Developing Transversal Skills and Strengthening Collaborative Blended Learning Activities in Engineering Education: a Pilot Study

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***Abstract*—There is an ongoing debate about the fact that educational models of the industrial age are no longer adequate. Future educational models need to provide students with the abilities to solve complex problems as well as to collaborate and interact to generate new meaning and knowledge. In order to do so, teamwork activities should be pedagogically strengthened and technologically augmented in science and engineering education. This paper presents a pilot study implementing a blended learning scenario in a bachelor course at École polytechnique fédérale de Lausanne (EPFL). In this framework, digital tools are proposed to support collaboration. The tools considered are a learning experience platform, an integrated Tasks Management Application, as well as a collaborative reporting editor. This article also presents our findings on the usability and adoption of those tools, as well as preliminary results on their impact on engagement and teamwork. We also mention the effect of collaborative writing on contributions. Finally, we draw insightful lessons on engagement, the use of learning analytics, and the peer evaluation of teamwork.**

This paper contributes to science and engineering education by providing new insights on teamwork activities supported by digital tools in blended learning scenarios.

***Index Terms*—science and engineering education, transversal skills, collaborative learning, learning experience platform, learning analytics, project management**

I. Introduction

There is an ongoing debate about the fact that educational models of the industrial age are no longer adequate. According to [1] future educational models should provide students with the abilities to solve complex and ill-structured problems through confident exploitation of technology, self-initiation and the arbitration of diverse viewpoints. Therefore, students should not only learn to address these problems, but also collaborate and interact with the right methodologies and tools to generate new meaning and knowledge. They also need to engage in knowledge work that involves sophisticated solutions and knowledge objects.

Against this backdrop, learning in higher institutions is no longer about accessing information or relying on teaching by others, but about making meaning of and employing knowledge in different activities and about jointly generating knowledge [2]. To achieve this goal, collaboration among students in science and engineering is key. As stated by [3] students must ”learn the skills for working effectively as members of groups.”

According to [4], thanks to collaboration, students are involved in a process of knowledge construction through discussion, debate, or argumentation, that will result in deep learning, deep understanding, and ultimately conceptual change. Such experiential learning is essential to expertise development as it involves linking knowing and thinking to doing, interacting, and feeling [5].

Despite the existence of numerous studies on collaboration [6] [7] [8], we argue that in blended and collaborative learning, the interdependency between the scenarios implemented and the digital tools integrated has to be further studied. This paper contributes to science and engineering education by providing new insights on teamwork activities supported by digital tools and their integration in blended learning scenarios (hereafter *blended scenarios*). We define blended learning as a thoughtful integration of classroom face-to-face activities and online activities [9], as well as using digital tools both on and off campus. Although blended scenarios can be applied in different contexts, such as lectures, exercises, and projects, we will only apply them to group projects which take place in a first-year course at École polytechnique fédérale de Lausanne (EPFL).

Tools provided to facilitate and enhance collaboration in the blended scenario are a learning experience platform for agile implementation and easy interaction, an integrated Tasks Management Application (TMA) for organizing the activities, as well as a collaborative reporting editor for continuous outcome construction. The TMA has a graphical awareness cue to display task completion (progress bar).

Our first hypothesis is that the students will adopt the TMA to manage the tasks required to complete the project (*H1*).

Our second hypothesis is that the TMA will facilitate

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TABLE I
PROGRAM OF THE COMMUNICATION COURSE.

Week	Part 1 - Lectures	
1 2 3 4 5 6 7	Lectures	
8	Mid-term	
	Part 2 - Teamwork	
	Activity	Assignment
9	1st session	Report 1
10	2nd session	Report 2
11	3rd session	Report 3
12	4th session	Poster
13	Oral presentation: Groups 1 - 16	
14	Oral presentation: Groups 17 - 32	

students' collaboration and work allocation, therefore avoiding potential conflicts [10] (*H2*).

Those hypotheses lead to the following research questions:

- Does the design of the TMA facilitate the collaboration? (*RQ1*)
- More specifically, does the implementation of a progress bar (see section III-A2) improve the distribution of tasks? (*RQ2*)

This paper is organized as follows: In section II we present the design of the pilot study. In section II-A we describe the standard scenario of the course. In section II-B we introduce the design of the new blended scenario and the use of the digital tools. In section III, we present the assessment of the collaboration in the blended scenario. In section IV we discuss the lessons learned. Finally, we conclude in section V.

II. DESIGN OF THE PILOT STUDY

The pilot study takes place in a first-year course on the topic of *Communication* taught at EPFL.

A. The standard scenario

The Communication course is part of the Global Issues (GI) course which was introduced in 2013 as a compulsory course for all first-year students at EPFL [11]. The objective of this program is to sensitize the students to the sociotechnical challenges of our society, as well as to develop transversal skills as early as possible in their curriculum. Students choose on a first-enrolled-first-served basis a course on one of the following six global issues: Food, Communication, Climate, Energy, Mobility and Health. Our definition of a global issue is a problem which affects a large number of people internationally, requires a coordinated action from several stakeholders, and include a technological and a societal dimension [12].

Moreover, students come from different bachelor programs in engineering, computer science, natural science, and architecture. They are mixed between programs for group activities. Teachers are assisted by Teaching Assistants (TAs) who come from EPFL and Université de Lausanne (UNIL) [13].

In this paper, we focus only on the Communication course. The course runs for a total of 14 weeks (one semester). As shown in table I, it is divided in two parts: the first one is a series of lectures, and the second one is dedicated to teamwork. In this second part, the teamwork activity aims at actively putting in practice the knowledge acquired in the first part and at developing transversal skills.

For the second part, students form a group of five teammates and choose a topic related to communication. They have to prepare a poster which tackles a global issue related to communication. It has to include the definition of the selected issue, its technical and societal dimensions, as well as the current and potential future solutions to tackle it, with the relevant scientific references [13].

During the first three weeks of the design of the poster, each team is asked to submit short reports (see table I). In report 1, students must describe their issue. In report 2, they must show that their topic integrates societal and technological dimensions. Finally, in report 3, they must explain the context related to their issue. In the three reports, each team has to define tasks and assign them to team members.

In the previous iterations of the course, there was no digital tool offered, neither to manage the tasks nor to collaboratively write the reports. The tasks and the report were submitted through a simple Google form. It contained a text input for writing the report, and five text inputs to write the tasks and the team member to which it was assigned.

B. The blended scenario

As stated in the introduction, we believe that implementing collaborative blended scenarios and introducing digital support tools can facilitate teamwork and increase engagement. It is also a way to align learning and professional practices, as well as to help students to develop digital skills. Our blended scenario relies on a learning experience platform called Graasp[1] designed to support active and collaborative learning, as well as an integrated TMA and a built-in collaborative reporting editor.

Before the beginning of the teamwork, the teachers create a virtual folder for each team in Graasp. The students are then granted full access to their team folder. Thus, they can collaborate freely by uploading files, creating documents and using the various applications embedded in the platform. Moreover, for each report the teachers create in Graasp one rich text document per team for collaborative reporting. After the submission deadline of each report, teachers and TAs can directly access them.

This approach gives students the opportunity for collaborative writing compared to the standard scenario. It also allows agile coaching by the TAs thanks to online comments and integrated chat discussions. Last but not least, the report is still available after the submission deadline in comparison with the Google form submission, the latter being no longer accessible once submitted. This feature enables students to access and possibly adapt all their reports throughout the project.

[1] https://graasp.org

As mentioned in section I, a specific app called the Tasks Management Application was developed in Graasp to support students in the management of their project.

The TMA comprises three lists, *To Do*, *In Progress*, and *Completed*, as well as a list of the team members (see figure 1). In the To Do list, the user can create a new task and then assign it to one of his or her team members by dragging and dropping his or her name on the task. Each task comprises a short title field and a longer description field.

Students are then instructed to create a list of tasks and keep it up to date. By doing so, we think that, students will have a clearer picture of the work accomplished as well as the work to be done (see section I, H2). We also believe that it will help students avoid conflicts by having a clear understanding of their role and the one of their teammates. Finally, being aware of the tasks and the role in the team will improve the team efficiency.

In order to make the distribution of the tasks more visible, we implemented a progress bar (see figure 2). This progress bar is displayed at the bottom of the app. This component provides a visualization of the fraction of tasks completed by each member of the group relatively to the whole team as well as an indicator of the progress of the overall project (as represented by the tasks). For each member i, it computes the share of the contribution to the tasks by computing $c_i = \frac{N_{completed,i}}{N_{completed}}$, with c_i being the fraction of the contribution, $N_{completed,i}$ the number of completed tasks assigned to user i, and $N_{completed}$ the total number of completed tasks. By making visible the contribution of each team member, we believe that this component may reduce workload inequalities among the team (*RQ2*).

III. Assessing the digital tools and their impact

In order to assess the digital tools and their impact on teamwork and engagement, we ran an experiment with 156 students enrolled in the Communication course during the spring 2022 semester.

We only concentrate on the teamwork part of the course where students were split into 32 groups of 5 students. Half of these groups were randomly assigned to the blended scenario and the other half were assigned to the standard scenario. In this section, we will only describe the observations we made in the blended scenario group. We will analyze the usability of the TMA (section III-A), its adoption (section III-B), its impact on teamwork and finally the collaborative reports (section III-D).

Students assigned to the blended scenario were instructed to use the Tasks Management Application and the group reporting feature integrated in the learning experience platform. The option of using tools hosted by the institution and fully integrated was preferred to the use of complex commercial packages for task management. This strategy is providing a more consistent user experience for students and is the only way to comply with European data protection regulations. Moreover, the ease-of-use of the TMA allowed the students to use the app immediately. With the help of two investigators, TAs answered to the questions of the students regarding the use of the proposed tools and no time was spent during the class to introduce them.

A. Tasks Management Application usability

In section II-B, we introduced the TMA and described its use in the blended scenario. In this section, we evaluate its usability, the effect of the progress bar, and infer relevant indications for future development.

1) Usability: The usability of the TMA is of great importance to ensure that the students can use it effectively. Indeed, its design can be ineffective and therefore impair the whole intervention. To assess it, we asked students to answer a System Usability Scale (SUS) **survey** about the TMA at the end of the project [14].

The average SUS score is equal to 58.75 (N = 24), which represents an okay usability and a marginally low acceptability [15]. This score is promising considering that the TMA was a prototype.

The four main points made by the students on the usability are the following:

- They suggested using check boxes to mark a task as completed instead of having to drag and drop them to another list.
- They found difficult to see to whom a task has been assigned.
- They found that it is not convenient to access the description of a task because of the button you need to click to display it.
- They mentioned that more features, such as ”planning tools” or ”calendar” would help in making the application useful, mainly for larger projects.

Moreover, 12 students left general remarks in the survey. Five reported an overall positive experience, while two reported an overall negative experience. Only the positive remarks mentioned the app.

2) Progress bar: As mention in section I, we also wanted to assess the implementation of a progress bar in order to see if it improves the distribution of tasks.

For this evaluation, eight groups had the progress bar displayed, while the other eight did not have it on display.

The comments left on the SUS survey are very contrasted. The first describes the progress bar as ”oppressing” and ”Big Brother”-like, the second describes it as ”satisfying”. The third comment acknowledges that the progress bar is a good idea but criticizes its lack of practicality.

While the progress bar was intended to deliver feedback to the students and motivate them to share the work more equally, we did not observe any significant effect on the group who had access to it compared to the group who did not. This result was obtained by measuring the share of participation among team members.

B. Tasks Management Application adoption

In order to evaluate the adoption of the TMA to manage the tasks, we used Learning Analytics (LA) to measure the

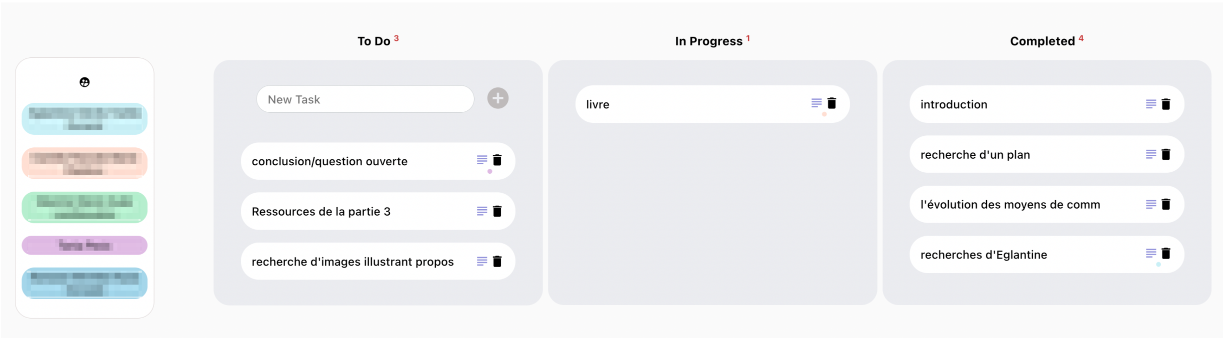

Fig. 1. Screenshot of the TMA. On the left, the list of the users is shown (the names have been obfuscated), and in the center, the three task lists.

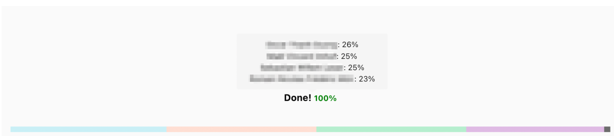

Fig. 2. The progress bar.

interactions of the students with the app. This is an indirect data-based measure of adoption through the quantitative engagement of the students in using the app.

Figure 3 shows that the adoption of the TMA was very low compared to what we expected (H1). Most groups worked with the TMA only during the 2-hour course sessions to complete the assignment (defining tasks) and then stopped using it. We also noticed that there has been a steady decline in the number of interactions with the app during the work sessions as shown in figure 3. More precisely, two groups used the app only during the first session and four groups did not use the app at all. Finally, only one group used the app regularly towards the end (days 18 to 20).

These results were made possible because, in Graasp, application developers have the possibility to report the interactions of the users by posting data packets representing these interactions, called *actions* [16]. These actions can then be exploited to track precisely how students interact with the applications, helping in observing their behaviors.

C. Tasks Management Application impact on teamwork

To complete our observations made with LA, we asked students to answer a **survey** evaluating their teammates and their engagement according to 18 different abilities. This survey was developed by [17] to assess teamwork skills in engineering and computer science.

To ease the process, we developed a specific application that gave a personalized survey to every student, by displaying the name of their colleagues dynamically. This enabled students not being comfortable with rating their peers in their presence to answer from home and not in class as it would have been the case with a printed questionnaire.

Unfortunately, the results of this survey were not very conclusive because only 9 students answered completely. With the 9 responses, only 29 students were evaluated. On average, each of them got 88.02% positive evaluations. However, 9 of them received at least one negative evaluation from at least one of their teammates.

Overall, this poor engagement reduces the significance of the results, thus preventing from concluding if the use of the app is correlated with having peers reporting satisfying collaborative skills.

D. Group reporting editor impact on contributions

As stated in section II-B, students were asked to write their reports in collaborative rich text documents in Graasp. In this section, we discuss the benefits of an interactive and collaborative reporting editor integrated in the learning experience platform on contributions made by students.

We noticed that the length of the reports of the teams who used Graasp was noticeably greater than the one of the teams that were not using the platform, as shown in figure 4.

To complement this result, we decided to evaluate the readability of the reports in order to see if there was a significant difference between the two conditions (with and without Graasp). We calculated the "Flesch Reading Ease" score of each of the three reports submitted by each team. We chose to use this score because it works on English and French texts, the two languages used by the students. It is also simple to compute and it is considered reliable by [18]. This score has a value between 1 and 100, where 100 is the highest readability score. The readability levels corresponding to this score are described by [19].

The score s_{Flesch} is computed as:

$$s_{Flesch} = 206.835 - 1.015 \left(\frac{N_w}{N_s} \right) - 84.6 \left(\frac{N_{syl}}{N_w} \right)$$

Where N_w is the total number of words in the text, N_s the total number of sentences, and N_{syl} the total number of syllables.

Figure 5 shows that for the teams that used Graasp, the reading ease scores of the three reports were almost equal (slightly lower) to the ones of the teams that did not use Graasp.

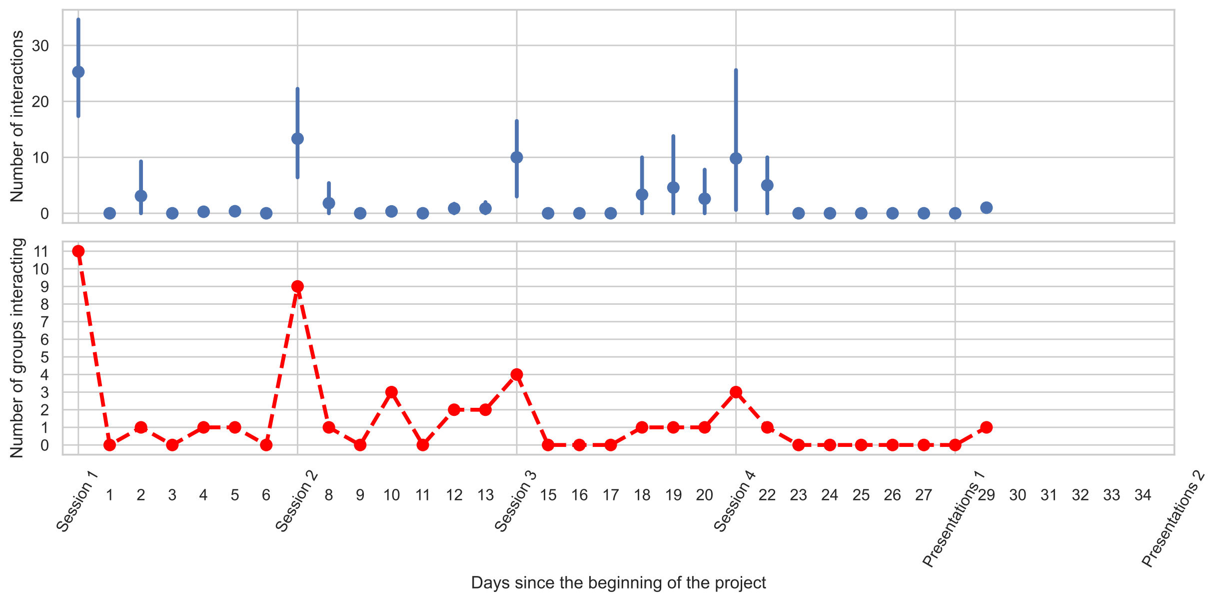

Fig. 3. Number of interactions with the TMA across the whole duration of the project. No interactions were recorded two days after the first presentations. The sessions are dedicated to teamwork. The TAss and teachers were available in the classroom during the sessions as described in section II.

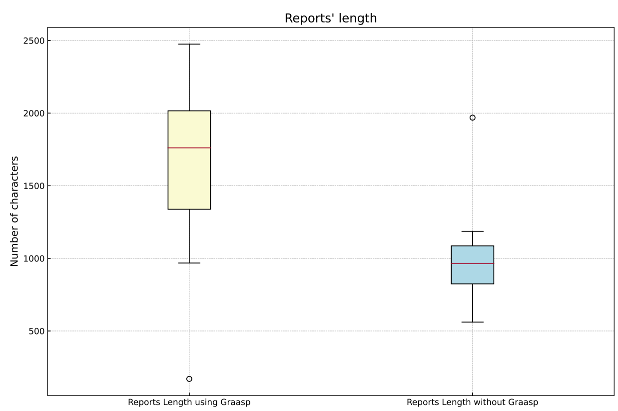

Fig. 4. Lengths of the groups' reports with or without using Graasp.

IV. Lessons Learned

With the results presented in section III, we learned three valuable lessons that will help in adapting the blended scenario and the associated digital tools.

A. Students' engagement

Although reporting tasks in the TMA was compulsory, we decided not to enforce this instruction to avoid biased adoption. This decision may have had the effect to reduce the engagement of the students with the tool.

The fact that some teams relied on less structured methods and tools to organize their tasks (e.g., instant messaging, collaborative cloud storage, face-to-face discussions) may indicate that the current blended scenario is not adapted to them.

Moreover, based on students comments, the project duration (4-weeks) may not require heavy management of tasks. In fact, some students mentioned the lack of relevance of the TMA for this project, others saw it as being a gadget rather than something really useful and one student even described it as useless. Hence, we propose the following changes to improve its usefulness:

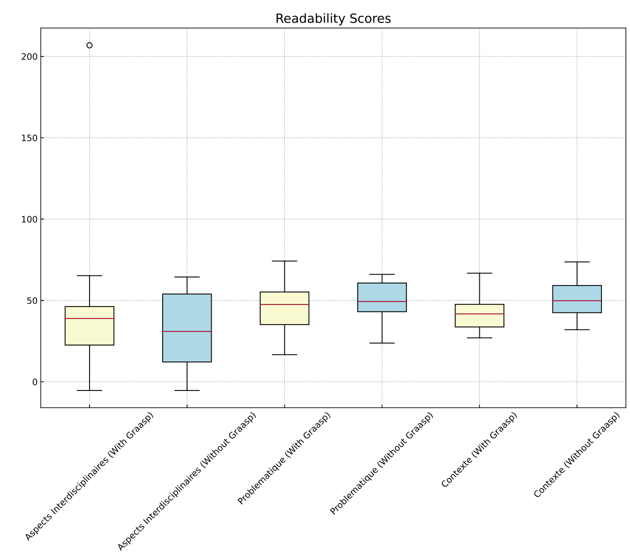

Fig. 5. Readability scores of the groups' reports with or without using Graasp.

- The design of the blended scenario and the TMA should be more aligned with the teamwork objectives.
- The usability of the app should be improved as mentioned in section III-A.

Fig. 6. General result of the teamwork evaluation survey aggregated by question.

B. Learning Analytics and awareness

In this pilot study, we used Learning Analytics to assess the engagement of the students with the tool (see section III-B). Future development could exploit the potential of these LA for supporting the Graasp users directly. Indeed, it is necessary to provide a convenient way for teachers, TAs and teammates to visualize the interactions users have with the platform, the apps, and between themselves. Learning Analytics dashboards visible to all can be integrated both in the platform and in the apps. They provide graphical visualizations and computational tools to show how students collaborate, both as a formative assessment and self-reflection support.

C. Teamwork evaluation survey

As described in section III-C, we used a survey to gather qualitative evaluation of teamwork. As shown in figure 6, we observed that out of 18 questions, 11 were either answered positively or dismissed. It is interesting to note that out of the 7 questions which received few negative answers, two questions (6 and 12) were related to work distribution and organization. We suppose that most questions appeared to be too sensitive or personal for students with our local cultural background, and we will use the survey in the future with only the questions 6 and 12.

It is interesting to notice the apparent contradiction arising from the answers to the questions 2 and 9. In most cases, students judged that asking if their peers asked for help was not applicable. On the other hand, most students were judged as having provided help to their peers. One may think that in this context, the tasks at hand do not require explicit demand for help, but help is provided by most students anyway as part of the collaborative process.

V. Conclusion

In this paper, we presented a pilot study on implementing a blended scenario and digital tools to better support teamwork in a bachelor science and engineering course, as a way to develop transversal skills, especially collaboration, communication, self-reflection, and digital competences.

The key finding of our pilot study is that the proposed digital tools (a learning experience platform, a task management app, and a collaborative reporting editor) have neither increased nor decreased engagement. In addition, we found that the task management app was not really useful in our blended scenario. This result leads us to hypothesize that it is not only important to adapt the tools to the scenario but also to adapt the blended scenario to the tools.

The lessons learned (see section IV) will be instrumental for these adaptations. They should help in moving from a neutral to a positive impact of the blended scenario and the digital tools not only for the students, but also to facilitate supervision for the teachers and coaching for the TAs.

For the next iterations of the course and considering our results, we will develop and validate the impact of a poster prototyping tool (see figure 7) better aligned with the main assignment, i.e., the production of a poster. It will be based on a graphical canvas with predefined areas, each associated with a dimension to be tackled in the poster. Each area will be connected directly to the task associated with its preparation through an active web link. Links between the poster areas, the task and the content of a running report will also be implemented. This approach should really strengthen the added value of the digital tools and indirectly increase engagement and facilitate teamwork. One should mention that the poster prototyping tool will only help preparing the content

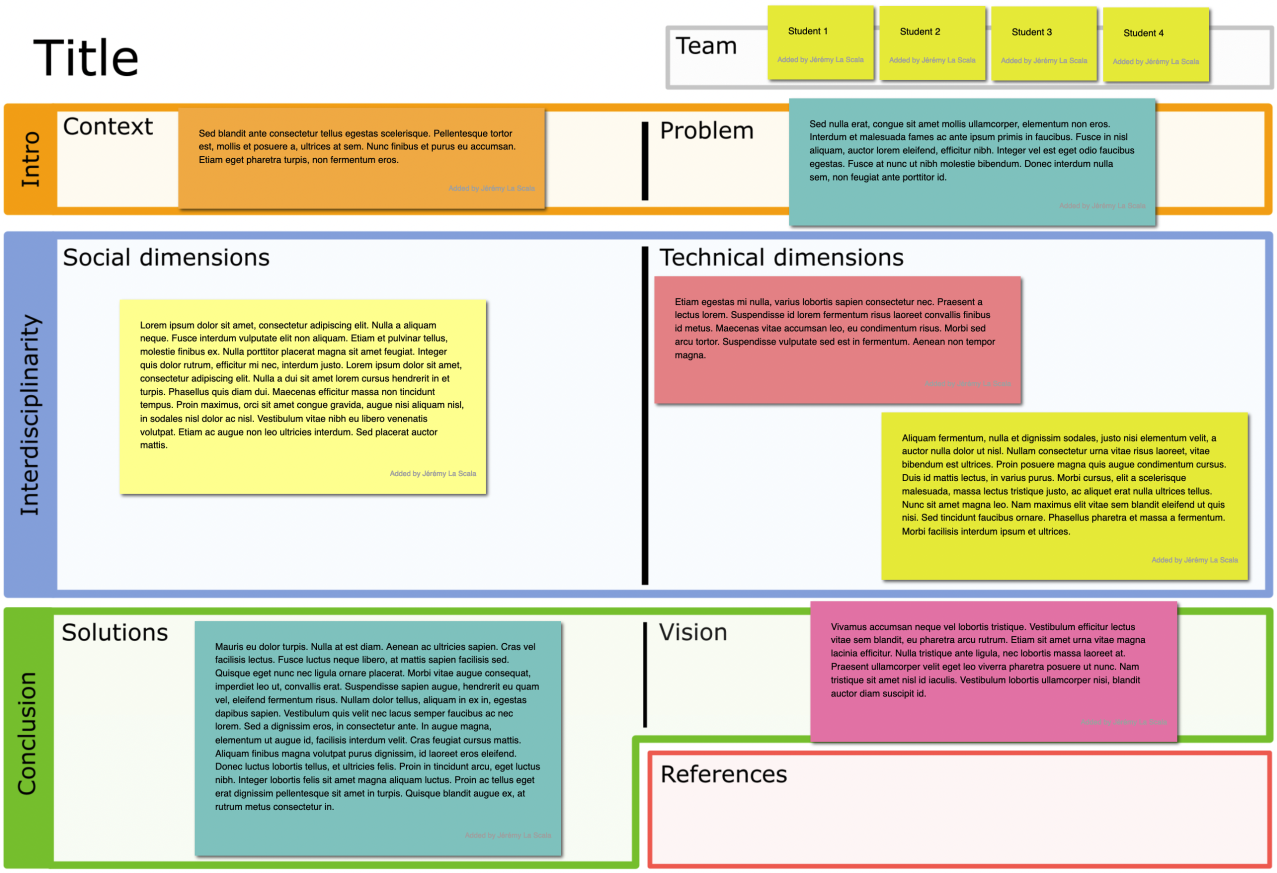

Fig. 7. Sketch of the future prototyping tool for the poster based on a predefined graphical canvas highlighting the key dimensions to be covered.

thanks to sticky notes. The final poster with its graphical design will be implemented with a software package chosen by the students to unleash their creativity and strengthen their communication skills.

Although the digital tools allowed the collection of learning analytics to quantitatively assess the engagement of the students, they should be made available to the teachers and the students in the next iterations of the course. This would help the teachers to reflect on their pedagogical design and the learners to reflect on their learning journey.

Finally, the tension between freedom and scaffolding in higher education has to be carefully managed. We think that it is better to encourage an active learning methodology and the usage of digital tools by showing students their added values, rather than enforcing them trough mandatory intermediary assignments or micro-management by the TAs.

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