Active Interdisciplinary Learning in a Design Thinking Course: Going to Class for a Reason

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***Abstract*—New technologies such as MOOCs make it crucial for universities to find the added value of bringing students to campus. Designing lectures that foster more interactions could address this issue, as student engagement and interaction are harder to replicate remotely and are seen as key to acquire both disciplinary and transversal skills. In this paper we present and evaluate an example of a novel interdisciplinary course on design thinking offered at our institution, which was designed to provide such active in-class learning experience. Our results show that in-class collaborative activities, cross-team peer-to-peer feedback and interdisciplinary work was well appreciated by students, yet it still remains a challenge to find equilibrium between theory, hands-on activities and reflexivity.**

Keywords—interdisciplinary, active learning, design thinking

I. INTRODUCTION

With the rise of online education and massive open online courses (MOOCs), there were predictions of the death of traditional universities [1]. These predictions mostly failed to materialize [1] and researchers even argue that MOOCs will never sweep away traditional face-to-face content [2].

Nevertheless, these new technologies make it crucial for universities to find the added value of bringing students to campus. Indeed, standard transmissive knowledge delivery, where instructors present theoretical content to students with limited interaction can be replaced quite easily through online material. This is less the case for live face-to-face interaction and collaboration between students. Incidentally, student engagement and interaction are seen as key to acquire both disciplinary and transversal skills.

Deeper learning of disciplinary skills can be triggered by constructivist learning approaches, such as problem-based learning or experiential learning [3]. Transversal skills, or 21st century skills, rather than being specific to a particular discipline, are cross-cutting and include ways of thinking, ways of working, tools for working, and living in the world [4]. An important aspect of these skills is to be able to interact and collaborate with people from the same and other disciplines. Thus designing lectures that foster interactions and promote interdisciplinarity could address some concerns about the relevance of physical classrooms by widening learning experiences and contributing to new flipped-classroom scenarios.

One topic that lends itself naturally to these types of active learning scenarios, is the teaching of design thinking, where students learn how to approach problem resolution using an iterative design process, which is in essence about the sharing of ideas and collaboration between people from different backgrounds, and active experimentation [5].

In this paper, we present an example of such a design thinking course offered at our institution similarly to the contribution by Melles et al [6]. However our contribution goes significantly beyond [6] in that we designed a course specifically for a heterogeneous population to provide such an interdisciplinary active in-class learning experience. We further detail and validate the experience through evaluations. Our contribution is also aimed as inspiration for other researchers and lecturers by providing them with examples of activities and supporting technologies to create active interdisciplinary learning experiences.

II. METHODOLOGY

This paper follows a design science research methodology (DSRM) [7] [8]. The DSRM proposes six steps [8]. The first step is to identify the problem to address (Section I). The second step is to define the objectives of a solution by reviewing existing literature (Section III). The third and fourth steps are the design and implementation of a solution (Section IV). The fifth step is to evaluate the solution (Section V). Finally the sixth step is to communicate about the designed solution, which is the aim of this article.

III. RELATED WORK

Hereafter, we define the objectives of a solution by contextualizing our research and reviewing background literature around issues with traditional learning, solutions for 21st century classrooms and active learning initiatives.

A. Issues with Traditional Learning

The issue with traditional classroom precedes the rise of MOOCs. For instance, Nair [9] argues that "the classroom has been obsolete for several decades". He argues that traditional classrooms were designed for basic skills needed during the industrial revolution and that this setting makes it difficult to deliver skills for the creativity and agility needed in today's workforce. Benade [10] concurs and argues that as the world is becoming more dynamic, complex, and reshaped by revolutions

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in digital technology, traditional "outmoded" transmission models of teaching must be rethought in radical new ways. Finally, novel technology-rich work environments combined with ill-defined, open-ended problems require diverse teams to deal with them [11]. However, many higher education curricula for engineers (and non-engineers) remain mostly siloed and rarely allow for interdisciplinary educational activities. Christie & de Graaf [3] argue that "after 40 years of educational research, the question of why so many students take a surface approach to their learning, appears to remain largely unanswered."

B. *Learning in and for the 21st Century*

Nair [9] proposes a list of design principles for 21st century teaching: it should be (1) personalized; (2) safe and secure; (3) inquiry-based; (4) student-directed; (5) collaborative; (6) interdisciplinary; (7) rigorous and hands-on; (8) embodying a culture of excellence and high expectations; (9) environmentally conscious; (10) offering strong connections to the local community and business; (11) globally networked; and (12) setting the stage for lifelong learning. Nair [9] concedes that these design principles do not necessarily mean to dispense of physical classrooms, but instead that they should be redesigned to "learning studios" and "learning suites". In terms of interdisciplinary learning, several approaches exist, such as mixing teaching staff from different backgrounds in one class (e.g., [12]) or mixing student from different backgrounds and making them work together (e.g., [13]), however these approaches are still marginal. Benade [10] proposes open school design to encourage flexibility in learning and teaching. It should encourage co-teaching, which can provide significant educational benefits. In their vision, there should be arrangements of multiple classes using a technology-enriched common space. Kloos et al. [1] see a future of six blended scenarios mixing MOOCs with face-to-face activities: (1) Local digital prelude, (2) Flipping the classroom, (3) Canned digital teaching with face-to-face tutoring, (4) Face-to-face and canned teaching, (5) Face-to-face teaching with remote tutoring, (6) Canned digital teaching with remote tutoring. Among these solutions, many argue for student-centered constructivist or active learning approaches. Two of these approaches, which had considerable impact in Engineering Education, are Experiential Learning Theory (ELT) and problem- or project-based learning (PBL) [3].

C. *Active Learning Activity*

One way of building an activity based on ELT and PBL is through a Jigsaw learning experience [14]. Jigsaw is a cooperative learning activity [15] where students depend on each other for success. In one implementation of this method, students are assigned to core groups. Inside each group, students have different roles. During the activity they sometimes split from their core group to join a specialized group composed of students of other groups with the same role. Research shows that elementary school students learn the material faster and perform significantly better on objective exams than a control condition of students learning the same material in more traditional classrooms [16]. At the university level, Pow-Sang [17] and Liao et al. [18] find that Jigsaw used in a computing class is effective for students. Liao et al. [18] for instance find higher student engagement (72% thought it helped learning) but observe that setting up the activity can be time consuming for instructors. Furthermore, in the context of interdisciplinary learning activities, the role of jigsaw is seen as being potentially very valuable [19].

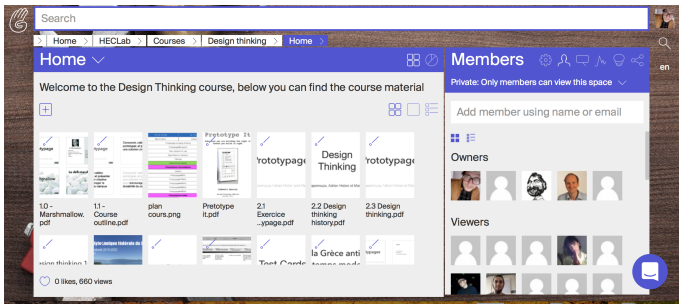

Fig. 1. Graasp shared workspace view screenshot.

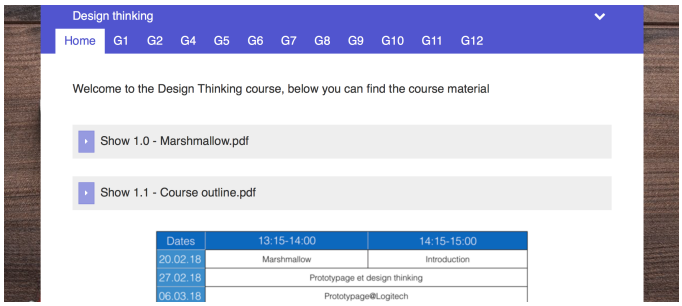

Fig. 2. Graasp public website view screenshot.

D. *Platforms Supporting Blended Learning*

Active interdisciplinary learning not only requires reinventing pedagogical scenarios. It also requires reinventing the learning platforms to better support agile and collaborative activities, as well as to ease the integration, the co-construction and the sharing of online resources. An example of such an environment is the Graasp[1] learning platform developed in the framework of European research projects on digital STEM education to support personal, collaborative, and inquiry learning [20]. The development of the platform itself is following a participatory design and design thinking process. It has been successfully deployed at a large scale [21]. The core concept of Graasp is the space, which can be thought of as a folder with permissions. Users can post and comment documents, videos, images and other files in their personal or shared spaces. One of its particularities is the fact that a space can be both a shared workspace and a public website. Figure 1 shows the workspace view whereas Figure 2 shows the public view of the same content.

[1] graasp.eu

IV. Active Learning for the 21st Century

At this stage there are several approaches to make class time more meaningful (such as flipped classrooms, jigsaw, technology-enhanced learning). However, such active collaborative and interdisciplinary learning approaches are not yet the norm in class. Below we present a case study of a Design Thinking course developed in collaboration between the Swiss Federal Institute of Technology in Lausanne (EPFL) and the University of Lausanne (UNIL) which adopts these approaches in order to provide guidance to fellow researchers and practitioners.

A. Course Format

The design thinking course is an elective course targeted at bachelor students from different STEM backgrounds from EPFL (e.g., computer science, engineering, architecture, mechanics) as well as students with business and humanities backgrounds affiliated to UNIL. In total 35 students from STEM backgrounds registered as well as 15 from business and one from political science. Table 1 presents an overview of the course format and population.

TABLE I. Case Study Overview

Format	Students (background)	Lecturers
14 weeks, 90 min per week	Bachelor 3rd year 51 (14 Female): - 35 STEM (6) - 15 business (8), - 1 political science (0)	1 design, 1 information systems, 1 economics, 1 guest speaker from industry

B. Deliverables

The course is centered on teamwork. Groups are formed by the lecturers to ensure diversity in terms of disciplines. The core task of the teamwork is to design a prototype to nudge behaviour towards a more sustainable campus. The course is divided in two phases. The first phase focuses on understanding and defining a problem, the second phase focuses on designing and prototyping a solution for the problem previously identified. For each phase, students had to deliver an oral presentation and they had to document their activities online using the Graasp platform. The project outcomes covered a broad range of topics from reducing carbon emissions through a carsharing app or reduced paper towel usage in bathrooms through fun stickers, to reducing stress with a cat bar or a shared vegetable garden.

C. Course Strategy

The particularity of the course is the fact that in every lecture there is a majority of time devoted to short, time-boxed and hands-on activities preceded by short theoretical introductions. Hands-on activities include creative tasks such as ideation, analytical tasks such as defining a user journey map, or evaluation tasks such as providing feedback to other students. The heterogeneous nature of the audience (i.e., affiliated to different schools/sections) implies that students find it hard to work together outside of class so that time spent together in class therefore becomes even more valuable. The course is designed around one central tenet: students need to see a real value in being present in class. Emphasis is placed on both having students work within their team and across teams, building on the diversity in the classroom. A number of additional "soft rules" are applied to the design of the course:

The ratio of lecturing to applied learning is kept to a 1/6 (as a rule of thumb). In practice, this means that in the framework of a 90-minute class, transmission of core theoretical elements is limited to 15 minutes in "frontal mode"; priority is given to the appropriation by the students of the method or theoretical elements.

Interdisciplinarity is forced upon teams; rather than allowing students to form groups (usually on the basis of prior acquaintance), teams are generated randomly under the constraint of maximizing disciplinary heterogeneity; random attribution of students to teams in terms of disciplines is fine-tuned by making sure that teams are gender balanced;

Get-out-of-the-building. Teams are required from the outset to gather information outside of the classroom by using ethnographic approaches; this serves both as a "reality check" and a source of inspiration for the teams' project. It also fosters the development of soft skills as students conduct interviews with potential users.

Document. Emphasis is given to the documentation of the process, of the prototype and of the result. This is an indirect way to trigger self and peer reflection, an additional important 21st century skill.

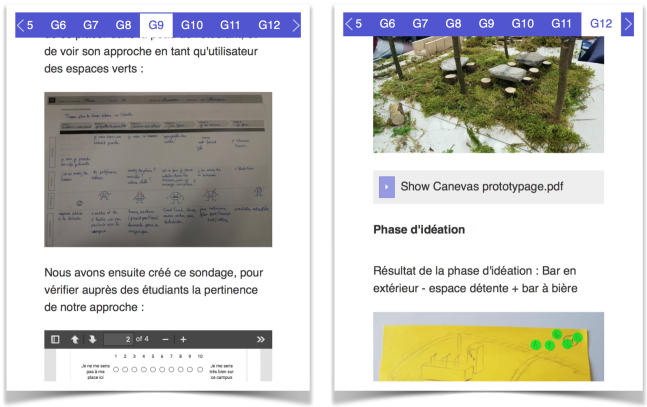

Fig. 3. Screenshots of student productions documenting their progress on the Graasp platform.

D. Collaborative Documentation

Using the online Graasp platform students were instructed to document their progress every week similarly to a blog post. Their progress was visible to all other students as well. The Graasp platform is used to provide a user-friendly collaborative web space for each team. The idea is to allow students to publish and share their production on a joint website where each team is given the rights to edit one dedicated tab. Figure 3 shows a screenshot of the production of two teams on the site. Students typically uploaded their productions (e.g., an image) after the course and added captions describing them.

E. Example of Jigsaw Activity

As part of the problem definition process, we performed several jigsaw-style activities, which mainly focused on splitting the core group to present the work to others and gather feedback and constructive criticisms. For instance, we performed the following activities around the concept of Test Cards to formulate and validate hypotheses[2].

- *Stage 1*: Using a standard lecture presentation, we introduced the notion of Test Cards and showed how they should be used.
- *Stage 2*: Within each team, we instructed students to formulate different hypotheses to test (using Test Cards).
- *Stage 3*: Splitting teams and forming teams with members from other teams, we asked students to present the hypotheses elaborated in their original teams and receive/give feedback.
- *Stage 4*: Going back to the original team, students were asked to refine the hypotheses on the basis of the feedback gathered across the classroom.
- *Stage 5*: Students were then instructed to further gather feedback by teams outside of the class (get out of the building) to confront their ideas to the "real" world.
- *Stage 6*: Online (on the Graasp platform), students were instructed to document the results and make them publicly available.

Fig. 4. Learning-studio-style classroom for the problem definition phase.

F. Classrooms

The course was delivered in two different classroom environments. For the first half of the semester, which focused on problem definition, activities took place in a learning-studio-style flat classroom with movable tables and chairs as shown in Figure 4. For the second half of the semester, which focused on prototyping solutions to the identified problems, the activities took place in a dedicated fablab-style classroom equipped with rapid prototyping tools (3D printers, laser cutter, drills, etc.) and accessible 24/7 with student cards (see Figure 5).

Fig. 5. Fablab-style classroom for the solution prototyping phase.

V. Evaluation

Two Student Evaluation of Teaching (SET) instances were conducted; one at mid semester after the first part of the course (focused on problem statement) and one at the end of the course.

The first SET received 30 responses (58%). We wanted to assess the usefulness of hands on group activities in class settings with time pressure. 90% agreed or strongly agreed with the usefulness of having hands-on activities. Further, 96% agreed or strongly agreed with the usefulness of giving/receiving feedback from fellow students. Time pressure and interdisciplinarity were also generally viewed as positive (74% and 80%) but it also met with some level of disagreement (10% and 7%). Finally 89% were satisfied or very satisfied with the course.

The second SET received 50 responses (98%). We wanted to inquire about collaboration, interdisciplinarity and hands on activities in the fablab style classroom. As the second part of the course was less time pressured, we did not further inquire about this dimension. The results (see Figure 6) showed an increase in the appreciation of interdisciplinarity group work (90% agreed or strongly agreed) and a strong appreciation of collaboration in

[2]blog.strategyzer.com/posts/2015/3/5/validate-your-ideas-with-the-test-card

general (92% agreed or strongly agreed). The material resources of the fablab style classroom were also particularly appreciated (96% agreed or strongly agreed). The results also show that all but two respondents say they attended the class regularly (note that class attendance or participation was neither mandatory nor part of the evaluation).

The items for which the students were least positive were the question of whether they improved their feedback skills (50%), their presentation skills (60%) and whether their disciplinary skills were assessed well (62%). Note that there was no statistically significant difference between the answers of students from different backgrounds (STEM vs non-STEM) to any question.

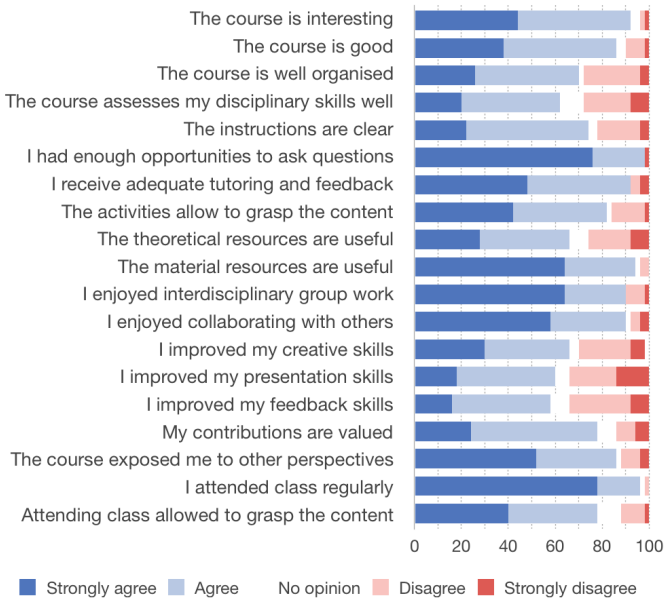

Fig. 6. End of semester SET results n=50 (98%).

VI. Discussion

The evaluation performed during and at the end of the design course point to a number of benefits perceived by the students, such as in-class collaborative activities, cross-team peer-to-peer feedback and interdisciplinary work. This is in line with previous work on active learning (e.g., [17]) and interdisciplinary courses (e.g., [12]).

They also highlight a number of issues or tensions. For instance what is the role of disciplinary skills in interdisciplinary activities? In this design course we deliberately did *not* assign students to predefined roles based on their disciplinary background (e.g., the business students focus on the business model, engineers on prototyping, art students on graphical design), by arguing that the interesting interdisciplinary interactions would emerge from trying to solve the same task together. Our results show that indeed this interdisciplinarity was valued, but some students found that their disciplinary skills were not valued enough in the course. In the next edition of the course, we will hence assign some disciplinary tasks to the students as specific contributions to the teamwork.

Furthermore, the course focused on the process rather than on the outcome. It was more important in terms of learning outcomes for students to understand the design thinking process, so that they could apply it elsewhere, rather than reaching a finalized version of the prototype they designed in their project. As such this implied that less time was spent on the project outcome, which might have been less motivating for students. This also somehow conflicts with the initial course strategy, which aimed to emphasize practice over theory (even if the "process" dimension was taught in a practical/applied way).

Last but not least, it remains a challenge to find equilibrium between theory, hands-on activities and reflexivity. Time pressure was both regarded as stimulating but also as something preventing reflexivity. One can also question having maintained the ratio of theory/practice throughout the course. Changes in rhythm may help maintain a sense of "novelty" and surprise. In fact being able to adapt (even) to minor changes like seating may participate in developing a form of resilience.

VII. Conclusion

The paper discusses the "imperative" to bring students to class "for a reason" and argues that interdisciplinary active learning approaches could contribute to providing such a reason. Collaborative interdisciplinary activities rely on well-selected physical and digital spaces to properly support the proposed active learning scenario. Two physical teamwork- and prototyping-oriented settings as well as one digital platform were selected to fulfill this objective. Even though active learning has been around for many years, it is still not used enough in university classes and even though there are more and more interdisciplinarity champions, there are only rare instances of courses breaking disciplinary silos in the higher education landscape. In this paper we presented such a course and showed how it was perceived by students. Our results are encouraging and show the potential for more such active interdisciplinary learning experiences in higher education.

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