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THE BEST OF TIMES, THE WORST OF TIMES; STUDENT DESIGN TEAM FORMATION

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ABSTRACT
In design education, challenge-based approaches where students work on real industry problems are becoming increasingly common. Such education relies heavily on teamwork. Consequently, this requires educators to form teams that can deliver the desired outcome while fomenting learning and collaboration among teammates.
Most of the literature on team formation in design education is focused on larger cohorts, of dozens or hundreds of students, where slackers or free riders are a major concern. In the present study, we focus on team formation within smaller cohorts, of pre-selected, highly motivated students. We use two global networks of collaborating universities teaching design thinking. In each project, a multidisciplinary group of three to five students from one university is teamed up with a similar group of students from a second university along with a corporate sponsor that provides the challenge.
We selected teaching team members from participant universities to interview about their practices regarding team formation. Both the interviewees themselves and their institutions had multi-year experience in forming multiple teams out of a group of pre-selected students. We interviewed 6 teaching team members (from 5 universities) for about an hour each. The interviews were recorded, transcribed, and analysed, to contrast their practices to each other as well as to theory. Practices range from a half-day session to a multi-week warm-up period prior to the proper course.
Our findings are that current practices have evolved through trial and error over time and are only partially grounded in theory on team formation.

Keywords: Team formation, challenge-based learning, design thinking, design education

1 INTRODUCTION
Higher education institutions have long adopted collaborative teaching methods where students work in teams towards a common educational objective, both because of the benefits it presents to the students learning process and to educate professionals that go on to be capable of collaborating with other professionals in working environments. Among these collaborative teaching methods used in design and engineering schools, challenge-based approaches have gained popularity [1] given not only the possibility that students have to collaborate towards a common learning objective but also towards the resolution of a real-world problem.
For all the benefits presented by challenge-based teaching/learning approach it does come with its fair share of difficulties. Any student who has participated in education tasks where they are teamed-up with other students has struggled with the difficulties of collaborating with others. To paraphrase Charles Dickens (1859), working in student teams can be the best of times and it can also be the worst of times. Well-constructed teams, where skills and capabilities are well distributed, and where there is a good chemistry between teammates can enhance both the learning objectives as well as allowing the production of innovative solutions to the proposed challenges. While a poorly constructed student team might on the other hand lead to in-fighting within the team, different levels of production and commitment or the team deciding to partition the work without collaboration with one another.

1.1 Challenge-based projects and team formation
An example of this kind of challenge-based design and engineering education approach are two international networks in which students from different global universities work, in student teams, on product design and development projects. One around Stanford University and their ME310 course and one global network of more than 25 different universities around the world called the SUGAR Network.

In each project, a multi-disciplinary group of 3 to 5 students from one university is teamed up with a similar multi-disciplinary group of 3 to 5 students from a second university along with a corporate sponsor that provides a challenge. Over the course of roughly 9 months these global teams work on researching the problem space, re-framing their challenge, and producing prototypes of design concepts. The challenge for the teaching teams, is to be able to form multiple cohesive teams out of a pre-selected group of highly motivated students that apply to participate in the course. In forming diverse and cohesive teams, teaching teams members assess and use multiple variables or criteria about the students with different degrees of control to form the teams. Among them are skill & background variables, personality & behavior variables, and diversity variables. However, there are also other sets of variables that are outside of the individual teaching teams' control that can also play a role into the forming of teams, such variables can be related to the partner universities teams, as different collaboration might require different skills and other variables can be introduced by the corporate sponsor.
To be able to cope with the challenge of forming these teams, teaching teams have developed their own methods for team formation. These methods have been honed by multiple years of experiential learning [2], small scale experimentation of trial and error and the usage of different theoretical approaches from different fields of study (management, design, psychology, decision making, etc.).

2 TEAM FORMATION BACKGROUND & APPROACHES

2.1 Forming teams

The extant literature describes criteria that could be taken into consideration, how to best recognize-spot-diagnose said characteristics in individuals, and which configuration of these characteristics is more desirable. The first factor, which criteria to consider, shows reasonable unanimity in the literature on educational team formation. While professional skills and expertise remain important, personality and behavioural skills are among the more important elements. Characteristics such as communication skills, effective interaction, project management skills, self-efficacy, autonomy, positive interdependency, among others have a great effect on the team’s ability to properly function [e.g., 2, 3, 4]. As to the last two, how to recognize the criteria and how to utilize them, we can find more dispersion in methods and results.

2.2 Approaches to team formation

When trying to answer the questions of how to recognize the desired criteria in students and how to utilize it to form teams, literature offers a plethora of methods and approaches. Some teachers use randomization or self-selection of teams, but these approaches have been shown to be less effective [3]. Besides those are the purposeful methods and approaches to team formation that attempt to measure certain criteria. These use either of two methods, ***self-assessment,*** and ***observer-assessment***.
Self-assessment methods are based on the use of tools where the participants reply to a series of questions and based on the answers certain criteria can be determined. We can find emphasis in the literature on team formation on these types of methods [3 - 8]. Among these types of approaches the most commonly used are Five Big personality factors, Myers-Briggs Type Indicators (MBTI) and other derivations from MBTI such as Wilde’s Teamology. Self-assessment methods rely heavily on the answers provided by the participants. However, issues arise with regards to the validity of the results obtained, based on possible misrepresentation, self-deception, or purposeful lying [10 - 12]. Secondly, it is not uncommon to find that in groups of students from a similar background there is more possibility for homogenous results on the personality constructs to appear [5]. Thirdly, the use of tools for cognitive and behavioural attribute identification, does not measure compatibility and effective interaction between participants which is shown to be significant in team performance [4, 13]. Finally, for the most well-known method, Myers-Briggs, questions of validity and empirical grounding have been raised [e.g., 14].
Alternatively, though less commonly studied in literature, there are observer-assessment methods. These methods are based on the use of activities designed to reveal behaviours and skills of the students thought practical exercises and interactions with others. During the execution of these activities a teacher observes the participates to attempt to recognize the desired criteria [e.g., 4, 9]. Such methods are among the most utilized in project-based/challenge-based engineering and design education, and the subject of this paper.

3 METHOLOGY AND DATA COLLECTION

To better understand the process of team formation in design and engineering project-based education a group of 6 teachers from 5 different universities, that each participates in the previously mentioned SUGAR Network, were interviewed. All interviewees had multiple years of experience in forming teams of students that participated in the network. The number of students assessed by the different teaching teams at each university ranged from 15 students to 100 students per year and the number of teams created ranged from 2 to 10 teams per university per year.

3.1 Data collection

We used semi-structured interviews with the different teaching teams. Each interview had an average duration of 60 minutes, and during the interview, the participant was asked to recount and explain the process that they follow during their team formation process. Our semi-structured interview protocol covered three main areas of interest. The first related to the activities used by the teaching teams in the process of team formation and how these activities were executed. The second related to the different criteria (behaviours and skills) being observed during the different activities. Finally, the third area related to the process used to create teams using the observed criteria in the different activities.

In the final part of the interview the participates were also asked to reflect on their own process beyond the simple execution. This led to conversations of evolution of their team formation process through the years and their own reflection and evaluation of their team formation process.

3.2 Data analysis

All interviews were conducted digitally, given the different geolocation of the participants, and recorded for analysing purposes. These recording where transcribed and a qualitative analysis software was used to process them. They were codified into the three areas of interest in order to contrast the practices at each university to each other as well as to the existing team formation theory. Furthermore, this codification also allowed to encounter recurring themes in their practices that help to better understand observer-rating based team formation processes and how they differentiate from self-rating team formation tools. These themes were: (1) Practitioner's expertise (2) Small-scale experimentation; and (3) learning from experiences.

4 FINDINGS

4.1 Contrasted practices

Initially teaching teams that were interviewed were deemed to have observer-assessment methods as their primary method for team formation. However, after the interviews took place, it was revealed that most of the teaching teams utilized mixed methods that combined the use of activities that integrated self-assessment as a guide for skills and behaviours to be explored/checked later in observer-assessment based activities. Below we present a contrast between the different teaching teams in three key areas; the activities they use in their team formation process, the criteria used to characterize the participating students, and finally how they use said criteria to form teams.

4.1.1 Activities

In the interview process each teaching team was asked to recount their process for team formation. Each teaching team had a particular set of activities that they use that differ in the particular from each other, however, most had a very similar aim and rational behind them. Most processes began with an application/selection process that was also used as an initial point for recognitions of attitudes and behaviours from candidates. These early moments of the team formation process helped to map a priori assumptions of the students' possible skills and behaviours. Typical activities used by the teacher during this stage were CVs, application letters, psychological questionnaires, and interviews of the candidates. Following the initial mapping of the students and their skills and behaviours, some of the teaching teams went on a stage of 'corroboration' of those initial findings. Teaching teams then explain that in this second stage some specially designed activities in which the students engaged in the resolutions of a task that required the use of typical skills needed during the projects were used. These tasks were normally oriented towards the resolution of design tasks with different levels of complexity and time. Tasks such as redesigning an existing object, building of prototypes for specific users or the use of a common task called 'The paperbike challenge', known to all teaching teams of the SUGAR Network are used. While the students performed these tasks the teachers engaged in deep observation of behaviours and interactions among the students and then these observations were used in a final step of team creation. Following these stages teachers then moved to the final team forming activity/deliberation, which in all cases did not include the student's participation any further. In some cases, the process would be comprised of multiple activities that spanned several months while others used a couple activities over one day.

4.1.2 Criteria

From the interviews it was observed that the teaching teams distinguished three different types of criteria and that each type equally informed the final creation of teams. The three types are (1) professional and practical skills, (2) behavioural and personality and (3) interactions with others.

The projects in which the students participate, are commonly guided by the type of challenge that the sponsoring organization provides. Different challenges require very different skills. These lead to the first group of criteria, professional and practical skills. These types of criteria were more commonly evaluated by activities which require the student to self-report them, such as CV's or cover letters. However, in case of available third-party observations, such as past teachers' assessment of those skills where highly valuable. Following this first set of criteria, the next two groups related more to behavior and personality traits that the participating students exhibited and how they interacted with others. These two sets of criteria, as described during the interviews, played a crucial role in how teams are formed and how they perform. Teachers argued that in many cases, these criteria had a bigger impact on their decision making. Teachers discussed during interviews, that in order to recognize and identify behaviours and interactions, observer-assessment such as interviews, design challenges and one-on-one interactions were preferable. These types of activities provided teachers the opportunity to, early in the process, recognize possible dysfunctional pairings of students and avoid them while creating teams.

4.1.3 Creation of teams

The final step of the team formation process is to actually compose the teams. During the interviews it was noted that the final process of team creation followed a very similar pattern in almost all interviewed teaching teams. Here it is quite important to note, that so far, we have been using the term teaching teams rather than only teachers. Almost all of the interviewed programs in the different universities, where comprised by a group of teachers that participated in the team formation activities and that contributed to the final creation of the teams. The proceeding activity that was described during the interview process was often described as a conversation or deliberation between teaching team members to compare and contrast findings and observations during the assessment activities. In some cases, this conversation was described as a validation of common agreement. In other cases, it served to bring to the table cases where further discussion was needed, if discrepancies between observations existed.

4.2 Thematic Analysis

The thematic analysis was intended to showcase the underlying behaviours that teaching teams seemed to be displaying, that were either implicit or purposeful on their team formation behaviour. The themes were selected for their relevance to team formation from the observer-assessment approach and the role of this observers in the process. The themes are here presented in no particular order.

4.2.1 Practitioners' expertise

The interviewees had in common multiple years of experience teaching multidisciplinary design/engineering projects in which they had been forming teams of students. These many years of experience translate into a vast repertoire of lessons learned and development of skills that allow them to better recognize characteristics in students. The many years of building a library of past projects and students assessed helps them to develop expertise that is then used in the team formation activities.

The projects for which these group of teachers build teams is by its own nature highly ambiguous and complex type of projects. During the interviews, teacher repeatedly mentioned the importance of balancing multiple important factors that need to take into consideration. Yet typically these factors are not always clear or known before teams need to be formed.

"You've seen their CV, you've seen teamwork [activities], you did the interview, you know a bit about the person, but you don't really know it all. But then when it comes to team forming, to the final forming,

it's kind of a mess, because you don't have all the information… You really try to put together all of these layers but in the end of the day, it's the experience that drives [the decisions]".

4.2.2 Small-scale experimentation

As part of the student projects *themselves*, small scale experiments or prototypes are widely used as a tool for problem exploration and resolution. Students build prototypes that then are tested in real or simulated environments that then are used as learning points to inform the next steps of the process. Similar approaches are embraced by the teaching teams when forming teams of students. During the interviews, teachers made references to the use of small-scale experiments in their process for identifying skills and behaviours in the participants and for corroborating possible team constellations.
As previously explained in section 4.1.1, teachers commonly used specially designated tasks to help reveal skills, behaviours and attitudes from the students that would help inform their process of team creation. These activities were also commonly used for prototyping of possible student grouping. Teachers expressed that these team prototypes would then yield learnings about team dynamics and interactions between the students. The learnings from these prototypes are then not only used to test possible constellations but also to gain further knowledge on the behaviour of each individual participant.
"We have more or less an idea of what teams we want, from the initial interviews and the CVs with cover letters that the students have submitted. But typically, we have some doubts in between putting this or that students together, or how certain students will behave when we put them together. So, we then go into the practical exercises, and we start moving students around in the different tasks to see if our assumptions where right"
Some examples of these tests were: (1) groupings of individuals of the same background to eliminate skill advantage on solving the tasks. (2) Students were grouped with others of similar personalities, such as multiple strong leaders in one group, with the intention of revealing how their attitudes and behaviours changed. (3) Teams that had already shown to work well, were given difficult or ambiguous tasks, and then examined on how they dealt with more adverse situations.

4.2.3 Learning from experiences

The final theme that was found from the interviews with the teaching teams related to the evaluation, learning and modification of the process through experiential [2] means rather than formal ones. During the final part of the interviews, teachers were asked about how they reflect, evaluate, and improve their team formation process. From this, it was found that none of them have implemented any intentional or formal reflective process to specifically converse about the process and possible improvements. However, while recounting how their own process has evolved through time, it was often commented that negative experiences, shortcomings from team/class performance or informal and "serendipitous" conversations with other teachers drove decisions to change specific parts of the process.
"I felt more that when we travelled there was a nice, uhm, serendipity about conversations that I would have with [other teachers]. Things like, why did this person behave like this or acted like that? Or did we miss something as a teaching team?"
Additionally, teachers reflected that as they gain experience from participating in team formation processes through many years, their observation skills are honed and changed by observations and decision that they have made in the past.
"Sometimes, you start to see that the people are not behaving like you thought they would, things like a person who you though were a quiet and shy person just takes charge of the team in bad moments. Other times, we have had [students] who presented themselves as very calm and easy going becoming very conflictive and you didn't expect it at all, so it kind of blows up in your face. From cases like that you start to think of things that you may have missed [in the activities] and that helps you see them better in the future" .

5 DISCUSSION AND CONCLUSIONS

As any coach of a sports team knows, the combination of the best individual players does not necessarily make for the best team. Hence, approaches including assessments of team composition have the most potential. In that context, observer-assessment methods provide a deeper understanding of the students and their characteristics which leads to more informed team formation. However, they also present disadvantages to the team formation efforts. They require more time and heavily depend on the abilities of the observer to properly recognize characteristics. Hence, combinations of self-rating and observer-based methods may remain the preferred means of forming teams, as it allows the teaching teams to spot behaviours and skills with self-rating tools and then corroborate thought interactions between students for mismatches that could have been hidden by the participants in the self-rating measuring assignment. Furthermore, in cases where small trials through small assignments and trial team configurations, allows teaching team members to not only observe said behaviours but to also test them with different combination of possible grouping of students.

Our findings show that current practices within the studied design thinking network have evolved over time through trial and error and are only partially grounded in theory on team formation. However, for as far as post-project evaluations on the success or failure of formed teams have been done, they show only limited correlation to how well assessment practices aligned with team formation theory (unjustified success, unexplained fighting). Thus, providing directions for improvement both regarding theoretical understanding of student design team formation as well as for practical assessment sessions.

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