project implementation. This model can serve as a guide for educators and administrators aiming to design and support interdisciplinary PBL projects that foster systems thinking and complex problem-solving skills among engineering students.

Future research should expand on this study by incorporating the perspectives of students, domain experts, supervisors, and external stakeholders involved in system projects. This broader range of insights will provide a more comprehensive understanding of the potentials and challenges associated with interdisciplinary PBL in engineering education. Additionally, there is a need to explore the long-term impacts of system projects on students' professional development and employability. Longitudinal studies tracking graduates who have participated in system projects could offer valuable data on how these experiences influence their career trajectories and ability to tackle complex, interdisciplinary problems in their professional lives.

Further investigation into the scalability of system projects is also warranted. Understanding how these projects can be expanded or adapted to different educational contexts and disciplines will be crucial for their broader adoption. This includes examining the potential for integrating system projects into existing curricula without extensive restructuring and exploring the role of digital tools and platforms in facilitating interdisciplinary collaboration. Finally, future work should consider the development of assessment frameworks that capture the unique learning outcomes associated with system projects, particularly in relation to systems thinking, interdisciplinary collaboration and student leadership. Such frameworks will be essential for evaluating the effectiveness of these projects and ensuring that they meet not only educational and academic objectives formulated by the study programs, but also the personal, transversal and transformative learning goals that students engaging in system projects set for themselves.

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Appendix A: Interview guide

Project Overview

- Can you briefly describe the system project (what is it, why this project, how did it come to be) and your own role in it?

Framing of the project

- Can you describe the framing you/your team have set up for the students?
  - What are the thoughts behind creating a more or less fixed/flexible structure for the project?
  - How significant is the system project compared to each study group's semester project?
    - Were the involved study programs selected by you or invited through an open call?
    - Do students work on the system project alongside their semester project, or is it fully integrated?
    - How do you/your team want this balance to be perceived by students?
  - How well do the students' curricula/learning objectives align with the project's goals?
    - Have you defined specific (domain-specific or transversal) learning objectives for the system project?
  - Are the students working on a concrete product as part of the system project?
    - If yes, what impact do you think this has on the process when students collaborate on a tangible product?
- What structure is in place to support students in system projects?
  - What are the expectations for students regarding overall coordination and management between groups?
    - Were students informed about this at the start of the project?
    - How do you think students handle this responsibility? Are they capable of taking on this role?
  - Are there structures in place to scaffold this (e.g., status seminars, sharing platforms, physical space etc.)?
    - How important are these for the collaboration?

Roles

- How do you see your role as a facilitator (and potentially other roles if relevant, e.g. supervisor, examiner) in relation to the groups?
  - Do you act as a specialist—helping with a better understanding of the product/system or assisting with collaboration structures?
  - Do you notice a change in how much support students need throughout the project?
  - How involved are you in facilitating collaboration between groups?
    - How much support do you think students need in establishing and developing interdisciplinary cooperation?
  - Do you find your role in this project more challenging than in other "regular" semester projects?
- How much coordination takes place between the involved supervisors/facilitators?
  - How important do you think collaboration between staff is for the project?
  - Do you feel that supervisors need additional support in system projects?

Progression

- If the system project spans multiple semesters:

- Do you observe any development in the project's goals/structure over time?
- Do you observe any development/change in the support needs of students, supervisors, and yourself as coordinator?

Institutional anchoring and Expansion

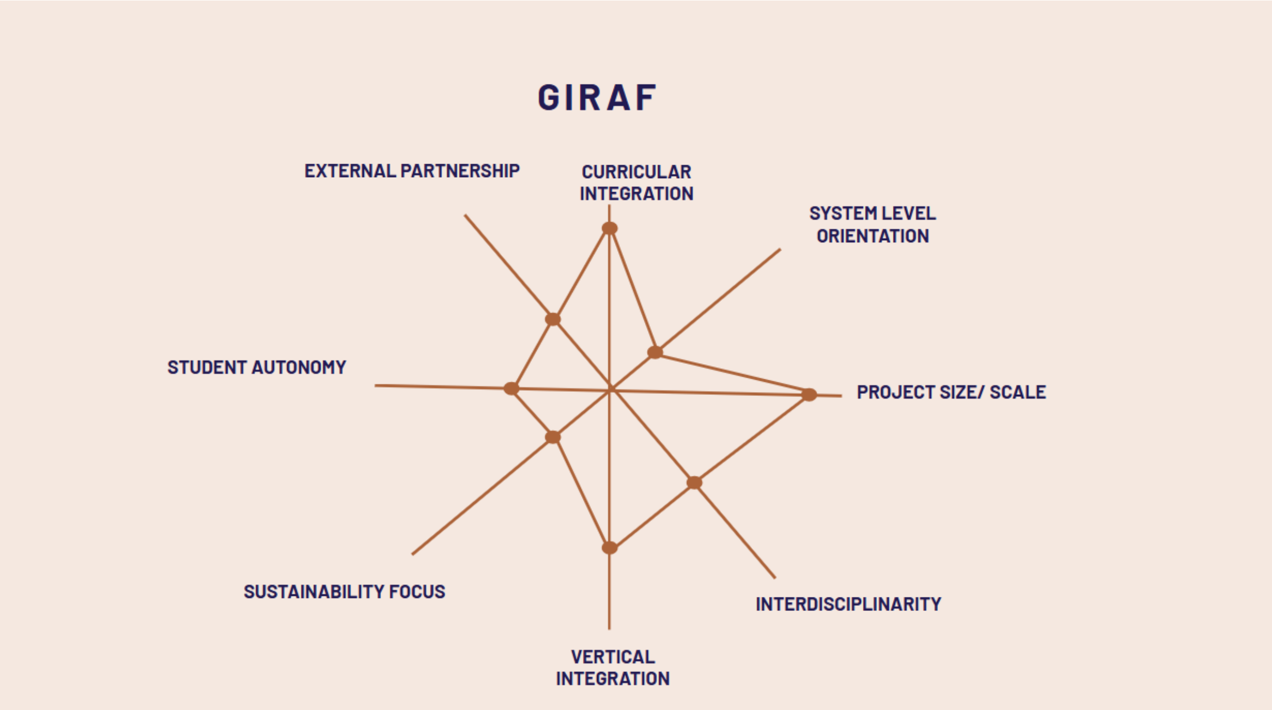
- In your opinion, what is needed to expand interdisciplinary system projects at AAU?
- What the advantages of system projects:
  - What are the biggest benefits for students?
  - What are benefits for supervisors
  - What are benefits for study programs, and AAU?
- What are the typical challenges/barriers for system projects:
  - For students
  - For supervisors
  - For study programs/AAU
- What could an ideal future scenario for system projects look like from your perspective?
  - What would it require to get there, in your opinion?

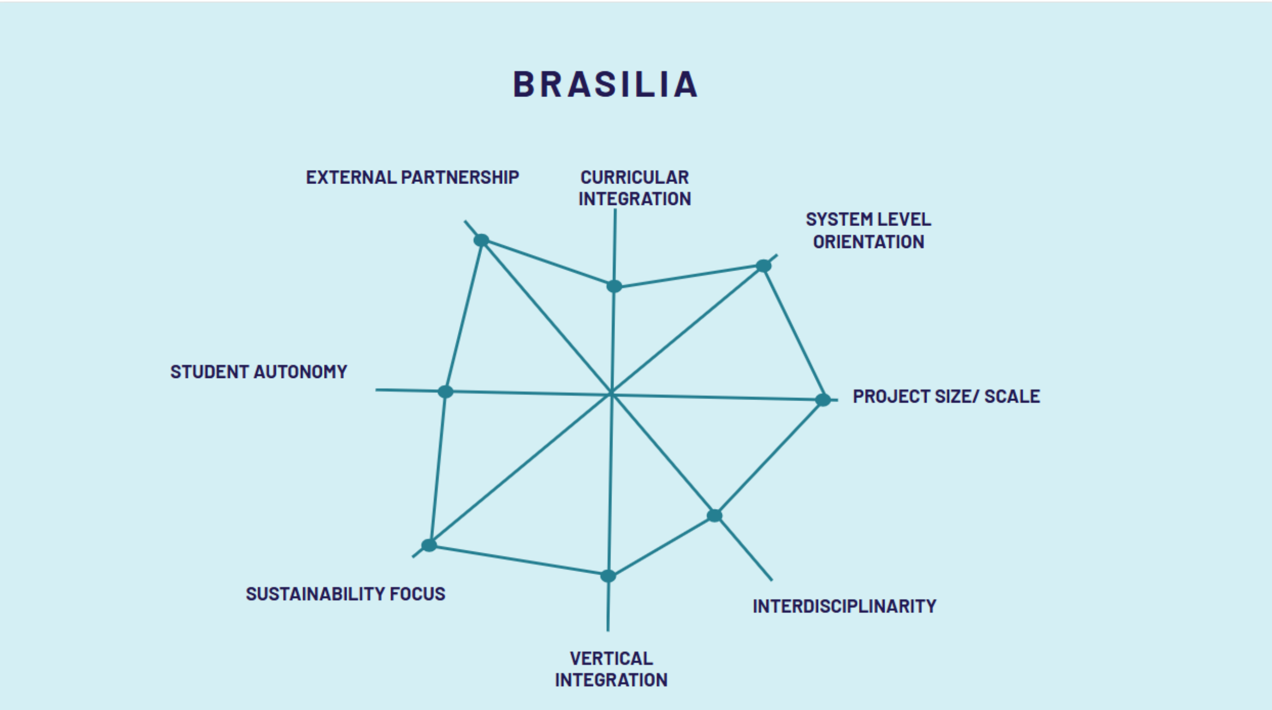
Appendix B: Cross-case synthesis

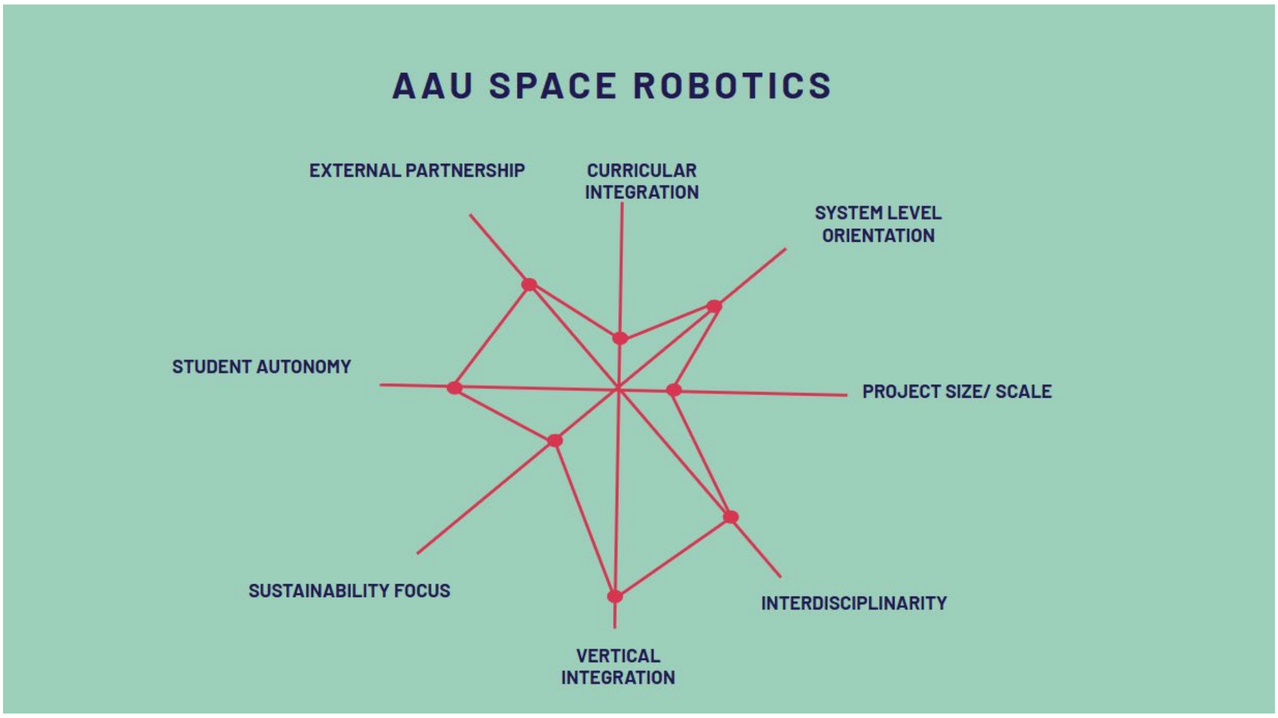
	Background/ History	Programs/ students involved	Project outcome/ Purpose	Curricular integration	Organisation and leadership	Strengths and barrierers identified by project coordinators
GIRAF	Title: "Graphic Interface foR Autistic Folks." Has been running since 2011. Referred to as a 'multi-project' at the department. Initial idea and collaboration with external partner was based on personal interest and network on the part of the first project coordinator. Current project coordinator is the 2nd coordinator.	Software development From 2023: + Interaction design + Bachelor of IT	Developing an app for autistic individuals. Collaboration with local special needs school. Resembling working as a 'software development unit'	Project fully integrated and mandatory on the 5th semester (15 ECTS) for Software students. Recently also Interaction design students, however ILO's not directly part of the curriculum – the focus is on collaboration. Should AI – does SW want it? Exam is group-based and discipline-specific. Common exception – shared section.	Semester Coordinator + Project Coordinator – becomes a "mini" Semester Coordinator -(Because many students are involved) – 50 hours allocated Project Coordinators. Stakeholders: Special needs school + S+ Gitte Østbæk (SUND) young people with cognitive challenges. + Inquiries from companies + Egebakken + Knowledge sharing: - Status meetings - Discord channel - GitHub (Package for the next group - students help the next batch (vertical sharing)	Strengths: Strong foundation/long history. Project theme is easy to scale up/relevant to other disciplines, e.g. social workers or other disciplines could come in later. If other disciplines are to be involved, they should come in as early as possible in the process. Coordinator has strong ties with external stakeholders – commitment and engagement. Student worker helps the transfer across semesters. Barriers: Aligning different curricula – some of which do not include ILO's specific to the project. Varied assessments/learning objectives. Inheriting previous students' work can be challenging.
AAU SAT	Since 1999. First send-off 2023	Electronic Systems, Antennas + Automation. Now 20-25 students at a time. At most: 70 students.	AAU SAT 6_ Live imagery for the mission. 5 own satellites. Project is evaluated based on the actual senf-offs (authentic) rather than specific intended learning outcomes.	Extra-curricular – however semester projects can be submitted as part of the AAUSAT project, but evaluations are independent of each other. No ILO's defined for the project.	Intially, the project was led by the coordinator, however students have taken charge -taking over from staff. Loose organization. Lab facilities play a key role in creating a space for organizing the collaboration. Discord is used for communication. Students attend the send-offs.	Loose frameworks create opportunities and development. Bottom-up is essential. Material costs are high, thus internal or external funding is important.
SPACE ROBOTS	Rooted in a specific robotics competition that evolves over each year. Drawing on previous experience with AAU RACING and LeadENG.	Materials and Production, Global business engineering, Energy, Robotics. Recently also Media and design. Bachelor and master students.	To compete in the yearly European Rover Challenge.	ILOs: Adapted to fit. Project not mentioned in the curriculum. Project transitions from semester to semester and year to year, following the competition criteria.	Grassroots-type leadership. Participation in competition is voluntary. Entire groups can be part of the space team, or one or two members from a group. Elected students serve as project leaders for the task. The task is to participate in the competition – not	Primarily financial barriers. Funding was recently raised for PhD. There has been no conflicts within the student team. Perhaps because participation is voluntary. Frameworks in the laboratory. Self-registered leisure organization with a CVR number. Instructor/researcher passionate about the theme (anchoring).

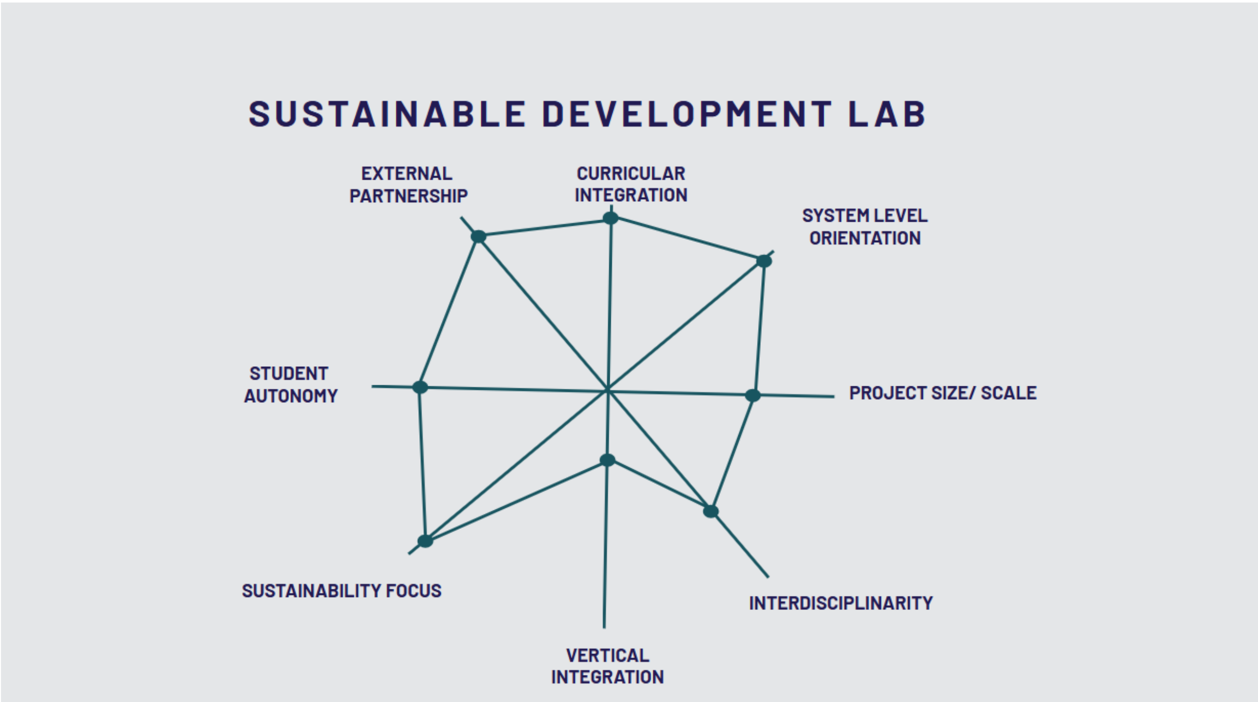
		One PhD student. A large mix of disciplines Currently, 25 students involved – previously 8.		The student team has been active for 1-2 years. Enthusiasts from the beginning have done significant work that has influenced success. Now in the 6th semester – started in the 2nd semester.	guided by supervisors but by students. The goal for the project coordinator is to interfere as little as possible.	Seed money – a lot can be accomplished with just 10,000 DKK.
SUSTAIN-ABLE DEVELOP-MENT LAB	Started E23 -with discussions and workshop. F24 – planning + initiated E24. 7th semester. International students seem to be interested as it provides collaboration with industry.	Techno-anthropology - fairly easily integrated into conver-sations/revisions of study regulations. Information studies (Humanities). Mixed groups from different disciplines.	The purpose is specifically inter-disciplinarity. External partners: TIVOLI and a recycling stations (ARK).	Fully integrated into the curriculum with learning objectives from each program and a shared exam. Bringing subject expertise into it. Explicit ILO's addressing sustainability competences. Workshop courses with an introduction to topics. Established agreements/meetings once a month.	System projects from IASPBL – interdisciplinarity is the focus and supported by PBL research. Initial meetings with interested instructors. Groups + WS offerings. Midterm seminar and exam. 2 external examiners and 2 supervisors. Resources – supervisor hours followed the students	Strengths: Interdisciplinary knowledge - challenging to meet each other's expertise and collaborate = gain. Improved understanding of one's own discipline. Parameters for learning and reflection. Barriers: Exams were not uniform – caused some challenges. Differences in approval based on learning objectives and study boards. Another study board did not agree (too many offerings for the students). (Other initiatives: "Jernbanebyen". Techno-anthropology and urban planning – cross-disciplinary groups on sustainable urban development. Connecting disciplines). 90 students – most declined. Difficult group formation process.
BRASILIA – RECYCLE PROJECT	Eligitarian _ EU project/ Erasmus Clear need in Brasilia. Started in 2018. 2019 – waste managers. 2030 agenda. 2023 – Portugal, Netherlands, Brasilia and Denmark.	**First:** AAU and University of Brasilia PBL structure – due to AAU + Production Engineering Techno-anthropology + Computer Science + Cyber & Computer Technology + Software (40 students). 35 pr. semester/70 a year from AAU.	Multiple sub-projects have different purposes. Example: Data manager project Special purpose (SDG) – incentives to change according to the learning goals.	Integrated into curriculum – part of semester project. Fits learning goals of the semester and education programs. Supervisor there to secure – fits the education programs.	Project owners -across semester. Mostly students from Brasil. "Guardian of the project" – help in the transition to secure the cohesion. Project manager officer – managing in the country (section). Student-driven organisaton – Erasmus criteria.	ORGANISATION**:** Supports the project well as it is now. To succeed it needs administration, to provide structure and funding. It helps the students – university positive. Recommendations for collaboration across scientific/ education background: minimize dependencies, generic learning goals that you formulate together with students, electives.

Appendix C: Individual mapping of system projects

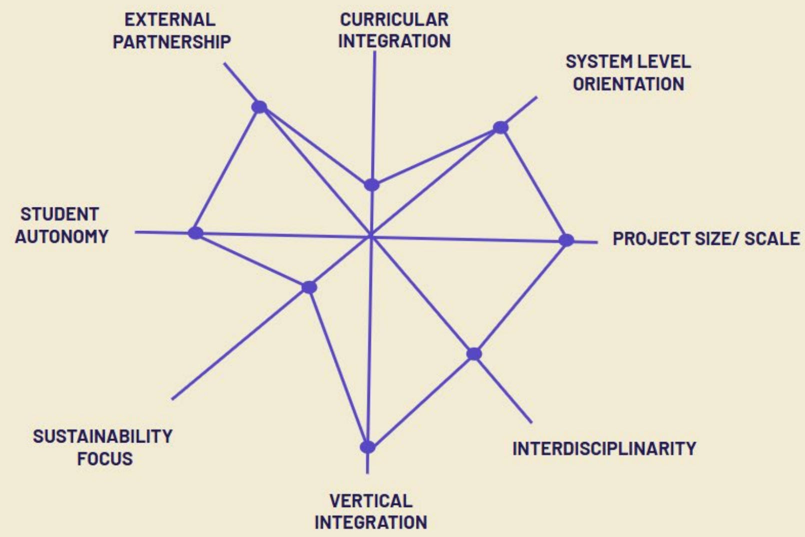





AAU SPACE ROBOTICS
EXTERNAL PARTNERSHIP
CURRICULAR INTEGRATION
SYSTEM LEVEL ORIENTATION
STUDENT AUTONOMY
PROJECT SIZE/ SCALE
SUSTAINABILITY FOCUS
INTERDISCIPLINARITY
VERTICAL INTEGRATION


SUSTAINABLE DEVELOPMENT LAB
EXTERNAL PARTNERSHIP
CURRICULAR INTEGRATION
SYSTEM LEVEL ORIENTATION
STUDENT AUTONOMY
PROJECT SIZE/ SCALE
SUSTAINABILITY FOCUS
INTERDISCIPLINARITY
VERTICAL INTEGRATION

AAUSAT


EXTERNAL PARTNERSHIP
CURRICULAR INTEGRATION
SYSTEM LEVEL ORIENTATION
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VERTICAL INTEGRATION