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RESEARCH PERSPECTIVES ON CREATIVE INTERSECTIONS

Learning about others: Developing an interdisciplinary approach in design education

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Recently we witness a rising interest in interdisciplinary collaboration in both industrial design and engineering education. Since developing technology and innovation invites more complex design problems that are usually beyond the professional skills and competences of a single person, learning how to work in interdisciplinary teams becomes a central concern within the undergraduate programs of these fields. With the aim of contributing to interdisciplinary design education, this paper explores a four-week extra-curricular education activity called Interdisciplinary Design Studio (IDS) that was carried out at Middle East Technical University. The empirical data comes from the accounts of the students who participated in the IDS, from the Departments of Industrial Design, Architecture, Mechanical Engineering, Electrical and Electronics Engineering, Metallurgical and Materials Engineering, Computer Engineering, Industrial Engineering and Business Administration, who came together in six interdisciplinary teams to develop innovative products following the stages of a design process. Drawing on their accounts the paper seeks to answer two questions: First, how and in what ways students learned about other disciplines; and second, to what extent and how these learning experiences shape their approaches towards developing ways to collaborate with people (both tutors and students) from other disciplines.

keywords: design education; interdisciplinary collaboration; teamwork; design project

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Interdisciplinary design education

Recently considerable emphasis is placed on interdisciplinary collaboration in both industrial design and engineering education. It has been suggested that professionals who do not experience interdisciplinary cooperation during undergraduate education have difficulties in working with their colleagues from other disciplines (Itkonen et. al., 2009). Considering that developing technology and innovation invites more complex design problems that are usually beyond the professional skills and competences of a single person, learning how to work in interdisciplinary teams becomes a central concern within the undergraduate programs of these fields (Feast, 2012; Dykes et al., 2009; Yang et al., 2005). Equipping students with integrative and collaborative skills in addition to discipline-based specialised skills is considered to be an important objective of education, as students would develop an understanding of different disciplines and would be able to collaborate more efficiently in the work context (Corkery et al., 2007; Britton et al., 2015).

There are various categorisations of interdisciplinary collaboration, all focusing on different aspects of interdisciplinary relations. Depending on level of integration, role distribution and work dynamics, Steiner (1998, as cited in Epstein, 2014) describes four collaboration patterns for interdisciplinary work: distributed, complementary, family and integrative. Each pattern proposes higher level of integration and more flexible role distribution than the previous one. *Distributed collaboration* is informal and voluntary, based on exchanging ideas and knowledge. In *complementary collaboration*, individuals combine their own disciplinary knowledge and skills with others' in order to complete the work. During *family collaboration*, people undertake interchangeable roles, which usually go beyond their disciplinary expertise. *Integrative collaboration* is considered to be an ideal form of collaboration, during which the collaborators have a shared vision and collectively work to realize that vision. The roles that individuals would undertake depends on the aim of the project as well as people's experiences and skills rather than their disciplines.

Peralta (2010) suggests that Steiner's four categories can be implemented to investigate the collaboration between designers and scientists as it opens up a discussion on division of work and participant engagement. Aligned with his categorisation of interdisciplinary collaboration, exploring architecture, engineering and construction students, Fruchter and Emery (1999) suggest an assessment methodology to evaluate cross-disciplinary learning experience. This methodology interprets cross-disciplinary learning as a journey, which consists of four stages presented in a continuum: islands of knowledge, awareness, appreciation and understanding. At the state of *islands of knowledge*, students only have expertise and experience in their own domain. It is followed by *awareness*, when students become aware of the goals and limitations of other disciplines. Then at the state of *appreciation*, students go beyond bare awareness, develop an interest in knowing more about other disciplines' perspectives, concepts and priorities, and start to ask meaningful questions. The ultimate state is *understanding*, when students participate in and contribute to discussions by being able to use the language of other disciplines. Reaching to the state of understanding is presented as the main objective of any interdisciplinary educational program.

Together, these studies highlight the need for exploring interdisciplinary education as a continuous learning experience that consists of different states, each with a different level of involvement, different role distributions and different learning objectives. With the aim of contributing to this body of literature, this paper investigates students' learning experiences in a four-week extra-curricular education activity called Interdisciplinary Design Studio (IDS) that was carried out at Middle East Technical University Design Factory (METU DF). Within this scope, its research questions are twofold: First, how and in what ways students learned about other disciplines; and second, to what extent and how these learning experiences shape their approaches towards developing ways to collaborate with people (both tutors and students) from other disciplines.

The paper begins by describing the research context. Then, it moves to the research design, explaining the methods used for data collection and analysis. Next, it presents the findings in two separate sections, which are followed by the concluding discussion.

Research context

IDS is the first activity of METU DF, an interdisciplinary research and education centre for product development and prototyping, which started its activities in 2015. The premise of METU DF is providing the space and production infrastructure to create an inspiring and encouraging environment for interdisciplinary collaboration for both faculty and students from various disciplines. The first IDS, which is examined in this paper, was organised as an extra-curricular educational activity, brought students from different disciplines together in interdisciplinary teams to work on design projects. It was designed and carried out by an interdisciplinary team of 12 faculty members, three of whom from the Department of Industrial Design, one from Architecture, one from Mechanical Engineering, three from Electrical and Electronics Engineering, one from Metallurgical and Materials Engineering, one from Computer Engineering, and two from Business Administration. The faculty members contributed to the IDS by both directly teaching through the seminars and workshops, and providing feedback on the projects in the mentorship sessions. In addition, two faculty members took administrative roles, and one of them also participated in the IDS as a tutor with an expertise in interdisciplinary teamwork. There were also two graduate students who assisted the IDS.

The first author of this paper was among the IDS tutors, and concurrently carried out a research project on interdisciplinarity in the IDS with the students. The second author supported the research project by doing participant observation throughout the four weeks. So, as a research team, we could follow the ways in which students developed their projects in the IDS from a close distance.

The IDS was carried out in 2015 fall and lasted for four weeks. It brought 42 students from different disciplines together to develop innovative products. In the IDS, there were nine students from the Department of Industrial Design, seven from Architecture, six from Mechanical Engineering, six from Electrical and Electronics Engineering, nine from Metallurgical and Materials Engineering, one from Industrial Engineering and four from Business Administration. Among these, there were both undergraduate and graduate students, but the majority consisted of the third and fourth year undergraduate students.

Throughout the four-week IDS, the first week was designed as the meeting and training week. During the first week, seminars and activities on interdisciplinary collaboration, design process, speed networking, business models, user research and idea generation took place. Students formed their teams after they met in the speed networking session. It was followed by a mind map session where they discussed their expectations from the IDS and the project topic, which was stated as emergency. In total, they set six teams, in which there were not more than two students from the same department to ensure interdisciplinarity.

The following weeks were expected to correspond to the three stages of the design project: conceptual design, detailed design and finalisation of the project. During these weeks, teams worked independently. At the end of each stage, teams made a presentation to share their progress and to get feedback from the tutors. In addition, during these three weeks, mentoring sessions were organised at lunch breaks. In these nine sessions, which took place on Mondays, Wednesdays and Thursdays, student teams were expected to ask their questions to tutors about their projects.

Overall, there were three forms of learning-focused face-to-face interaction between tutors and students. The seminars and workshops in the first week, the mentoring sessions, and the presentations at the end of the three project stages. In the IDS, faculty members identified their role as "mentors", rather than "tutors", and made themselves available beyond the mentoring sessions to make an appointment and give feedback to the teams that need help about a specific aspect of the project.

Research design

The empirical data comes from our research with the students who participated in the IDS. There are two main sources of data. The first one is the interviews conducted with students both during the IDS, starting from first week conducted in each week, and after the IDS. We carried out 51 interviews with 29 students who volunteer to take part in our research. In the selection of our participants it was important for us to understand the perspective of the students from all disciplines, and to include at least three students from all teams. Overall, we interviewed nine students from the Department of Industrial Design, four from Architecture, six from Mechanical Engineering, three from Electrical and Electronics Engineering, three from Metallurgical and Materials Engineering, one from Industrial Engineering and three from Business Administration.

In the interviews we asked students to reflect on their learning experiences in the IDS. Rather than asking specific questions, we offered them the ground on which they could share their approach towards interdisciplinarity, design and teamwork in an educational project. The interpretation of their relationships with the IDS tutors as well as their teammates was crucial in developing an understanding of their learning experiences.

The second source of data is the written answers students have given to the weekly feedback assignments that we sent them via email. In these assignments students were given a set of questions, which changed every week according to the stage of the project as well as our observations on the process. In the first week, we asked (1) students' roles in the team and how those roles changed during different activities, and (2) their prior expectations from the IDS and whether those expectations were met. Questions of the second week include (1) a general inquiry about the IDS asking students to comment on the process by providing information about motivations, challenges, roles and relationships with team members/mentors, and (2) a question that asked the things they learned about themselves during the process. In the third week, we asked how teamwork was going, whether their role in the team was changed by time and the challenges they faced during the IDS. The feedback assignment of the last week specifically asked (1) what students learned about the facilities of different departments such as labs, workshops and machines, and (2) whether they build sustainable relationships with the tutors.

In total, 32 students responded to at least one of these weekly question sets. These were seven students from the Department of Industrial Design, four from Architecture, five from Mechanical Engineering, six from Electrical and Electronics Engineering, eight from Metallurgical and Materials Engineering and two from Business Administration.Conducting interviews at the beginning of, during and after the IDS, and collecting feedback through weekly question sets helped us investigate how and to what extent the students' assumptions regarding and expectations from other disciplines have changed in time.

In the analysis we adopted a thematic approach, and coded both the interview transcriptions and weekly feedback assignments. The themes were derived through the exploration of students' reflection on learning about other disciplines and their approach to interdisciplinarity within the team as it evolves throughout the IDS. Quotes that would best illustrate our findings were selected and anonymised before they are presented in the paper. As the disciplinary backgrounds of the students are significant to contextualise the quotes, at the end of every quote we noted the department of the student to whom it belongs.

Step I: Learning about other disciplines

In line with our expectations from an interdisciplinary interaction, our findings confirm that throughout the IDS, students have learned about other disciplines via both the seminars and workshops, and student teamwork. They, however, identify their interactions with tutors and peers as two different types of learning experience. Overall, students foreground learning from peers over tutors as a more effective way of understanding different disciplinary perspectives, as we will demonstrate in the following sections.

Learning from tutors

As mentioned above, in the IDS there were three types of learning-focused face-to-face interaction between tutors and students. All of the students were already familiar with the first one, listening to the tutors in seminars and workshops. The other two forms of interaction, getting feedback in the informal mentoring sessions and the more formal team presentations at the end of the three project stages, however, were not common in the pedagogical approach of every participating discipline. For instance, whereas one-to-one critique-based studio education constitutes the basis of the industrial design and architecture disciplines, it was a new form of learning interaction for most of the engineering and business administration students.

Our findings show that in the seminars, tutors have generally discussed the topics that were completely new for the students from other departments. In these seminars students were exposed to other disciplines that they are not familiar with. In the following quote, an architecture student narrates how the seminar by a tutor from the Department of Business Administration opened a fresh window to a discipline that previously she did not know much about:

> *I was impressed very much from it. It was like… It was about the marketing strategies of the brands. When I thought about it I realised that it was something I had never thought about before. I found that very interesting. It was like such a beautiful discipline it was, such beautiful things these guys were learning, such practical stuff. (Architecture student)*

While the main role of the seminars and workshops in learning about other disciplines seems to make a brief introduction to the participating disciplines, students did not seem to consider themselves directly "learn" from these seminars and workshops. Rather, the seminars and workshops offer a different and fresh way of looking at the world; thus, provide the students with a chance to "discover a new vision".

Overall students expressed positive feelings regarding the seminars and workshops carried out by the tutors. Yet, they remained more critical about feedback sessions while evaluating how useful they were for their design processes. According to the students, the goals and expectations of the tutors from different disciplines were neither clear nor common.

> *It was around the second week, the tutors were providing critique, like, do this, do that, some suggestions… It was like the tutors didn't have a full command of things… they didn't have a common denominator or objective. Everybody had their own interpretation about the studio. They hadn't decided about it, and that was interesting. We were receiving stuff from everyone in a different direction. (Architecture student)*

This finding explains students' low participation in mentoring sessions, and their avoidance of getting regular feedback from the tutors. Particularly in the third and the fourth weeks, we observed that only few teams were present during the sessions. In response to our questions regarding their poor attendance, students stated that the different disciplinary perspectives they encounter in the mentoring sessions caused them to get confused and lose their direction as a team. As a result, they quit attending the sessions and discussing their projects with the tutors.

> *To tell the truth, because our tutors were all from different disciplines, their feedbacks confused us, in general, instead of illuminating. [Due to this confusion] we had difficulties in deciding how to proceed. (Mechanical engineering student)*

In a studio where all participating tutors were encouraged to contribute equally, it was inevitable for the tutors, to emphasise different priorities in our feedbacks. As tutors, we did not find this problematic; we identified this as openness and flexibility, and expected the students to take all these different perspectives in, digest them and address in their design solutions. However, students seemed to prefer a more focused design perspective. Their accounts show that they need the tutors to speak one voice, which would tell them how to proceed in every stage. This is probably due to the fact that the IDS was the first time students encountered an interdisciplinary tutoring team, in which every tutor would focus on and question different aspects of a design project.

In spite of the fact that students do not consider that seminars, workshops and mentoring sessions had a particular impact on their learning about other disciplines, they underlined the value of the networking opportunities created by these activities. They indicated that they were happy to have a list of academics from various fields at the end of the IDS, so that when they need to consult people from these fields, they would have a name to contact. Therefore, regardless of whether the seminars, workshops and mentoring sessions directly contributed to their design process in the IDS, they served to develop an interdisciplinary network with academics for their prospective postgraduate studies and professional relations.

Learning from peers

While learning from tutors mainly corresponds to gaining new visions regarding other disciplines, students placed much emphasis on discovering disciplinary differences to explain how they learned about other disciplines throughout their collaboration within the team. Disciplinary differences were discovered around three issues: first, the meanings of similar concepts; second, priorities in a design project; and third, learning environment and relations.

Same concepts, different meanings

Students stated that at the beginning of the design project, they realised in the team discussions that despite using the same concepts, design and engineering students referred to different processes. The first time they discovered these differences was the mind map assignment given in the second day of the IDS. In this assignment, teams were asked to visualise their approach to the design process. Working on the assignment, students had a chance to discuss the basic concepts from different disciplinary perspectives. Design, and design problem and design process in relation to it, were the key concepts that were central to these discussions:

> *[In engineering] there's that thing, you're already given a problem and there are some suggested ways to solve it. [In design], the problem also is abstract. For example, emergency can be anything. There's a much broader point of view. Like, I approached to the problem as chronical emergency, then this and that happens. The result can take an entirely different direction according to your approach. We [engineers] don't have that flexibility. (Mechanical engineering student)*

The engineering student highlights that in engineering design process, problem is predetermined, whereas industrial designers have flexibility to define their own design problems. An industrial design student confirms the same comparison, observing that conceptual design phase, which is the initial phase of the design process, is missing in the definition of design from the engineering perspective. She says,

> *[For engineers] there's no conceptual design phase. Actually, design is still making something, drawing, producing. It has a similar meaning in engineering, too. But they don't have conceptual design phase at all.*

Especially they might have a prejudice towards producing something from scratch. They don't have an idea of creating a concept from scratch and actually making it happen. For them, the concept of design corresponds to revising. (Industrial design student)

Like design, concepts related to production, such as model, mock-up and prototype were also mentioned frequently by the students to be highly differently understood in the design-related disciplines (industrial design and architecture) and engineering disciplines. While in engineering education the primary aim of physical models is to test whether the design works or not, in industrial design education models are not always the end products of the projects, rather they are elements of the creative process. They are not always expected to 'work', i.e. they do not have to include the working structure or mechanism, and they can be made out of cardboard, clay and foam. Along with paper sketches, physical models in various scales are used by the designers throughout the whole design process to externalise their ideas to explore ideas and concepts, to think through doing, and to empathise with and get feedback from the user, etc. (Vyas et al. 2009). At the end of the mind map assignment, students have discovered these two disciplinary approaches with different expectations from models:

I learned that [engineers] make one model! We told that we make lots of models and choose among them. They only make one that gives the correct answer. They have one product and make changes on them. We make plenty and choose from them. (Industrial design student)

Although students encountered the different expectations from models in the first week, negotiations on the concepts of production, prototype and model remained in some of the teams until the last stage of the project, when students worked on the physical model of their design to exhibit in the final presentations:

In production, for instance, we say we need to manufacture this. [Engineers] say how and so, etc… What we mean by production is making a model (laughs). I guess they think you know… They say, 'Are we really going to manufacture this?' We say, 'No, not really, we meant the model'. For us, manufacturing is not immediately putting something out to the market. (Architecture student)

Priorities of the disciplines

In the first week, during the lunch breaks students had an opportunity to start informal discussions on their motivations for participating in and expectations from the IDS. During these discussions, we observed that engineering students often referred to the typical aesthetics-functionality dualism as they talked about the relationship between design and engineering disciplines. This dualistic view, which is underlined within the literature to have a detrimental effect on the professional relationships between engineers and designers/architects (Faulkner, 2007; Kaygan, 2014), seemed to strongly shape their presumptions regarding the priorities of the design-related disciplines in a design project. We encountered the aesthetics-functionality dualism in the early interviews with engineering students, as well:

> *I would say [understanding of design in design-related departments] is more aesthetical. But in terms of functionality [engineering] design is more useful, it satisfies people's need more. I can say that [design], on the other hand, is more about satisfying the need of pleasure. (Mechanical engineering student)*

In another first-week interview, an electrical and electronics engineering student explains in what ways he expects his teammates to contribute to the design project, comparing industrial design and architecture students to engineering students. He suggests that at the beginning of the project engineering students will develop the project, then designers would create a "shell" to complete the product. Doing this, he delineates a sharp division of work between the two disciplines: engineers are responsible for how the product "works", and designers for how it "looks".

Interviews show that in some teams this dualism further dominated the discussions on the priorities of each discipline, implying hierarchy between these priorities. In the following quote, a business administration student says,

> *When [the mechanical engineering student] said, "This is art", we joked like, "Art? At least he could say aesthetics." He says, "For me, that machine is important, doing that job is important." Designers say, "But come on, aesthetics is also important for the user. What is the point if it can't be used easily?" But the engineer insists, "As long as the job is done, then it's OK." At that point I couldn't hold it anymore: "If I can't sell it, it doesn't work at all." (Laughs) I brought my management thing to front and couldn't bare the discussion. (Business administration student)*

The business administration student is frustrated by the engineering student's insistence on arguing for the superiority of functionality over 'art', and intervenes by underlining the primary concern of her discipline: whether the product can find a place in the market or not. Doing this, she aims to show the engineering student a third disciplinary perspective, which can "beat" functionality.

As evident in the business administration student's account, however, in response to the aesthetics-functionality dualism, industrial design students in general highlighted user (rather than the aesthetic appeal of the product) as the main concern. It was a shared assertion by industrial design students that while from their disciplinary viewpoint, user is at the heart of design, it is never an issue in engineering design. The below quote narrating the mind map assignment illustrates this:

> *We had a conflict. For example, they said, "I'm designing a gear case for a car. Actually I'm not doing something for the end user. The end user, the one who buy the car, doesn't see it." But we, [designers], directly interact with the end user. That's why we conduct user observation or user testing. On this topic we had a conflict. What we understand from design is the one for the end user, but it's not the same for them. They sometimes understand design as working of one part of a machine. (Industrial design student)*

Learning environment and relations

When the IDS began, the DF building was not ready to use yet. To create a quick and temporary solution, a couple of studios and seminar rooms within the Faculty of Architecture were allocated for the IDS. These places were used during the seminars and workshops in the training week, mentoring sessions and presentations. Thus, for the learning activities in which mentors were involved, suitable places were booked. Apart from these, students did not have a dedicated studio where they could meet as a team and work together on their projects. As a result, students had to develop their own solutions for coming together, considering the convenient place for all team members. Both the accounts of the students and our observations revealed that students preferred to come together at the weekends and mainly in the industrial design studios, which can be accessed by the industrial design students in the teams. In addition to the industrial design studios, however, some of the teams also visited the buildings of other departments towards the end of the IDS. Particularly at the prototyping stage, students visited other departments to use the labs and workshops.

Our findings show that by visiting other departments' buildings throughout the IDS, students discovered how educational approaches and environments can differ in various disciplines. In the undergraduate education, studios, which can be accessed 7/24 and which are used by only one level of a single department, constitute the main learning environment of the industrial design and architecture students. For the engineering students, on the other hand, classes for large numbers of students, labs and workshops constitute the main learning environment. As they saw each faculty's physical environments and had a chance to spend time in these buildings, students discovered connections between the differing design and project approaches and the educational settings of various disciplines.

Students' accounts on the differences in educational environment mainly focused on describing the informal workspace culture within the Faculty of Architecture. A mechanical engineering student, for instance, describes how surprised he is to observe that the studio-based design education much more flexible in comparison to the class- and lecture-based engineering education:

> *Now, we always work in [industrial design fourth year studio]. There's nothing like a lecture there, there is no concept like this. We, [engineers], definitely enter the lecture at 40 pasts and classes finish at half pasts. And [since they don't have set hours], [designers] don't have things like 'being late'. People are free. They are given [a project] and they work on it. (Mechanical engineering student)*

An industrial design student also compares the lecture-based formal learning culture to studio-based informal learning culture.

> *For example, one evening my friend from materials [engineering] came. Actually, our jury was going on. There were the last two students. He lowered his voice and asked, "May we enter?" I said, "Of course, come on!" It's because that's very different from their understanding of 'class'. There we were talking about [our IDS project] and the jury was still going on. They found it strange. (Industrial design student)*

Discovering the disciplinary differences in the educational environment, industrial design and architecture students consider themselves privileged to have the studios where they can get access 7/24. They state that studios are like their home, since they do not only offer the space to work, but also host the informal and enjoyable relationships among the classmates. Through this, studio-based learning culture supports the sense of belongingness and community within the faculty building:

> *Here we create an environment for ourselves as students. They don't have this. They take their lecture and it finishes. This is how they're studying. […] In the first week we had a need for paper. The stationary was closed. I said, "I'm sure there're some at one of the studios." I went to a studio, opened a drawer and yes, there was. They were saying, "Don't take it, how easy manner is this!" But because [studios] became like our home. Because I'm sure when we leave something there, someone else also takes it. (Architecture student)*

Moreover, students suggested that the disciplinary approaches to education in design-related fields and engineering are also influential on different student-tutor relations:

> *In mechanical engineering, you can graduate without a professor knowing your name. You take classes, get an average grade, you graduate. None of the tutors know your name. But in design, tutors are like your mentors. You conduct a project, make something, she comes and evaluates it, advises you, do this, don't do that kind of. I mean the mindset is different in these two departments. One is like mass production [education] and the other is more like a handmade. (Mechanical engineering student)*

Both their interaction with the industrial design tutors who participated in the IDS and their observations in the industrial design and architecture studios provided engineering students with an opportunity to discover the nature of tutor-student relationships in this environment. Since studio education is based on regular critique sessions and jury evaluation that require intense one-to-one interaction, compared to their own disciplines, they witness a closer and relatively less formal relationship between tutors and students in design-related fields. Drawing on a conversation with her engineer teammates, an architecture student says,

> *They were really surprised to hear that we were Facebook friends with our tutors. "How can you have such a relationship?" Because unavoidably a network is established with the people from your department. I observed that it isn't the case for them. (Architecture student)*

To sum up, our findings show that whether being surprised or frustrated, students went through an intense learning experience during the IDS. As they discovered the perspectives, vocabularies, goals and constraints of other disciplines, they have moved along the continuum suggested by Fruchter and Emery (1999). Students started the IDS within the category of *islands of knowledge*. Yet, as their accounts clearly demonstrate, they gained awareness in time and to a certain extent began to appreciate the priorities of other disciplines. In the next section, we will present the findings on the overall reflection of students on developing a shared understanding on which they could build their design projects.

Step II: Developing an understanding of interdisciplinarity

So far we have demonstrated how during the IDS, students had an intense interaction and collaboration with other disciplines through which they discovered the disciplinary differences. Having gone through a series of conflicts and negotiations, student teams managed to find a way to work as an interdisciplinary team and developed a shared understanding. Learning about other disciplines and figuring out how to work together seem to help them to develop an understanding of interdisciplinarity in four ways, as we discuss below.

Shift from multidisciplinary to interdisciplinary collaboration

Comparing multidisciplinary to interdisciplinary collaboration, Richter and Paretti (2009) state that the former is an additive process, while the latter involves synthesis. Both our observations and the students' accounts confirm that during the course of four weeks, the collaboration between students evolved from multidisciplinary to interdisciplinary. During the first weeks of the IDS, students expected to complete certain tasks related to their own discipline and hand on the project to another student from a different department, yet soon they discovered how to develop ideas and create something collectively. In order to explain this transformation, a mechanical engineering student uses the analogy of production line:

> *We, people from different disciplines came together and did something. But that thing [way of working] disappeared [in time]. For example, you're a designer, do your design, then we'll take it from you and give it to the mechanical engineer. It isn't like that anymore. There's a product and everyone gives input to it. We're no more like a production line. (Mechanical engineering student)*

While the process was initially interpreted as a linear one, during which the disciplines contribute to the project separately, it turned into a collaborative process, during which the knowledge, ideas and skills of each discipline are synthesised to reach a common goal. Experiencing this shift from multidisciplinarity to interdisciplinarity, students discovered their very own understanding of interdisciplinary collaboration.

Flexibility in division of work

Once students developed an understanding of interdisciplinary collaboration, they also began to think more critically about how to work as a team and how to divide work among team members. The accounts of the students revealed that they tend to divide work according to their interests and abilities rather than assigning tasks simply based on one's department. Going beyond disciplinary boundaries, students contributed to the project not only by using their disciplinary knowledge and expertise, but also by doing what they would like to do or what they are good at. For example, one of the teams preferred to present their final product in a stop-motion video. It was a self-initiative of one of the team members, who had an interest in making stop-motion animation. Then some of the team members volunteered to join him, and they prepared the final video collaboratively.

Similarly, a materials and metallurgical engineering student shares how she was not limited to her own discipline, but could contribute to different areas:

> *We divided work and split into groups according to our interests and skills. We became even more and more satisfied with our project and that's why we continued idea exchange with enthusiasm. We don't care about our departments so much. For example, instead of telling me "You're a materials engineer, deal with the materials", they ask me what I would like to do. (Materials and metallurgical engineering student)*

Although occasionally students question undertaking different roles and responsibilities, our findings show that, overall, they are happy with this flexible approach to division of work. Not having predetermined roles, either as a member of a discipline or as a leader/follower, seems to enhance their appreciation of collaborative work. Working on various team exercises enables students to discover how to complement each other with their background in different disciplines.

Contribution to self-development

Students commonly argued that experiencing interdisciplinary collaboration not only increases the overall quality of the project, but also contributes to their self-development. As they took different roles within the team in relation to the given tasks, they realised that disciplines are not entirely distinct in terms of their approach to design and project. Instead, some understandings of a discipline may apply to another one in a way that widens the vision of that discipline. A mechanical engineering student explains how he gained a new vision as a result of his interactions with an industrial design student:

> *What was good about [working with the industrial design student] is that she taught me the parts I didn't know. I haven't thought of making apps before. I also liked things like our logo, which were her designs. Stuff like that complemented my shortcomings. I mean I didn't have such a vision, I have such a vision now. That's good. (Mechanical engineering student)*

During the IDS, students had a chance to approach problems from different perspectives. Both working with the students from different departments who have various perspectives, and undertaking different roles and responsibilities within the team helped students to develop new understandings and thus, broaden their perspectives. The following account illustrates how being introduced to new dimensions during the IDS, enriched the way a student approaches to a design problem:

> *During the [IDS], I realised how cultural and artistic points of view suddenly removed the curtains before me. I understood that I used to mistakenly think that art and aesthetics was only a cultural accumulation and I didn't realise their effect on my technical abilities and my life. Really, instead of approaching to a problem straight, I learned and I'm still learning approaching it from "n dimension", considering the inside, outside and around. During this event, thanks to aesthetics, sociocultural and artistic points of view added extra three dimensions. I used to look at things as one dimensional, technical, but now I consider four dimensions that I can*

> *describe as technical, aesthetical, sociocultural and artistic. (Mechanical engineering student)*

Sustainable interdisciplinary relations

During the interviews, students put emphasis on making friends from other departments. It is commonly believed that having an interdisciplinary network of friends is a valuable opportunity. Students mentioned that they could consult the people from the IDS whenever they need expertise from a certain discipline. Besides, some of the students stated that they would like to collaborate with those people in future projects. The experience of an interdisciplinary collaboration seems to change students' perceptions of collaborating with other disciplines in a positive way. An industrial design student puts it:

> *Now, I have one friend from electrical engineering, two from materials engineering and one from business administration, from whom I can get ideas whenever I got stuck. Thanks to interdisciplinary collaboration, I manage to give different ideas a chance and understand them. It was a perfect opportunity to break down the prejudices. It helped me to understand the ideas built on different grounds better. (Industrial design student)*

Overall, the students openly shared their intentions for sustaining their relations with both their team members and the other participants of the IDS. Our observations also confirm this finding. Once the IDS has finished, most of the teams remained in contact and some of them worked on projects that were independent from the IDS.

Conclusions

This paper investigated an extra-curricular interdisciplinary design studio to understand students' learning experiences during an interdisciplinary activity, where they learn about other disciplines, and to explore how these experiences shape the ways in which students collaborate with others. Drawing on our findings, we highlight three conclusions to offer new insights regarding curriculum development of interdisciplinary courses in design education.

First, in the IDS, most of the learning about other disciplines and the ways of interdisciplinary collaboration occurred beyond tutors' supervision and control. Although the seminars and workshops carried out by the tutors enabled students to gain new visions regarding other disciplines, their progress from the category of *islands of knowledge* to *understanding* of interdisciplinarity is achieved mainly by peer learning within their design teams. In the interviews, students stressed the significance of the mind map assignment as they told us the stories of how they discovered differences between the priorities and vocabularies of participating disciplines. Through this assignment, team members found the opportunity to discuss the basic terms such as design, design problem and model. They began to gain an *awareness* and *appreciation* of how a design project may consist of different stages (for example, explorative stages are not common in engineering design, and iterative models accompany all stages of the design process in industrial design) as well as how some main concerns at the centre of design approach in a discipline, such as user and use context, can be missing in the design approach of another discipline. Although to some extent these discoveries triggered frustration and conflict among team members, they eventually constituted the basis of an intense learning experience that led to a shared understanding.

This finding underlines the significance of creating team assignments that would encourage students to open into debate their disciplinary perspectives, priorities and constraints. It can be argued that this kind of debate would naturally take place throughout the whole collaboration process. However, as we demonstrated in the above sections, an assignment that requires students to produce an outcome to be submitted serves as a particularly good opportunity to, first, reflect on and describe their disciplinary stance, and second, identify the similarities and differences with other team members' perspectives. While designing curriculum of interdisciplinary design education, therefore, it may be a better strategy to work on how we can reinforce peer learning by providing teams with dedicated time and structured discussion tasks.

Second, as discussed before, since during the IDS, the DF building was still under construction, students did not have a dedicated space to work on their projects as a team. They mainly used the industrial design studios, and towards the end of the project, visited the labs and workshops of other departments as well. As tutors, during the IDS we observed that the lack of a dedicated space had a challenging effect on teamwork, since it caused difficulties in arranging time and space for meetings, and storing project materials during the process. The importance of having a specifically-designed workspace for interdisciplinary collaboration has received considerable acknowledgement in the existing studies (Björklund et al. 2011; Fixson, 2009). It has been suggested that particularly open and pressure-free spaces that encourage informal relations among team members play an important role in fostering team creativity (Magadley and Birdi, 2009; Vyas et al., 2009).

Even though both the literature and our observations confirm the challenges caused by the absence of a dedicated workspace, our findings revealed that during the IDS this disadvantaged situation was transformed into a learning opportunity. By visiting different departments and spending time in various learning environments, such as studios, labs and workshops, students discovered the learning culture of different disciplines, including the nature of tutor-student relationships prevalent in these cultures. This helped students to build links between learning culture and disciplinary perspectives. Considering how it enhances students' understanding of interdisciplinarity, during an interdisciplinary design education, whether there is a dedicated space to work or not, it may be useful to encourage students to visit and spend time in other disciplines' learning environments.

Third, although there were students from seven different disciplines, in the interviews students particularly focused on the disciplinary differences between industrial design and engineering. Students' accounts seem to repeat dualistic views on designer-engineer relations, which have a great detrimental effect on interdisciplinary relations in professional life (Kaygan, 2014). The typical aesthetics-functionality dualism revealed itself persistently throughout the project. Industrial design students clearly indicated that they prioritise the user by putting more emphasis on user's needs, interests, and preferences during the discussions taking place at the idea generation and product development stages. However, engineering students often referred industrial designers' concerns as aesthetics-related and tended to position these against functionality, which is the main concern of the engineers. Although there were students from four different engineering departments, the disciplinary differences among engineering departments were not bring into discussions, and engineering is contrasted to industrial design as a single discipline. Drawing on these findings, we suggest that despite the presence of various disciplines, the relationship between industrial design and engineering is still the most problematic one during an interdisciplinary collaboration. Although, the IDS helped students to develop an understanding of different disciplines, the aesthetics-functionality dualism remains too strong to be challenged and to open room to new concepts such as user and use context in a four-week project.

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