Lessons learned from an international cross-disciplinary engineering collaboration: a case study of the Educado project

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Abstract

Since 2018, the "SDG Challenge", collaboration between Aalborg University (AAU) and the University of Brasilia (UnB), includes the project Educado, a platform designed to provide education and information for waste pickers, a group of workers who lack access to such resources. This project originated due to the shutdown of the largest dump site in Latin America in 2018, shifting the traditional income source for the waste pickers to a structured recycling cooperative system. In this multifaceted project, the ambition is helping the former waste pickers improve their quality of life, by enhancing their current work conditions and providing resources for further education. This paper presents the reflections and lessons learned from over four years of collaboration, focused on the challenges encountered and the solutions developed. Educado is a complex and unique collaboration between students from: Production Engineering, Product and Design Psychology, Cyber, Software, and Computer Engineering. Additionally, the project was run by a student-driven company named "SomethingNew" between 2020 and 2023. This paper discusses issues identified within the project, including the need to adjust for new students every semester, and carrying over conclusions between student groups. Secondly, managing an excess of teams working on the project, and difficulties in communication between teachers, supervisors, and students especially during the COVID-19 pandemic. Finally, general lessons learned within the collaboration are discussed. The main contribution of this paper is a framework of recommendations and methodologies for international cross-disciplinary engineering collaborations between universities, based on the experiences acquired. The lessons learned from this case study provide guidance for future collaborations and highlight the importance of collaboration, communication, and adaptability in achieving successful outcomes in cross-disciplinary engineering projects.

Keywords: Engineering Education; International Collaboration; SDG Challenge; Multi-disciplinary;

1 Background

The "SDG Challenge", partnership led by Aalborg University (AAU) and the University of Brasilia (UnB), was initiated to develop practical solutions to real-world problems related to the Sustainable Development Goals, following United Nations (2015). One of the projects launched by the SDG Challenge in 2018 is Educado, a platform designed to provide education and information for waste pickers who lack access to such resources. This project came about following the closure of the largest dump site in Latin America, which, according to Campos (2018), caused a shift in the traditional income source for waste pickers to a structured recycling cooperative system. Educado's objective is to enhance the quality of life of former waste pickers by improving their access to information and providing access to further education.

The Educado project is a multifaceted collaboration involving students from different engineering disciplines such as Production Engineering, Product and Design Psychology, Cyber, Software, and Computer Engineering. The project was also managed by a student-driven company called "SomethingNew" between 2020 and 2023. The processes involved in managing this collaboration and development over the years (see Image 1), with different people and dynamics involved, resulted in a valuable case in PBL education, as it, following principles stated by Jørgensen, U., & Kolmos, A. (2017), is a project and collaboration designed to provide students with the skills and knowledge to address complex, real-world problems.

Image 1: the summarized timeline of the Educado Project over the years

Smith et al. (2018) argue that international collaborations in engineering education can result in successful outcomes by adhering to effective collaboration, communication, and adaptability practices. This paper presents the reflections and lessons learned from over four years of collaboration on the Educado project. It discusses the challenges faced during the project, including team turnover and communication difficulties experienced during the COVID-19 pandemic. Additionally, it offers a framework of recommendations and methodologies for international cross-disciplinary engineering collaborations between universities based on the experiences acquired.

According to Alhouti et al. (2021), in cross-disciplinary engineering projects, particularly when aiming for product development, successful outcomes rely significantly on the implementation of effective collaboration, communication, and adaptability practices. The significance of this paper is to emphasize the importance of good practices regarding these aspects in achieving successful outcomes in cross-disciplinary engineering projects, especially when aiming at product development. This study provides valuable guidance for future collaborations and emphasizes the need for continuous efforts to address sustainable development challenges.

2 Collaboration Methodology

The methodology used for collaboration in the Educado project is discussed before highlighting the challenges, lessons learned and framework for future collaboration. The SDG Challenge projects are conducted in cycles of one semester, composed by three main phases (see image 2): (i) SDG Challenge event (SDGe), in which we plan and kick-off the projects; (ii) onboarding, in which we mobilize students in the different universities, within the participating courses, to develop the projects during the semester; and (iii) the Semester Projects themselves, in which the scopes defined in the SDGe are executed by the teams recruited in the phase (ii). After phase (iii) of one given SDG Challenge cycle, the flow goes to phase (i) again, but of the following cycle.

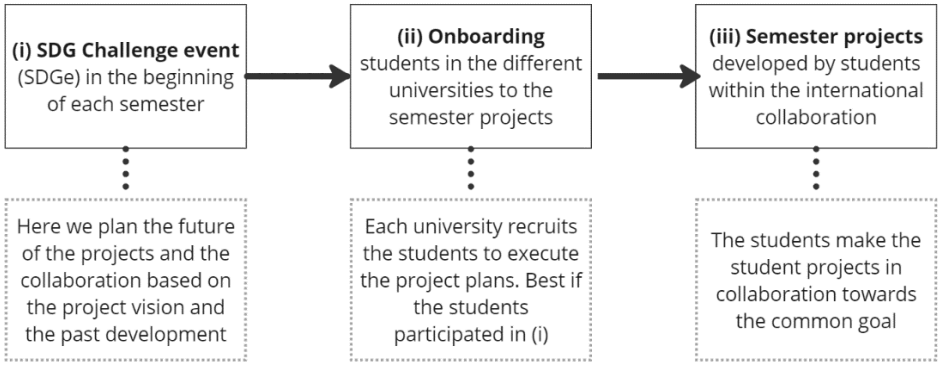

Image 2: the general view of a cycle of projects in the SDG Challenge

The following methodological description and analysis will concentrate in the phase (iii) of Educado, which is the collaboration and development per se – although all the phases are approached. We break this section in

high-level cross-university collaboration, low-level student group collaboration, and internal policies used by both AAU and UnB.

2.1.1 High level collaboration

In the context of collaborative work among professors involved in the project and partnership, the main mode of communication was through occasional meetings scheduled among the involved parties, in addition to emails and instant messages. However, for the purpose of establishing common procedures and connections between different project teams, voluntary students played a key role as intermediaries. While physical meetings between teachers and students would occur during the annual SDG Challenge event (SDGe) in Brasilia – which takes place in the beginning of each semester cycle - there was no defined framework for coordination during the semester. Therefore, the collaboration primarily relied on ad-hoc communication channels and the voluntary efforts of students to facilitate effective collaboration.

2.1.2 Low Level Collaboration

Throughout the Educado project, student-to-student collaboration has taken various forms, driven by both the need for diverse knowledge-sharing and practical factors such as the number of students involved in the project during a particular semester from both universities. Consequently, the collaboration between students can be classified into two main categories: paired student groups and mixed student groups.

Paired student groups comprise students from both universities who have a direct link with each other. To foster interdisciplinary collaboration, these groups usually comprise students from different fields, rather than those with identical backgrounds. For example, a computer engineering group from AAU may be paired with a Production Engineering group from UnB. These groups combine and broaden the perspectives of the project, using their different specializations.

In some semesters, direct pairing is not possible due to differences in student numbers or other factors such as groups reforming or combining. To manage such uneven teams, the methodology is to have mixed student groups, in which the different teams continued working on established grounds and building on previous conclusions but avoiding overloading groups with many collaboration partners. Although mixed student groups have a more limited collaboration aspect than paired student groups, they still utilize different aspects of the Educado project using previous student projects, enabling groups to work more independently.

In summary, the paired student groups are teams that actively collaborate with other teams during the semester; and the mixed student groups are teams that are also involved in the common theme and goal of developing the Educado product, but that do not collaborate or have very limited collaboration over the semester.

2.1.3 Internal Policies

With the collaboration methodologies described, the internal policies for onboarding students to the project, and the level of autonomy given to each student group is discussed for both AAU and UnB.

2.1.3.1 UnB

Within the context of the SDG Challenge, Educado was developed at the University of Brasilia (UnB) in Brazil as part of the Production Systems Project (PSPs) courses. The project scope was presented to the students mainly by the teachers or by some volunteer students, accompanied by short description documents. The SDG Challenge website played a role in some phases of the project for onboarding new students. However, students executing the semester work were not necessarily the ones who participated in the initial planning event (during the SDGe), which caused some disconnection between the plan and execution, as discussed in the next sections of the paper. At University of Brasília, the students have in general little to no decision power of which project they will take in the semester, as the professor is the one who has the final word, making it easier to guarantee that there will be teams to execute a certain scope, but potentially decreasing the affinity students have with the scope, since the scope might be not of high interest to certain students. During the project,

students had a considerable amount of freedom in decision-making, and collaboration was considered substantially decentralized.

2.1.3.2 AAU

At AAU, the collaboration structure placed a significant amount of responsibility on the students for the success of their projects – with substantial independency of decisions and planning. This is the case since the before the beginning of the project, because the students have the final word of which scope, they will execute in their projects. As a result, there is a flatter power structure, with a lot of autonomy given to the students to decide the paths of the project and the depth of their engagement in the collaboration.

In the case of Educado, besides the development of the product and the solution for the waste pickers' situation, the goal of the project is to encourage students to develop their skills on independent collaboration continually, which is supported by both the supervisors and SomethingNew.

This autonomous approach also means student groups that participate in Educado, join specifically due to a desire to be part of the project, and the project proposals are usually spread via word of mouth or through a supervisor suggesting it within a project presentation round. More formal project proposals have not been made for the Educado project, due to the limited amount resources available for AAU and SomethingNew to help support the projects.

The students from the departments of Computer Engineering, Cybersecurity, and Product and Design Psychology all fall under the umbrella of the Electronic Systems department at AAU. This organizational structure simplifies the onboarding process for new students, as many of the methodologies and supervisors are shared between these subjects.

However, the software engineering course involved - i.e. "Software 5" (SW5) - is part of a different department, requiring the collaboration structure to be a bit more complex to match the different procedures and requirements even in the collaboration within AAU. Particularly, in the SW5 course the students do not have autonomy to decide the project they will execute during the semester, as the entire course is dedicated to the Educado App. This also increases the supervision and project support required, having SomethingNew supporting the teams, as well as a Product Owner from Electronic Systems with knowledge of the problem and product.

3 Challenges & Lessons Learned

Over the course of the years of collaboration, the team has encountered various challenges, and through their efforts, have gained valuable insights and lessons learned. In this section, we will discuss the challenges faced during the project and the corresponding solutions developed.

3.1 Remote collaboration

The Educado project has always relied on remote collaboration due to the involvement of students from different countries and continents. While the project managed to progress, the collaboration was not always consistent, and some parts of the project suffered from infrequent communication, possibly due to time zone differences, busy schedules, and focus on the respective specific parts of their projects. However, it was observed that collaboration was more consistent when the students had previously met in person and participated in the physical SDG Challenge event (SDGe). The opportunity to build personal relationships and establish a sense of teamwork through physical interaction proved to be invaluable in maintaining a consistent level of collaboration.

In turn, the COVID-19 pandemic had a significant impact on the project. While the full transition to online meetings made communication easier and allowed for more flexibility in scheduling, it was more difficult to conduct co-working sessions, as the physical space is often more appropriate for this type of collaboration. However, the project benefited from the increased ease of international collaboration due to the shift towards online work. Nevertheless, the pandemic made it more difficult to understand the problems fully, as it was not possible to visit stakeholders and relevant problem locations. Consequently, the team had to find alternative

methods of information gathering and testing solutions. Finally, the relationship between the different individuals involved in the project was different as they are typically facilitated through physical interaction. Despite these challenges, this period in the Educado project demonstrated the importance of adaptability and effective communication in achieving successful outcomes in cross-disciplinary engineering projects, with an important goal of having students meet physically at the start of their semester projects as shown in *Image 2*.

3.2 Mixing methodologies

Establishing common high-level methodologies proposed a larger challenge, due to the interdisciplinary nature of the project. A main objective for a higher-level methodology is to enable the students from all different fields to excel in their speciality, whilst creating a common thread throughout. A large factor in a successful implementation is aligning the factuality / supervisors before the beginning project, and most importantly the flexibility of supervisors to modify existing methodologies internal to either field or university to better fit a global collaboration. In this way, the Problem Based Learning (PBL) proved to be a good starting point, as with a common understanding of the problem space, nuances more specific to different fields could be solved within said fields and requirements for a successful implementation easily translated between the different fields.

However, some challenges persist such as ensuring a common understanding also between students, especially ensuring that conclusions drawn in previous semesters by previous students are not lost. To overcome this challenge, the idea of a shared library with both the reports and a project summary including most important lessons are being made.

It should also be noted that whilst knowledge sharing around methodologies specific to a field, e.g., computer engineering is encouraged, by limiting the methodology mixing to a higher level, the different universities are also able to teach closer to their specific methodologies, simplified the collaboration significantly.

3.3 Project Distribution/ Complexity

It should be noted that at a certain point during the project's development in Brazil, an excessive number of student projects were initiated. This was due to the teachers having complete control over assigning students to projects and becoming enthusiastic about certain projects without the underlying infrastructure to facilitate such rapid growth in participation, resulting in an overabundance of students being involved. As a result, the team working on the Educado project found itself with an over-dimensioned team. This created complexity and made it challenging to manage and define cohesive scopes for each team, as well as ensure that all team outputs were well-coordinated. This hurdle is best solved by creating clearer project scale plans and coordinating better on a higher level as described in Section 2.2.1.

3.4 Property Rights

Since the Educado project involves a diverse group of students with different backgrounds and expertise, the issue of property rights to the platform is important. Given the mixed background of students contributing different aspects to the project, determining ownership can be challenging. However, to ensure the project's success in helping waste-pickers and helping the students feel motivated and taking ownership of their contributions, it was chosen that the property rights structure must grant ownership to everyone involved.

As the project's end-product is a software-based solution, open-sourcing the project is the simplest methodology for addressing property rights. By adopting an open-source approach, all involved parties have full access to the code and can use it for any future project. This open approach to property rights aligns with the Educado platform's non-profit nature, which relies on student projects as main contributions.

During SomethingNew's management of the project, the code remained available to anyone wishing to access it, however without a public-facing code repository. The next step for the project is to complete the open-sourcing process and ensure public availability. For software-based projects like Educado, this approach is highly recommended as it encourages students to contribute and feel ownership of their contributions, a big source of inspiration and motivation for students.

3.5 Project Management

As discussed in section 3.3, the project faced challenges in management and coordination due to the over dimensioned group of teams and students involved. In addition to this, there were communication issues arising from the different platforms used for communication and task management by each team, and the lack of a formal way to hold meetings between all the different teams. These teams were also enrolled in different courses with varying requirements, making it difficult to reconcile these requirements with the project's needs. This required volunteer students to act as intermediaries between the project and the teachers' requirements.

Another challenge was the decentralized power and management structure with no one exclusively dedicated to the project consolidation. Therefore, it was difficult to define cohesive scopes for each team and ensure that all outputs were well coordinated. To mitigate these challenges, it would have been helpful to have a product owner from the beginning of the project and a team responsible for the development and design of the solution.

3.6 Learning From Past Mistakes

The conception of the Educado project started almost five years ago in 2018, and its future success is based on the ability to learn from past mistakes and evolve the project.

Concrete examples of problems found within the project are (i) scoping the project too broadly, making it confusing for future student groups to join the project by including too many aspects and future potential growth plans, and (ii) focusing too far on the future, neglecting current next steps due to an ingrown understanding not translated to newer students.

These issues, among others, have arisen through the project development, and while the goal is not to commit errors, it is sensible to think many errors have been made, and the point is to focus on identifying and improving on past mistakes.

This requires an open mind from all the faculty and students to continuously improve. This understanding that learning and improving is imperative in creating a long-standing successful collaboration is also one of the main subjects that lead to the creation of this paper, with the goal of presenting the projects challenges and the solutions found.

For example, the scope creep issue has been solved by re-scoping the project to only revolve around the waste-pickers and the problems facing them here-and-now. Because only once the here and now are solved, is it sensible to expand the scope the future help and learning.

3.7 Knowledge Management

One of the most important lessons learned during the collaboration was related to knowledge management. The various teams worked on different semesters and courses, producing a range of outputs that were locally managed by each course. As discussed in topic 3.5, the lack of a central person to consolidate the project resulted in a chaotic collection and management of the outputs, which had several consequences. For example, it was not uncommon for teams taking over the project in subsequent semesters to have no contact with some of the previous outputs and starting development from scratch, without benchmarking against prior solutions. Additionally, at the current stage of the project, it remains uncertain if all the outputs from different teams have been collected. This approach generates waste in the development flow, with some team efforts being ignored, and rework often necessary. A possible solution to this issue is to assign a dedicated person to manage the project and maintain a structured digital repository for the different outputs of the project, to ensure a unique place for consolidation.

4 Framework for Structured Collaboration

The framework of collaboration consists in a set of prioritized aspects and good practices that were important to the achievement of the results seen within the Educado project. More importantly, this framework also presents the challenges the project has faced and the solutions that have been found to this issue-set. With

this framework of challenges faced and the solutions found within the Educado project, the goal is for this framework to be useful for future international, multidisciplinary, engineering PBL based projects:

Risks and points of attention	Adequate solutions identified
Unstructured and infrequent communication due to time zone differences, busy schedules, and focus on the respective specific parts of their projects.	Establish a standard communication flow, defining, from the beginning of the project, (i) the communication channels and applications; (ii) dates for recurring general meetings with all teams during the semester. Involve the professors in the meetings to increase engagement and send calendar invites via email.
Crashing methodologies between different courses and universities	Implement from the beginning of the project a culture of flexibility, adaptability and conflict resolution, explicitly talking about this in a first meeting with all the people involved in the collaboration. Moreover, make constraints clear from the beginning, including course requirements, availability of the teams and project development methods. Manage this in the recurring general meetings with all teams during the semester.
Lack of alignment between different professors/supervisors involved	Establish a Steering Group composed by all the supervisors involved and make a recurring meeting to ensure frequent discussion of the collaboration
Excessively decentralized power and management structure	Assigning a student responsible (Product/Project Owner) with at least one year position to consolidate the project is essential. This person can be a volunteer but must be rewarded with extension credits or other valuable monetary or academic returns. The period of one year ensures at least two semesters under the management of this person. Besides consolidating results, this person should also be responsible for the cohesive vision of the process and leading the teams towards it.
Excessive number of student groups involved, resulting in an over-dimensioned team and lack of cohesive scopes; difficulty in management and coordination	Ensure, in the period of project planning before the start of the semester, that the Product/Project Owner agrees with the need to involve any given number of teams from each course. He/She should be responsible for assessing the usefulness of the team, which will be important not only to ensure the result but also for the relevance of the experience for the students.
Unclear or potentially conflicting property rights over products	Open sourcing the project and product, and being clear about it since the beginning, is recommended to grant ownership to everyone involved and minimize complexity and conflicts related to unknown product ownership.
Knowledge waste, rework and teams unnecessarily starting from scratch	Establish a unique location for consolidation of files over time. This needs to be defined since the early stages of the very beginning of each project. Appointing an exclusive individual to oversee the undertaking and sustain the organized digital repository for the various products of the project is also important. Make the location/repository available for all the teams from the beginning of their involvement.

Table 1: Risks and Points of attention and the subsequent adequate solutions

When planning a large multidisciplinary inter-university collaboration like the Educado project, a checklist based on the findings of the Educado project should be considered:

(i) Establishing structured means and frequency of communications.

(ii) Establishing methodologies limitations and making methodologies complementary.

(iii) Creating a steering group of all relevant supervisors.

(iv) Assigning student product owners, especially after the first semester of a project.

(v) Agree on a feasible scale where all students can contribute and feel like they have a meaningful impact on the project.

(vi) Specify the ownership of each student and supervisors' contributions.

(vii) Create a structured methodology for knowledge sharing and retention, ensuring the project continuously moves forward.

Lastly, it has also been observed that for projects that extend over multiple semesters, it is crucial to appoint a student responsible for each project. This will ensure consistent vision, management, and knowledge consolidation. For the SDG challenge, which involves multiple projects in the Educado format, we recommend the establishment of a project management office. Each project/product owner will be enrolled in this office to ensure an effective project leading. The University of Brasilia is currently working towards setting up this project management office.

5 Conclusion

To summarize, the paper presented the collaboration methodologies, reflections and lessons acquired from the Educado project, which is part of the "SDG Challenge" collaboration between Aalborg University (AAU) and the University of Brasilia (UnB) over a four-year period. The project aimed to provide education and resources to waste pickers who were affected by the shutdown of Latin America's largest dump site. The project involved students from different fields such as Production Engineering, Product and Design Psychology, Cyber, Software, and Computer Engineering. Various challenges were identified during the project, such as adapting to new students each semester, managing multiple teams, and communication difficulties between teams, especially during the COVID-19 pandemic. The paper offers a framework of recommendations and methodologies for cross-disciplinary engineering collaborations between universities, based on the project experiences. The study highlights the significance of collaboration, communication, and adaptability for successful outcomes in cross-disciplinary engineering projects. The findings provide guidance for future collaborations in this area.

6 Reflection & Future Work

As a reflection on the Educado project, the partnership between Aalborg University and the University of Brasilia has been impactful and fruitful and, therefore, will continue. Moving forward, the aim is to further develop the platform to a point of full implementation with the waste pickers. To achieve this, the project will be conducted with the Product Owner in the Project Management Office established at UnB, considering the business model and financial sustainability of the solution.

Regarding future collaboration models, the framework presented in this paper will serve as a guide. The focus will be on establishing a common vision and ensuring cohesion in the development process, while also involving stakeholders in the phases of development. This approach will ensure that the project remains lean and selects scopes that maximize the benefits of the project by evolving the essential features of the product for sustainable long-term success.

It is worth noting that the international cross-disciplinary collaboration will continue in a strong Problem-Based Learning (PBL) based model, with a focus on the experience of the students and the real-world impact of the project.

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