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From forming to performing: team development for enhancing interdisciplinary collaboration between design and engineering students using design thinking

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Abstract
This article aims to expand our knowledge on interdisciplinary design education by focusing on team development, which has remained a less explored aspect of interdisciplinary collaboration so far. An interdisciplinary design studio course, Collaborative Design, for food engineering and industrial design students in higher education provides the research context. The empirical basis of the paper comes from interviews with students on their experiences of interdisciplinary collaboration in the course, and the educator's observation notes. Drawing on these data, this article critically reflects on how and to what extent the teaching materials, methods and strategies incorporated into the course design guided and supported students' transition through the four stages of becoming a performing interdisciplinary team. The article concludes with four suggestions for design educators. First, encountering new ways of thinking, talking and doing that make sense for both disciplines engages students in interdisciplinary collaboration. Second, humour and positive social relations play an important role in team success in all stages of team development. Third, using the first weeks of the course to reveal the disciplinary differences and potential issues that would lead to conflicts through class discussions and warm-up activities facilitates a smooth transition from forming to norming. Fourth, adequate representation of each discipline should be ensured both in the design problem and solution, and among the tutors.

Keywords Interdisciplinary · Collaboration · Design · Engineering · Teamwork · Design thinking

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Introduction

As the scope of design practice and interventions has extended to tackle larger, more complex and multidimensional problems of society, designer's collaboration with other disciplines, especially engineers, became an important topic on design educators' agenda (Tang & Hsiao, 2013; Leake & Weightman, 2011). Recently we have witnessed the initiation of various interdisciplinary programmes and courses in both design and engineering fields, some of which aim to combine the strengths of both disciplines under hybrid programmes (Blanco et al., 2017; de Vere et al., 2010; Fixson, 2009). This article aims to expand our knowledge on interdisciplinary design education by focusing on team development, which has remained a less investigated aspect of interdisciplinary collaboration so far. It explores the context of an interdisciplinary design studio course, Collaborative Design, for food engineering and industrial design students in higher education. The course was taught in 2018 and 2019 fall semesters jointly by one tutor from each department, and coordinated by the author of this paper. The empirical basis of the paper comes from interviews with students on their experiences of interdisciplinary collaboration in a design project during the whole semester, and the observation notes I took at the end of every class in 2019. Drawing on these data, this article critically reflects on how and to what extent the teaching materials, methods and strategies incorporated into the course design scaffolded development of performing student teams.

The article begins with a review of existing literature to elaborate on the prevalent challenges for successful interdisciplinary collaboration between design and engineering students. Then it presents Tuckman's four-stage small group development model, which provides the theoretical framework of this study. After explaining the course design, where the research is contextualised, the research design, conduct and analysis are outlined. Following the presentation of the findings, the article is concluded with the discussion of the implications and recommendations for fostering successful interdisciplinary collaboration via guided team development in design education.

Challenges for interdisciplinary design collaborations

Levi (2017) suggests that a team's success is defined by three criteria: which are first, completing the given task, second, maintaining good social relations, and third, promoting each member's personal and professional development. Accordingly, in a successful team, while completing the task, team members develop positive social relations that help them sustain the harmony and collaboration throughout the project. The social support created within the team as well as the acquiring of new skills and expertise, then, contribute to the personal and professional development of team members by satisfying their social and growth needs. Review of the previous research on interdisciplinary design collaboration in educational contexts, however, reveals the communication and cognitive barriers before fulfilling these three criteria.

The main obstacle faced by the interdisciplinary design teams is creating a shared understanding and goal among team members on which they can build on their design solutions (Détienne et al., 2012). In teams consisting of designers and engineers, such barriers arise from the differences in value priorities and design processes of the two disciplines (Pei et al., 2010; Rasoulifar et al., 2014). Research on the interdisciplinary collaboration experiences of design and engineering students reveals that students discover strong disciplinary differences around a number of issues, such as the meanings of similar concepts (e.g. while in engineering the physical model is used as the testable end product, in design education models are rather used as explorative elements of the creative process), priorities in a design project (e.g. efficiency, durability, cost vs. user-centredness, form, ergonomics), and learning environment and relations (e.g. hierarchical and class-based vs. flat and studio-based) (Kaygan & Demir, 2017; Yim et al., 2004). Leading to frustration and conflict within the team, such disciplinary differences bring a detrimental effect on both the social relations and the individual development of team members (Dickey, 2010). They create an important obstacle for achieving team success also because to what extent a team shares a common understanding of the problem, design approach and the goal has a direct impact on the quality of the end product (Kleinsmann, Valkenburg & Buijs, 2007).

In the absence of a shared understanding and goal, students fail to demonstrate appreciation for interdisciplinarity. As a disciplinary framework, interdisciplinarity synthesises different sets of knowledge, concepts and methods from various disciplines to develop a unique approach to problem solving, which facilitates working on a shared problem that cannot be adequately solved by a single discipline (Repko, 2012). Integration of disciplines lies in the core of interdisciplinarity, and distinguishes it from other collaborative frameworks, i.e. multidisciplinarity and crossdisciplinarity (Kleinsmann et al., 2012). Thus, successful interdisciplinary collaboration to address complex design problems requires teams' integration of knowledge, research and design methods and the overall process, without prioritising any discipline-specific perspectives. Existing research, however, identified strong cognitive barriers that students face when moving into interdisciplinary contexts (Klaassen, 2018). Especially in teams with less experience of interdisciplinarity, integration is often hindered by students' 'disciplinary egocentrism', which limits their successful implementation of interdisciplinarity in two ways: failing to connect interdisciplinary subjects to their own disciplinary fields of expertise, and failing to recognise and value the contributions of multiple disciplines to the solution of complex problems (Richter & Paretti, 2009).

The review of the literature in the fields of design and engineering education shows that scholars have placed considerable emphasis on defining these challenges to better understand the underlying communication and cognitive barriers. Some studies have been concerned with facilitating better communication to support shared understanding by developing and testing tools and interfaces (Blanco et al., 2017; Kleinsmann, Valkenburg & Buijs, 2007; Pei et al., 2010; Rasoulifar et al., 2014) and exploring group interactions in teams (Qu et al., 2020; Kiernan et al., 2020). Other studies have provided a list of pedagogical strategies that can create positive student attitudes towards interdisciplinary integration (Carulli et al., 2013; Klaassen, 2018; Richter & Paretti, 2009), and the required skills and competences for students to achieve successful interdisciplinarity (Lattuca et al., 2013, 2017).

This paper aims to contribute to this growing body of work by exploring interdisciplinary collaboration from a team development perspective. Theoretically, it draws on Tuckman's seminal small group development model. The premise of the small group development model, which was initially developed by Tuckman (1965), and later reviewed and extended by Tuckman & Jensen (1977), is that to function effectively, every team needs to navigate through four stages: forming, storming, norming, and performing. While this theoretical framework has been extensively utilised in research on organisational collaboration practices (Bonebright, 2010), it remains unexplored in the educational context. This paper addresses this gap by seeking to understand how interdisciplinary collaboration can be interwoven gradually and systematically into the stages of team development. It raises the following research questions:

- How can the four-stage team development model be used as a structure to scaffold successful interdisciplinary collaboration among design and engineering students?
- How do students' expectations and concerns regarding interdisciplinarity change at different stages of team development?
- What strategies should be incorporated into the course design at different stages of team development to systematically guide students' transition into a performing interdisciplinary team?

Team development

In what follows I will define Tuckman's seminal small group development model with reference to Tuckman & Jensen (1977) as well as Bonebright (2010) and Levi (2017), who have presented a recent review of this model.

The *forming* stage involves orientation and getting acquainted. At this stage uncertainty is high. The team focuses on getting a grasp of the task assigned, and creating a ground for the interpersonal relations among team members as well as with leaders. Team members demonstrate positive attitudes towards others, and eagerness to get to know them. This stage is followed by the *storming* stage. Storming is the most challenging and critical stage, as it is characterised by conflicts among team members and lack of unity on team goals, roles and division of work. Disagreements may lead to dissatisfaction and even hostility, and at this stage, splitting into sub-groups that are formed around strong personalities or different areas of agreement may be observed. Team members may also challenge and demonstrate resistance to the authority or style of the leader. They start to realise that the task is more difficult than they initially expected, and may demonstrate anxious and defensive manners. In return, conflict regarding the task and their roles may grow. In order to become a functioning team, members need to get through this stage by resolving conflicts. Indeed, low-level conflicts that occur at this stage are instrumental, as through them members encounter different points of view, start understanding the positions represented by other team members, and improve the overall diverse thinking ability of the team.

Reducing conflicts helps clarify the team's goal, and leads to the *norming* stage, where cohesion and team identity are developed. At this stage, as ground rules, understandings and norms are established, the team discovers ways and methods of working together effectively and harmoniously. As the levels of trust and support increase, team members feel comfortable and become more open to express their opinions. At this stage different points of view continue to exist and occur, yet team members approach them by demonstrating appreciation and respect paying attention to avoid conflicts. In the *performing* stage, the team is ready to collaborate effectively with consensus and a shared focus on the task. Team performance rises, and if the team has been successful at setting ground rules and norms, and developing strong social relations until this stage, it can easily manage the stress that increases due to the approaching project deadline.

Therefore, teams need to progress linearly through each stage of development in order to reach their maximum performance of collaboration. By managing conflict through this transition, teams build trust and team identity, develop cohesion, and start working collaboratively towards a shared goal (Tekleab et al., 2009). Grounding our course design in this theoretical perspective, in Collaborative Design we developed teaching materials, methods and tasks in order to guide and support students' transition through these four stages of becoming a performing interdisciplinary team.

Course design

Collaborative Design is an elective course offered at Middle East Technical University, Department of Industrial Design with the aim of providing industrial design students with the experience of collaboration with food engineering students. I designed the course jointly with a colleague from Department of Food Engineering. We agreed on the topic "food away from home" (e.g. festivals, campsites, parks, picnics, and travelling), which would foster innovative food and food packaging solutions from both design and engineering students, as it falls into the intersection of both disciplines' fields of interest and expertise.

The course was designed with the aim of supporting teams to go through the first two stages of team development smoothly, and to start functioning autonomously after the first six weeks. As presented in Table 1, the first six weeks were occupied with lectures, workshops and in-class activities guided by detailed handouts and research assignments. From the seventh week on, teams worked autonomously, still under weekly supervision of the tutors. Since the students were from not only two different departments, but also various levels of study, teams were required to attend all classes and work in the studio together. Yet when the teams started to work autonomously, students were flexible to spend the class hours also in the workshop, lab or out for user test.

According to the learning objectives, by the end of the course students were expected to:

- Gain fluency in using design thinking tools and methods,
- Define an interdisciplinary design problem and prepare a strategy in order to formulate a design solution,
- Study real-life design problems as an interdisciplinary team,
- Demonstrate abilities to plan, manage and present the results of a design project,
- Report the material accumulated and generated throughout the design process.

The course was taught in 2018-19 and 2019-20 fall semesters to 20 industrial design (ID), and 11 food engineering (FDE) students. As Table 2 shows, students worked in nine teams.

Table 1 Course outline

Week	Content
1	**Introduction & Meeting** • Introduction to the course & the project topic: "Food away from home". • Class discussion: Short talks by volunteer students from both departments on what "design" means from their disciplinary perspective, illustrating with their projects. • Forming the project teams.
2	**Design Thinking** • Teamwork: Presentation of "Have you ever been to?" videos. • Lecture: Design thinking and design process. • Workshop in random pairs: Warm-up design thinking project.
3	**Observe** • Workshop: Brainstorming on the project topic via mind mapping. • Lecture: User and context of use. • Teamwork & feedback: Preparing fieldwork plan for user research. • Teamwork: Conducting user research.
4	**Define** • Teamwork & feedback: Analysis of field research data and preparing empathy map. • Workshop: Problem definition. • Workshop: Problem detailing via role playing.
5	**Food Design and Packaging** • Lecture: Food packaging from a food engineer's perspective. • Seminar by expert from industry: Sensory analysis of food. • Research: Existing technologies, products, and Do-It-Yourself solutions related to the team's use context and user.
6	**Ideate** • Workshop: Idea generation by using brainstorming cards, and idea detailing.
7	**Prototyping & Test** • Teamwork & feedback: Plan and produce low-fidelity prototypes. • Workshop: Test rehearsal before going to user test. • Teamwork: User test with the prototypes.
8	**Crits & Iterations** • Reflection & feedback: User test results. • Teamwork: Teams keep working on their projects.
9	**Interim Presentation**
10	**Crits & Iterations** • Teamwork: Iterations as required. • Teamwork: Taking final design decisions. • Teamwork: Starting producing high-fidelity prototypes of the finalised design.
11	**High-fidelity Prototyping & Test** • Teamwork: Completing high-fidelity/revised prototypes of the finalised design.
12–13	**Preparing for Final Presentation** • Teamwork: Drafting plans for the final presentation (video and slides). • Teamwork: Feedback on teams' presentation plans by the course tutors.
14	**Final Presentation**

Methodology

Since the research questions of this study require to capture students' interpretations of their own experiences of interdisciplinary collaboration, which is a complex process, this research adopts an interpretive approach that draws on two sets of qualitative data (Graebner et al., 2012). The primary source of data comes from semi-structured interviews with students. I invited all students via email once the classes were over. Overall, I interviewed 22 out of 31 students who took the course during the two academic years. Participation in

Table 2 Distribution of departments in each team

Teaching Year	Team no	Distribution of departments
2018-19	1	2 ID, 1 FDE
	2	2 ID, 1 FDE
	3	2 ID, 1 FDE
	4	2 ID, 1 FDE
2019-20	5	2 ID, 2 FDE
	6	3 ID, 1 FDE
	7	2 ID, 1 FDE
	8	3 ID, 1 FDE
	9	2 ID, 2 FDE

Table 3 Distribution of departments and the number of the interviewed students in each team

Teaching Year	Team no	Distribution of departments	Number of interviewed team members
2018-19	1	2 ID, 1 FDE	3
	2	2 ID, 1 FDE	3
	3	2 ID, 1 FDE	3
	4	2 ID, 1 FDE	2
2019-20	5	2 ID, 2 FDE	3
	6	3 ID, 1 FDE	3
	7	2 ID, 1 FDE	3
	8	3 ID, 1 FDE	1
	9	2 ID, 2 FDE	1

the interviews was voluntary, and interviews were conducted after the course grading was announced. This strategy worked well in order to ensure students that what they tell me in the interviews would have no impact on my evaluation of them, and to help me create an informal atmosphere in which students can share their views on the course open-heartedly. On the other hand, waiting for such a long time before inviting students to the interviews also resulted in low participation of the students who took the course in the last semester of their studies. As presented in Table 3, I could interview only one student each from teams 8 and 9, since in the time of the interviews some of them had already entered professional life, and did not volunteer to spare time in their busy schedules. My goal was to interview at least two students from each team in order to capture different disciplinary views, and it was achieved in 7 out of 9 teams (See Table 3).

In total, I carried out interviews with 15 ID and 7 FDE students. To ensure that every interview has the same starting point and covers the key issues that address the research question, an interview guide was prepared and followed during the interview (Roulston, 2010). The guide consists of three sets of open-ended questions, which focus on first, the students' motivations for taking an interdisciplinary design course, second, students' understanding of basic concepts introduced in the course, and third, the teamwork experiences throughout the semester (See Appendix A).

The first two sets of questions functioned merely as warm-up questions, where students had the opportunity to recall the design process, the contents of the lectures and workshops, and reflected on the basic concepts they encountered in the course. Their responses to the last set of questions constituted the larger part of the interviews, and were often illustrated

Table 4 Descriptive codes derived in the first-cycle coding of the interview data

Weeks	Activities	First-cycle codes	Discipline
1	Class discussion	Triggering opinions regarding the other discipline	ID, FDE
	Class discussion	Increasing curiosity and motivation for interdisciplinary collaboration	ID, FDE
	Class discussion	Discovering similarities between two disciplines' design processes	ID, FDE
	Class discussion	Discovering differences between two disciplines' design processes	ID, FDE
2	Design thinking lecture	A new design perspective	ID, FDE
	Design thinking lecture	A holistic design perspective	FDE
	Design thinking lecture	Designers are inspired regarding how to explain design to non-designers	ID
	Visit to the other department	Discovering differences between two disciplines' learning environments and cultures	ID, FDE
	Visit to the other department	Having fun and establishing positive social relations	ID, FDE
3	Mind mapping	Conflicting perspectives on the same concepts	ID, FDE
4	Problem definition	Conflict on adequate involvement of engineering in problem definition	FDE
	User research	Having fun in the field	FDE
5	Lecture	Designers learn on and from engineering	ID
6	Brainstorming	Integrating disciplinary perspectives via idea generation	FDE
	Brainstorming	Testing the interdisciplinarity of the problem	ID, FDE
	Brainstorming	A new idea generation tool	ID, FDE
	Brainstorming	Having fun and reinforcing positive social relations	ID, FDE
All	Crits	Having a professor from one's own discipline	FDE
Last weeks	Finalising the project	Positive relations facilitate efficient division of work	ID, FDE
Last weeks	Finalising the project	Discovering a different understanding of 'prototype'	ID

by 'stories' from various stages of the project. In their responses, students commonly chose to follow a chronological narrative, reflecting on how both the design process and relations among team members evolved throughout the semester in relation to each other.

At the beginning of the interviews, I informed students about how I would use the interview data, and received consent for audio recording. The interviews lasted approximately 45 minutes. Voice records were transcribed verbatim, and were analysed using MAXQDA 2020, a qualitative data analysis software.

Interview data was coded thematically in two cycles. In the first cycle, interview data was coded, descriptively by interviewee-centric terms (Linneberg & Korsgaard, 2019). As expected from the first-cycle coding, descriptive codes led to a categorised inventory of the data (Saldana, 2015). They were useful to identify the commonalities and differences within the two disciplines' perspectives, and to capture students' interpretations of the weekly course content, e.g. in-class work, lectures, feedback sessions, etc. (See Table 4).

In the second coding cycle, the codes were evolved into analytical themes in light of the theoretical framework adopted. Patterns were explored across the first-cycle codes, codes were handled independently from the associated weeks and tasks to be combined into theoretically-informed categories. The emerging themes were matched with the corresponding

Table 5 Data structure

First cycle codes	Second cycle themes	Stage of the team development
Triggering opinions regarding the other discipline Increasing curiosity and motivation for interdisciplinary collaboration Discovering similarities between two disciplines' design processes Discovering differences between two disciplines' design processes A holistic design perspective Discovering differences between two disciplines' learning environments and cultures Conflicting perspectives on the same concepts	Discovering the other discipline via guided interactions	Forming Storming
A new design perspective A holistic design perspective Designers learn on and from engineering A new idea generation tool Discovering a different understanding of 'prototype'	Gaining new knowledge, skills and perspectives for professional development	All stages
Having fun and establishing positive social relations Having fun in the field Having fun and reinforcing positive social relations Positive relations facilitate efficient division of work	Valuing humour and positive social relations to create harmony in the team	All stages
A holistic design perspective A new idea generation tool Designers learn on and from engineering	Appreciation of interdisciplinarity via self-reflection through gaining new knowledge, skills and perspectives	Forming Storming Norming
Conflict on adequate involvement of engineering in problem definition Testing the interdisciplinarity of the problem Having a professor from one's own discipline Integrating disciplinary perspectives via idea generation	Adequate representation of both disciplines to achieve integration	All stages

stages of the team development, and the data structure is finalised as presented in Table 5 (Linneberg & Korsgaard, 2019).

The second set of data came from the observations I carried out in the class. I kept a diary in which I took weekly notes regarding students' interactions with each other during class discussions and in-class activities. When it was not possible to write down everything during the class, I made jotted notes that consisted of a couple of keywords, which would later help me remember a conversation or a remark, and once the class was over, I expanded these notes into complete field notes (Glesne, 2011). Students' approaches to a given task, questions they asked to other students and tutors, and their responses to others' comments provided good examples of how they went through the stages of team development. In the analysis, I coded these notes after completing the analysis of the interview data, as I used the same theme list in the analysis of the observation notes. While interviews provided me with students' individual perspectives on becoming an interdisciplinary team in the course, observation notes revealed the interactions within the class, on which students did not always reflect.

For the credibility and trustworthiness of research, I adopted several strategies. The first strategy is revealing the data structure to ensure transparency and accountability in qualitative research (Table 5). The data structure provides a graphic representation of my progress from raw data to themes through analysis and demonstrates how my conclusions are linked to the data (Gioia et al., 2013; Guba & Lincoln, 1994). The second strategy is conducting the analysis via MaxQDA. It is argued that the use of qualitative data analysis softwares contributes to ensuring methodological rigour, since such softwares have the potential to serve as a mechanism to prevent "anectodalism" through formalisation of data analysis process (Sinkovics et al., 2008). Indeed, being able to list all quotations assigned to every single code in MaxQDA 2020 helped make sure that I avoid "selectively choosing only the most exceptional quotes, 'cherry-picking' the ones that support their idea(s), and/or selecting quotes from only the very few participants whose interviews were rich enough to generate quotable material" (Goldberg & Allen, 2015, p. 14). The codes and themes listed in the data structure all demonstrate commonality across the participants, and as a third strategy in the presentation of findings, I selected quotes from the interviews to illustrate and provide evidence for this commonality. In the selection of the quotes, I paid attention to select the quotes that are concise yet most representative. To make visible that quotes in the article do not come from the same participants, I gave a number to each student (e.g. S1, S2, S3), and indicated the number of the participant to whom the inserted quote belongs in the relevant paragraph.

Findings

Weeks 1–6: teaching based on in-class activities through forming and storming stages

Getting to know

Since Collaborative Design is an elective course with a small capacity (max. 12 students from each department), all students were highly motivated towards participating in the course. In the first week, I asked students to explain their expectations from the course. It was common among them to indicate that in professional life they will be working with people from other disciplines, and they consider the course as an opportunity to gain experience in interdisciplinary collaboration. As suggested in Tuckman's team development theory regarding the forming stage, in the first week all students demonstrated positive and enthusiastic attitudes towards other students and the tutors. They commonly indicated that they were aware of the fact that in professional life they would be working with people from other disciplines, and they considered the course as an opportunity to gain experience in interdisciplinary collaboration.

After introducing the course and the project topic, I asked the class how they would describe what 'design' and 'design process' correspond to in their own disciplinary education. Students from both departments described the process in detail by referring to specific courses they had taken. After the descriptions, students started to ask questions to each other and discuss by comparing the two design processes. One food engineering student, for instance, reflected on the lack of user research in the engineering design process during these discussions as follows:

> I see that our design process is very similar to yours. But we do not have a user in mind, we start with a technical problem, such as adding a new function to an existing product. For example, prebiotic food or food containing extra protein… We identify this problem considering the current trends in food. We go to people to test our product later, but we never consider them at the beginning! (S12)

As the discussion deepened, students asked more specific questions on the design process. One design student (S14), for example, asked the engineering students, 'I am very curious about how you decide on the form of the food. For us [designers], form is an extremely important issue. How do you develop the form?' An engineering student (S19), being puzzled by the question, responded that they do not think about the form, it is merely the random outcome of production. The design student, then, smiled and indicated that it is very surprising to see how a major concern in one discipline's design process is not even recognised in another's, although they both develop new products.

Previous research has proved that learning environments and professional relations cultivated in these environments demonstrate differences among engineering and design departments (Vyas et al., 2009). Because acknowledging disciplinary differences helps interdisciplinary teams to respect and appreciate each discipline's perspective and priorities, in the first week students were also given the following assignment that requires them to visit each other's learning environments:

> *Have you ever been to?*
> Our previous experiences showed us that in interdisciplinary teams students develop a better understanding of different disciplinary perspectives, when they visit and spend time in the learning environments of their teammates. Next week, we expect you to make short visits to each team member's department at a time slot that suits all team members (e.g. you can meet for a coffee or lunch, or spend time in a specific learning environment such as a studio or lab that your teammate uses often). Shoot very short videos (30 s. to one min.) in each location and combine them to create a team video.

All students participated in these visits, and the videos showed that students were very eager to 'host' their teammates. It was evident in the videos and the class discussions that during the visits, students made great effort in the role of hosts to draw a realistic picture of their learning environment and culture to their teammates. Students indicated that they learned a lot regarding student-teacher relationship, social life in the lab, studio and workshop environment, notions of 'prototyping' in designers' workshop and food engineers' lab. However, as expected, when compared to the visits at the later stages of the project, when students met in one discipline's working environment (i.e. studio, workshop, and lab) to carry out project work, their learning in this visit was superficial. The main contribution of this assignment, which also triggered the feeling of accomplishment via teamwork from the first week of the course, was rather to the development of positive interpersonal relations at the forming stage.

Design thinking, process and basic concepts

In the second week, I introduced design thinking as a problem solving skill and mindset via a lecture. Doing this, my aim was to provide engineering students with a holistic understanding of design process, by underlining the links between its each step (observe, define, ideate, prototype, test), so that the role of every single step in the design process would be clear. I explained basic concepts of 'ill-defined problems', 'divergence-convergence' and 'user-centeredness', and listed the strongest characteristics of design thinking such as being comfortable with ambiguity, relying on insights, risk-taking, test and iteration instead of excellent planning and avoiding failure (Carlgren et al., 2016; Hassi & Laakso, 2011; Schweitzer et al., 2016).

Since it would be the first time when engineering students would go through such a long and iterative design process, I presumed that presenting the whole process from the beginning would help prevent possible frustrations that might occur in the following weeks. Engineering students' accounts confirm that this strategy worked well, and the lecture not only prepared them for a multi-staged and iterative design process, but also inspired them to consider design as a more systematic and holistic process. In the interview with an engineering student, when I asked the most important thing that she had learned in the course, she responded as follows:

> S6: I found your lecture very informative. You showed something like starts with something general, then it would narrow down and then we would open up again?
> Author: Divergence - convergence.
> S6: Yes, exactly. I liked that part a lot because [in engineering] we do not have such a systematic idea generation. We have never done brainstorming, for example. I liked very much following those steps until the end of idea generation. We arrived at a [problem statement] without haste, putting effort into that idea.

The lecture on design thinking was primarily designed to introduce engineering students to designer's way of thinking, design process and the key concepts in the process. While preparing the lecture, I paid attention to use a plain and clear language to make sure that the engineering students would easily understand and reflect on the content of the lecture, particularly by comparing it with their existing knowledge on design process. Surprisingly, in the interviews this lecture was placed much emphasis also by design students as an important part of the course that provided them with a vision of 'how to communicate design process and thinking to non-designers', who also included their team members in the course. Thus, beyond my anticipation, it also triggered a new way of thinking and talking about design process, i.e. a simplified version of it, for design students.

Mapping the project topic

After the first two warm-up weeks, on the third week teams started to work on design projects. As a first step, teams were asked to 'map the project topic' by following these instructions:

> As a team write down the project statement on the centre of the paper. Underline all the words or phrases that you can expand upon, in order to open up discussion around.
> Innovative food and food packaging consumed in a context away from home.
> Explore each word/phrase. On post-its, write down the related concepts, ideas or alternative words/phrases that can improve your understanding of the problem that can be addressed by a design solution. Organise these items through your team discussions to create a mind map. In the discussions focus on WHAT and WHO questions.

Students were encouraged to fill in as many post-its as possible without judging any ideas within the team. During the workshop, I observed that teams' approaches to the assignment and the methods they chose diversified depending on which team members adopted the leading role. For instance, two teams organised the post-its in the form of a table, instead of a map, by ordering them under the relevant underlined word or phrase in the form of a column. When I asked them regarding this, engineering students indicated that they suggested the list format to their teammates, considering that it was 'a neat and simpler way of presentation'. I also observed that engineering students tended to write down only a couple of ideas, which often remained generic and technical, such as 'cost' for innovative and 'preserve' for food packaging. I talked to all teams and explained them once again the importance of (1) adequately exploring every underlined word by proposing creative and multiple ideas, and (2) organising their ideas in the form of a map to be able to capture the hierarchies and relations between them. I also joined the teams that needed inspiration, and brainstormed with them until they gained pace.

As more students got engaged in mindmapping, teams started to come up with original ideas, especially regarding the keywords 'innovative' and 'a context away from home', which inspired their problem statements in the following weeks. Both observation and interview data show that this assignment offered a ground for the encounter of different disciplinary perspectives, by requiring team members to not only reveal but also explain and defend their fundamental understandings, priorities and concerns. By explaining their positions regarding every single word in the project topic, teams, in an interviewee's (S2) words, 'internalised' the design problem they defined in the next step.

User research and problem definition

Exploration of the topic was followed by a lecture on user and use context, which underlined the importance of understanding the user in their real context at the beginning of the design process, through the use of appropriate and well-conducted research methods. The lecture was followed by a workshop, where students prepared their interview and/or observation guide, defined the strategy for finding participants, and made a division of work among themselves. I observed that since design students were already experienced in this task from their previous studio courses, they tended to take a leading role. Engineering students played an accompanying role in general, and they referred to user interviews and observations as 'fun activities', rather than new methods they learned and implemented. The distance between engineering students and user research seems to be caused by the assumption shared among both design and engineering students that the former already has an 'expertise' on user research. Overall, team members worked in harmony, focusing on the logistics of the fieldwork, which was required to be completed in the following week.

At the end of the workshop, we, the tutors, talked to every team to give feedback on their interview/observation guides, strategies, and backup plans.

In the fourth week, students analysed the data collected in the field, and presented their findings in an empathy map. Drawing on their empathy maps, teams wrote down one-sentence statements of the design problems they wished to address. Afterwards, we asked them to simulate the situation in which the problem occurs via roleplaying. Roleplaying served as a useful method for defining the problem statement in an interdisciplinary design project. In the roleplaying activity, we asked students to collaboratively contemplate on (1) the situation or incident to be simulated, (2) the physical environment it occurs, (3) all relevant actors, their characteristics, and feelings, and (4) the conversations between them. Elaborating on these four dimensions required students to reveal their own priorities (e.g. technical features of food vs. user experience) by using their own vocabularies from a disciplinary standpoint (e.g. people vs. user). One design student, for instance, compared the two disciplinary perspectives during problem statement in the interview as follows:

> I realised that while for us the problem statement could be more focused on socialisation in the office, for them it could be something more nutrition-based. Or if it is edible [packaging], [the new product] could offer something new in terms of production. (S18)

Therefore, defining the project statement and refining it via roleplaying became a key activity where different disciplinary perspectives were inevitably uncovered, questioned, and contested, as expected from the storming stage in team development.

Interview data shows that teams' main challenge at this stage was to define a problem that requires equal contribution of both disciplines. 'The identification of an interdisciplinary design problem' was one of the five evaluation criteria in the rubric that we prepared for the preliminary jury. However, beyond its being a criterion, experiencing interdisciplinary collaboration was the distinguishing aspect of this course for all students. This is why conflicts occurred in many teams around the question of 'Is my discipline represented adequately in this problem statement?'. The teams that successfully ended up with an interdisciplinary problem moved to the norming stage smoothly in the following weeks. For some other teams, the conflicts remained unresolved until the end of the idea generation workshop, where they gained a better and more concrete understanding of 'what counts an interdisciplinary problem that can lead to interdisciplinary solutions' through trial and error.

A day in food engineering department

Teams spent the fifth week in the Department of Food Engineering. While planning the course, the fifth week was considered as a break between problem statement and idea generation steps to provide teams with extra time to reconsider and refine their problem statements in light of (1) a lecture on food packaging, (2) a seminar on sensory analysis of food, and (3) a research assignment on existing technologies, products, and Do-It-Yourself solutions related to their problem statement.

In the interviews, the lecture was mentioned by almost all design students in their responses to the question 'What is the most important thing that you have learned in this course?'. Their accounts show that the lecture provided them with a good understanding of

(1) how a designer can benefit from the expertise of an engineer in new product development, and (2) what kind of questions should the designer ask to obtain the necessary technical knowledge from engineers. Students stated that the lecture was designed to address non-engineers, and it nurtured interdisciplinarity in teams as it introduced a totally new disciplinary perspective which they could easily link to their own concerns in design process. For instance, the lecture started by explaining that from a food engineer's perspective the objective of food packaging is to preserve the product in safe and good condition throughout the anticipated shelf life. Design students indicated that as they learned about the innovative technologies and materials as well as concepts such as edible packaging, they better captured the potential that collaborating with engineers in packaging design offers to an industrial designer. Thus, the day spent in the Department of Food Engineering was the biggest step for design students' discovering the connections between the two disciplines' fields of expertise. Moreover, realising the potentials of such connections for offering more comprehensive solutions to complex problems, they also discovered that interdisciplinary collaboration can 'empower' them as designers.

Idea generation using brainstorming cards

In week six, we carried out an idea generation workshop. First, teams wrote down their finalised problem statements, on which all team members agreed. Next, the brainstorming cards were distributed. On the first card, the rules were listed: defer judgment, encourage wild ideas, build on the ideas of others, stay focused on the topic, one conversation at a time, be visual, and go for quantity. Among these, the first three rules were stressed to encourage a constructive atmosphere within the teams. Students used one individual (silent brainstorming), and three team group (hot potato, evil mastermind, 'if I were…') brainstorming methods to generate as many ideas as possible. Overall, all teams were engaged in the activity, and completed the brainstorming with several ideas to explore further. Then, they evaluated the ideas, selected the most promising ones. Finally, they detailed the selected ideas via sketching in turns by building on the sketches of each other, so that no idea could be linked to single team member at the end.

Students described this workshop as 'fun' and 'useful' due to its focus on creating as many ideas as possible without judging. Regardless of the extent of their satisfaction with the quality of the generated ideas at the end, working towards a common goal by using a playful method led them to put the existing concerns and disagreements aside, and focus on the problem at hand. Paralleling their accounts, during the workshop I observed that they could easily add on each other's ideas and generate variants of a single idea by enriching it without sticking to their own disciplinary perspectives.

Integration of disciplines around an innovative idea was a foreseen outcome of this workshop. In addition to this, interview data have revealed that the idea generation step also helped students test the interdisciplinarity of their project statements. Especially for the engineering students who considered their teams' problem statements too abstract or too design-focused, generating several ideas to which an engineer's contribution becomes obvious was reassuring. The below quote illustrates this finding. A design student explained how the conflict that was occurred regarding the engineering student's contribution was resolved after the idea generation workshop:

> [In the problem statement session] she kept asking, "But what can we do? How can we solve this?" And it was not easy for us to answer her so quickly back then. We said, "Don't worry, it can be solved in various ways, don't think in such a negative manner." But we couldn't give her anything concrete, of course. Then, after the idea generation, I think after using hot potato card, we had many ideas, and she said "Yes, it can be something like this, like that." Once we had concrete ideas in hand, the problem among us was resolved. (S11)

Weeks 7–14: supporting autonomy as teams move to norming and performing stages

As expected, once the teams moved to problem solving productively, their dependence to discipline-specific basic knowledge and guiding methods was replaced with the need for an autonomous structure which was supervised by the tutors in the role of mentors. In the remaining weeks we encouraged teams to plan and manage their weekly division of work, time and tasks considering their own needs to complete the project on time. During these less structured weeks, our main concern was maintaining equally active participation of all team members, preventing motivation loss, 'free riding' and exclusion of certain team members. To this end, we developed two strategies to support both team autonomy and transparency.

First, we asked teams to use the course hours efficiently by working in the studio, workshop or food labs, as all students were available during course hours. Since after the sixth week they started prototyping and test, which were then followed by necessary iterations and improvements, we encouraged them to use the production sites at both departments. In their weekly feedback and later in the interviews students appreciated having such a flexibility during course hours, indicating that out of course hours they often had the tendency to divide work among themselves instead of working together, since their schedules did not easily match. Design students valued working in food labs as it provided with them a completely new understanding of 'prototyping' in terms of materials, tools, machines, and processes. Some students even draw a link between the physical environment and the originality of the course, suggesting that if they had spent more classes in food engineering department, the course would offer a stronger sense of interdisciplinarity to design students. As a result, students learned from and taught each other as they produced their working prototypes together. The below quote from a design student illustrates this:

> Author: How was it like to work in the food engineering labs?
> S15: It did not look like working in our studios at all because, first of all, there are so many rules you have to pay attention to there! And I had never put something into a test tube before in my life, so it was also fun. I mean, we did not know how to… [Our engineer teammate] directed us, she would say, "Add this, add that, now we stir it" etc. It was a fun process. So, it was very different from our studies here. Because we are used to this environment [in our department], we do not see something new here anymore.

Second, we asked teams to get weekly feedback from us on their progress, division of work, and time planning during course hours. In these feedback sessions, we, two tutors, always gave feedback together due to the interdisciplinary nature of the projects. As an interdisciplinary teaching team, we could give holistic feedback, by looking at the design solution through all relevant lenses, such as user, manufacturing, cost, sustainability, shelf life, etc. The interview data shows that having a tutor from both disciplines in these sessions was important for the students, particularly towards the end of the design process, when they had to make final decisions. Since the course was led by industrial design department, compared to design students, engineering students expressed more often that having an engineering tutor consolidated their sense of belonging, and feeling of adequate representation in the course.

> Umm [the engineer] professor's being there was relieving us because we (engineering students) were minority, maybe one third or two fifth of the whole class. It was important for us that he confirmed our ideas, it was reassuring. It is because we are still students, and his being there and saying "Yes, what you say is correct" was reassuring. (S22)

Overall, students associate the performing stage with feelings of enjoyment, satisfaction and pleasure. Despite working very hard, they often used the words 'fun' and 'pleasure' to describe the last weeks of the course. They draw a mutual relationship between performing and these feelings: Once the team believe that they are working towards a shared goal, work becomes pleasurable and fun; and once they are impressed with the outcomes of interdisciplinary collaboration, which would not be possible to produce within their own discipline, they keep performing to achieve their goal.

Of course, these feelings were not shared evenly by every student. While none of the teams failed to complete and present their project in the final jury, some students expressed their dissatisfaction with the unbalanced division of work within the team or the lack of enthusiasm and interest of one team member that lasted for the whole semester. Thus, we cannot claim that the impact of the methods and strategies presented in this article can be considered independent from the individual differences in students' motivation, expectations and interests. Still, the commonalities that occur in our findings enable us to capture to what extent they contributed to team development in the first six weeks, and to sustain interdisciplinary collaboration in the remaining weeks.

Discussion

This paper explored how Tuckman's four-stage team development model, including forming, storming, norming and performing, can be used as a pedagogical structure to guide and support successful interdisciplinary collaboration among design and engineering students. While doing this, it sought to capture any discipline-based differences that appeared in students' expectations and concerns regarding interdisciplinarity at different stages of team development. The findings presented above highlight four main discussion points.

First, Levi (2017) asserts that personal and professional development of each team member is one of the key success criteria in teamwork. The paper's findings confirm this argument, showing that gaining new knowledge, skills and perspectives for professional development throughout the four stages was placed strong emphasis by students as a distinctive feature of a fulfilling interdisciplinary design course. Previous studies have underlined the lack of appreciation of interdisciplinarity among students as a major challenge for achieving interdisciplinarity among students (Carulli et al., 2013; Klaassen, 2018; Richter & Paretti, 2009). My findings shed fresh light on the solution of this problem by demonstrating how encountering new ways of thinking, talking and doing that make sense for both disciplines engages students in interdisciplinary collaboration. This concerns several aspects of course design: content of and language used in lectures, methods used in in-class activities, physical learning spaces, and techniques and materials used in prototyping. The biggest obstacle before this goal is achieving a balance between providing the basics for one discipline and preventing boredom and redundancy for the other discipline. In our experience, using design thinking methodology as the backbone of the course worked as a useful strategy, because it presented a completely new disciplinary perspective on design to engineering students, and simultaneously offered a simple version of design process to design students, which still inspired them to reflect on how to communicate design process and thinking to non-designers.

Secondly, in addition to completing the given task and contributing to the personal and professional development of team members, Levi (2017) identifies a third criterion that defines a team's success, which is establishing and maintaining good social relations among team members. My findings underlined the role of humour and positive social relations in team success in all stages of team development also from the perspective of students. In the forming stage, informal social activities connected to the course content fostered a genuine interest among students in discovering another disciplinary culture. In the storming and norming stages, in both problem definition and idea generation steps, design thinking activities required team members to build on each other's ideas by brainstorming and role playing. It is essential to ensure the balance of fun and productivity was important in these activities to both encourage students to share their ideas openly without the fear of being judged, and complete each activity with concrete outcomes that would provide evidence for their progress as an interdisciplinary team. In the performing stage when teams function autonomously, the feelings of fun and pleasure shared in the team are associated with another benefit: helping the team cope with the stress caused by the approaching project deadline. Existing studies concerned with communication in interdisciplinary design teams have primarily focused on developing and testing tools and interfaces (Blanco et al., 2017; Kleinsmann, Valkenburg & Buijs, 2007; Pei et al., 2010; Rasoulifar et al., 2014) and professional group interactions in teams (Qu et al., 2020; Kiernan et al., 2020). As a new perspective on the topic of communication in interdisciplinary collaboration, I suggest that a potentially fruitful direction for future study would be the exploration of the relationship between positive interpersonal relations among students, especially humour, and establishing interdisciplinarity in design teams.

Thirdly, I claim that before rushing into the project work, using the first weeks to reveal the disciplinary differences and potential issues that would lead to conflicts through class discussions and warm-up activities facilitates a smooth transition from forming to norming. The sooner conflicts rise to the surface, the sooner teams start to handle them or seek help from the tutors. As intended by systematic team development (Tuckman & Jensen, 1977), conflicts that occurred in the early weeks were instrumental as they encouraged students to question and, as a result, to discover the other discipline, by improving the overall problem definition and solution seeking abilities of the teams. The class discussion on what design and design process correspond to each discipline, the visits to departments, and mapping the project topic led to the discovery of not only differences but also similarities between the two disciplinary perspectives in many teams, as students mentioned frequently in the interviews.

Finally, I assert that in interdisciplinary teaching it is vital to ensure adequate representation of all disciplines. This should be achieved first in problem statements and solutions. In the course we placed much emphasis on the interdisciplinarity of the design problem and the idea on which the teams worked towards a design solution. It is important to provide students with a clear understanding of what makes a design problem interdisciplinary, and to guide them to revise their problem and solution ideas when necessary to ensure that it falls into the expertise of both disciplines. Equally important is the participation of tutors from both industrial design and engineering. Previous research has argued for the significance of teaching in interdisciplinary teams to encourage interdisciplinary learning, by highlighting the difficulties in achieving interdisciplinarity among tutors (Self & Baek, 2017; Kaygan & Aydinoglu, 2018; Lee, 2014). In addition to equipping students with new skills and knowledge, in this research, teaching as an interdisciplinary team also contributed to ensuring the adequate representation of each discipline. Since the course was coordinated and led by the Department of Industrial Design, active participation of an engineering tutor throughout the semester supported the engineering students' feelings of belongingness and encouragement for involvement.

Conclusions

Interdisciplinary collaboration is an effective way to address complex problems with creative solutions. However, a successful collaboration requires teams first to get ready to work in harmony towards a shared goal and to appreciate interdisciplinarity. This article asserts that rather than expecting teams to go through developmental stages on their own, team development should be scaffolded by teaching materials, methods, and strategies that are concerned specifically with preparing teams for autonomously performing. As students gain positive experience of interdisciplinary collaboration during higher education years and complete courses with the feeling of satisfaction, we can expect them to be more open and eager to work with other disciplines in professional life.

Appendix A: Interview guide

Set	Questions
1	How did you decide to take the course? What was your motivation?
	Have you ever experienced interdisciplinary collaboration before? If yes, could you describe it?
	In this course we brought students from two disciplines. What do you think about this composition?
	When the course started, did you have any opinions, assumptions, or prejudices regarding the discipline you would collaborate with? If yes, could you explain them?
	What do you think about the project topic? Was it particularly of your interest?
	Did the course meet your expectations? Why/Why not?
2	What does interdisciplinarity mean for you? How would you define it?
	What do design, design project, and design process refer to in your discipline?
	Is there any concept, approach, and perspective that you have encountered for the first time in this course and surprised?
	Has there been any differences in your understanding of these concepts (including interdisciplinarity, design, design project, design process and the others mentioned by the student) after taking this course?
3	In this course you worked in an interdisciplinary design team. During the course were you happy with your team? Why?
	Was working with this team different from any other teamwork experiences you had before? If yes, how and why?
	How would you define your role in your team? Were there any tasks or project stages where you played a particularly leading role or where you could not participate as much as you wished Were these aligned with your expectations?
	How would you describe the roles of your teammates? Could everyone participate evenly? Why?
	Do you remember any tasks or project stages which you found particularly important, instructive, enjoyable, or that make you feel bad? If yes, could you describe them? Why?
	Overall, how and to what extent did this course contribute to your professional development? Why?

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References

Blanco, T., Casas, R., Manchado-Perez, E., Asensio, A. & Lopez-Perez, J. M. (2017) From the islands of knowledge to a shared understanding: interdisciplinarity and technology literacy for innovation in smart electronic product design, *International Journal of Technology and Design Education*, Vol. 27, pp. 329–362

Bonebright, D. A. (2010). 40 years of storming: a historical review of Tuckman's model of small group development. *Human Resource Development International*, 13(1), 111–120

Carlgren, L., Rauth, I., & Elmquist, M. (2016). Framing design thinking: The concept in idea and enactment. *Creativity and Innovation Management*, 25, 38–57

Carulli, M., Bordegoni, M., & Cugini, U. (2013). An intergrated framework to support design & engineering education. *International Journal of Engineering Education*, 29(2), 291–303

de Vere, I., Melles, G., & Kapoor, A. (2010). Product design engineering - a global education trend in multidisciplinary training for creative product design. *European Journal of Engineering Education*, 35(1), 33–43

Détienne, F., Baker, M., & Burkhardt, J. M. (2012). Quality of collaboration in design meetings: Methodological refexions. *CoDesign*, 8(4), 247–261

Dickey, M. D. (2010). Jiselle and the royal jelly: Power, conflict and culture in an interdisciplinary game design course, *International Journal of Art and Design Education*, Vol. 29. No. 2, pp. 163–172
Fixson, S. K. (2009). Teaching innovation through interdisciplinary courses and programmes in product design and development: An analysis at 16 US schools. *Creativity and Innovation Management*, 18(3), 199–208
Gioia, D. A., Corley, K. G., & Hamilton, A. L. (2013). Seeking qualitative rigor in inductive research: Notes on the Gioia methodology. *Organizational Research Methods*, 16(1), 15–31
Glesne, C. (2011). *Becoming Qualitative Researchers: An Introduction* (4th ed.). Boston, MA: Pearson Education
Goldberg, A. E., & Allen, K. R. (2015). Communicating qualitative research: Some practical guideposts for scholars. *Journal of Marriage and Family*, 77, 3–22
Graebner, M. E., Martin, J. A., & Roundy, P. T. (2012). Qualitative data: cooking without a recipe. *Strategic Organization*, 10 No(3), 276–284
Guba, E. G., & Lincoln, Y. S. (1994). Competing paradigms in qualitative research. In N. K. Denzin, Y. S. Lincoln, & [Eds] (Eds.), *Handbook of Qualitative Research* (pp. 163–194). New York: Sage
Hassi, L., & Laakso, M. (2011). Conceptions of design thinking in the management discourse, European Academy of Design Biannual Conference, Porto, Portugal
Kaygan, P., & Aydınoğlu, A. U. (2018). The role of space in interdisciplinary collaboration in design education. *International Journal of Technology and Design Education Vol*, 28(3), 803–817
Kiernan, L., Ledwith, A., & Lynch, R. (2020). Comparing the dialogue of experts and novices in interdisciplinary teams to inform design education. *International Journal of Technology and Design Education*, 30, 187–206
Klaassen, R. G. (2018). Interdisciplinary education: a case study. *European Journal of Engineering Education*, 43(6), 842–859
Kaygan, P. & Demir, Ö. (2017). Learning about others: Developing an interdisciplinary approach in design education. In E. Bohemia, C. de Bont & L. S. Holm (Eds.), *Conference Proceedings of the Design Management Academy* (pp. 1595–1611). Hong Kong, 7– June 2017. London: Design Management Academy
Kleinsmann, M. S., Valkenburg, R. & Buijs, J. A. (2007) Why do(n't) actors in collaborative design understand each other? An empirical study towards a better understanding of collaborative design, *CoDesign*, Vol. 3, No.1, pp. 59–73
Kleinsmann, M., Deken, F., Dong, A., & Lauche, K. (2012). Development of design collaboration skills. *Journal of Engineering Design*, 23(7), 485–506
Lattuca, L., Knight, D., & Bergom, I. (2013). Developing a measure of interdisciplinary competence. *International Journal of Engineering Education*, 29(3), 726–739
Lattuca, L. R., Knight, D. B., Ro, H. K., & Novoselich, B. J. (2017). Supporting the development of engineers' interdisciplinary competence. *Journal of Engineering Education*, 106(1), 71–97
Lee, J. (2014). The integrated design process from the facilitator's perspective. *International Journal of Art and Design Education*, Vol. 33, No. 1, pp. 141–156
Leake, J. M., & Weightman, D. (2011). Engineering and industrial design education collaboration, 2011 ASEE Annual Conference & Exposition, Vancouver
Levi, D. (2017). *Groups Dynamics for Teams* (5th ed.). Los Angeles: Sage
Linneberg, M. S., & Korsgaard, S. (2019). Coding qualitative data: a synthesis guiding the novice. *Qualitative Research Journal*, 19 No(3), 259–270
Pei, E., Campbell, I. R., & Evans, M. A. (2010). Development of a tool for building shared representations among industrial designers and engineering designers. *CoDesign*, 6(3), 139–166
Qu, L., Chen, Y., Rooij, R., & de Jong, P. (2020). Cultivating the next generation designers: group work in urban and regional design education. *International Journal of Technology and Design Education*, 30, 899–918
Rasoulifar, G., Eckert, C., & Prudhomme, G. (2014). Supporting communication between product designers and engineering designers in the design process of branded products: A comparison of three approaches. *CoDesign*, 10 No(2), 135–152
Repko, A. F. (2012). *Interdisciplinary Research: Process and Theory*. Thousand Oaks, CA: Sage
Richter, D. M., & Paretti, M. C. (2009). Identifying barriers to and outcomes of interdisciplinarity in the engineering classroom. *European Journal of Engineering Education*, 34(1), 29–45
Roulston, K. (2010). *Reflective Interviewing: A Guide to Theory and Practice*. Thousand Oaks, CA: Sage
Saldaña, J. (2015). *The Coding Manual for Qualitative Researchers*. Thousand Oaks, CA: Sage
Schweitzer, J., Groeger, L., & Sobel, L. (2016). The design thinking mindset: An assessment of what we know and what we see in practice. *Journal of Design, Business & Society*, 2(1), 71–94
Self, J. A., & Baek, J. S. (2017) Interdisciplinarity in design education: Understanding the undergraduate student experience, *International Journal of Technology and Design Education*, Vol. 27, No. 3, pp. 459–480

Sinkovics, R. R., Penz, E., & Ghauri, P. N. (2008). Enhancing the trustworthiness of qualitative research in international business. *Management International Review*, 48, 689–714

Tang, H., & Hsiao, E. (2013). The advantages and disadvantages of multidisciplinary collaboration in design education, 2013 IASDR Conference: Consilience and Innovation in Design

Tekleab, A. G., Quigley, N., & Tesluk, P. E. (2009). A longitudinal study of team conflict, conflict management, cohesion, and team effectiveness. *Group & Organization Management*, 34(2), 170–205

Tuckman, B. W., & Jensen, M. A. (1977). Stages of small-group development revisited. *Group & Organization Management*, 2(4), 419–427

Tuckman, B. W. (1965). Performing stage in team development. *Psychological Bulletin*, 63(6), 384–399

Vyas, D., Heylen, D., Nijholt, A., & Van Der Veer, G. (2009). Collaborative practices that support creativity in design, in I. Wagner, H. Tellioğlu, E. Balka, E., C. Simone & L. Ciolfi [Eds] *Proceedings of the 11th European Conference on Computer Supported Cooperative Work*, London and New York: Springer, pp. 151–170

Yim, H., Lee, K., Brezing, A., & Löwer, M. (2014). A design-engineering interdisciplinary and German-Korean intercultural design project course, in M. Laakso & K. Ekman, K. [Eds] *Proceedings in NordDesign 2014 Conference*' Aalto University, pp. 27–36