CHALLENGES AND VALUE PERCEPTIONS OF AN INTERDISCIPLINARY MODULE AT THE UNIVERSITY OF TWENTE

A Descriptive Study

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Abstract

Interdisciplinary education has become a universal trend and a staple feature on most university's curricula. Its propensity for interaction among disciplines, purportedly endows students with the skills to tackle complex societal issues that haunt our modern society.

A descriptive, mixed-method study was undertaken to characterise the challenges faced, and the value perceptions of, both academic staff and students in a second-year Bachelor module at the University of Twente. The 15 European credits module funnels three separate tracks: Industrial Design Engineering, Mechanical Engineering and Industrial Engineering Management into an authentic industrial project. It requires substantial input from all three specialities to solve the proposed problem, and to meet the learning objectives.

It was found that both academic staff and students fully recognise that the learning experience prepares students for their future professional lives. However, "solving complex societal issues" – a commonly stated benefit in interdisciplinary literature, was not seen as a contributing factor for this module. Three issues for students were investigated, they included communication issues, teamwork problems and prejudices against the other disciplines. Just under half of the groups experienced communication issues that appeared to be magnified by the interdisciplinary situation. Teamwork issues were present, but were mostly generic in nature, and therefore could not be pinned to the interdisciplinary situation alone. Finally, prejudice against disciplines and the feeling of being judged for belonging to a certain discipline was high. Interestingly, however, the students did not feel that the prejudices inhibited the ability for the team to work together optimally. Teacher challenges included high student numbers and the ripple effects thereof, i.e. time constraints, finding suitable tutors, etc. These contextual pressures appear to be in direct contrast to the espoused policies of the university. Recommendations on how to mediate some of the issues, such as vigilant alignment of policies to practice, are offered. Finally, suggestions for further research are included.

Acknowledgements

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To all of you, thank you.

Methodological Overview

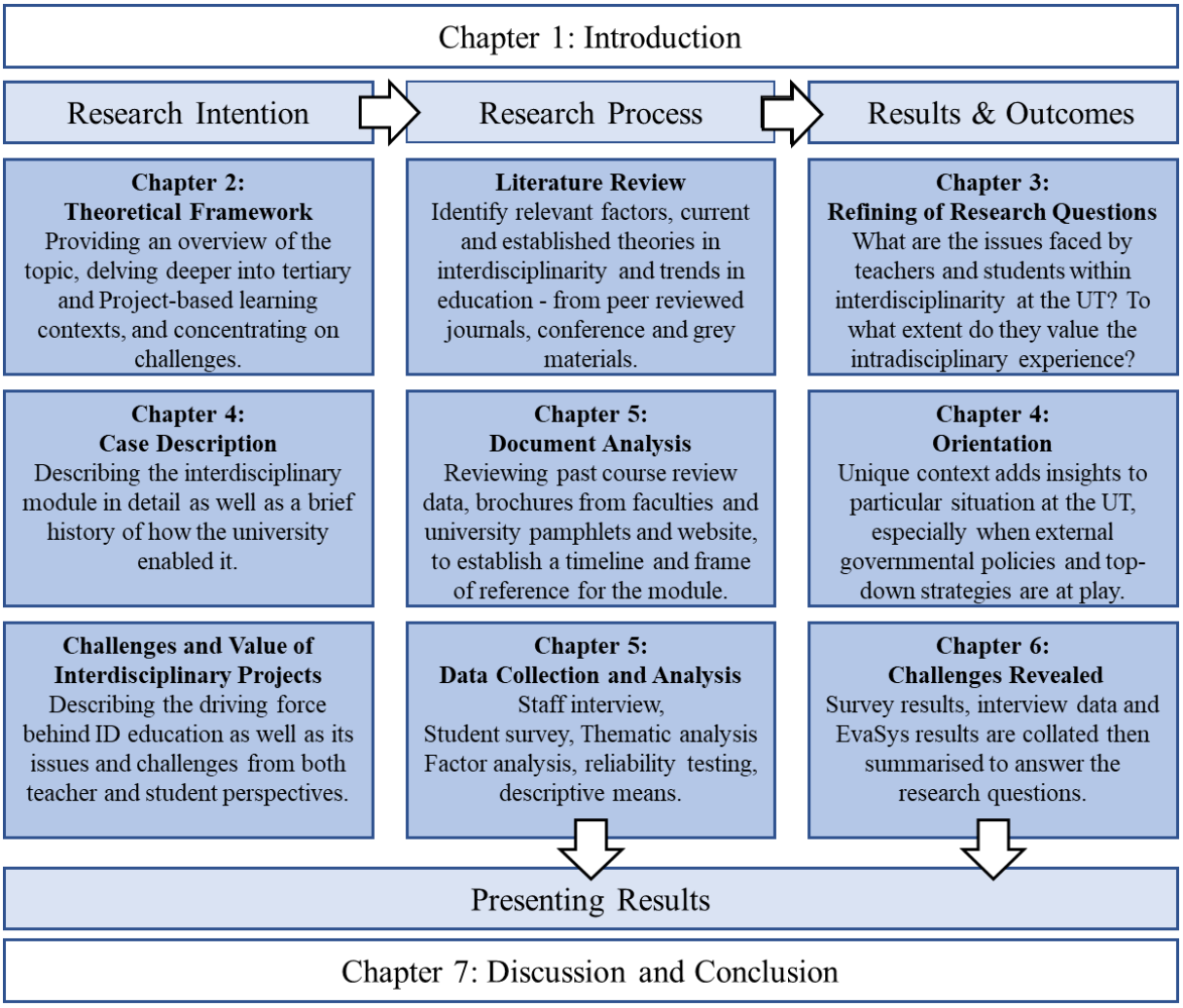

Figure 1. Overview of the research course of action. Each phase is summarised with relevant examples.

1. Introduction

Interdisciplinary (ID) education has been gaining momentum over the past few years and is now an established component in most universities' educational strategies (Lyall, Meagher, Bandola-Gill, & Kettle, 2015). It could even be asserted that the 21st century university hails the rise of interdisciplinarity as its governing educational paradigm (Kleinberg, 2008). Interdisciplinary education is a manner of instruction that takes students from different disciplines and facilitates the learning of three processes. It involves the exchange or reconstruction of knowledge, skills and attitudes; training in the ability to take perspectives and; the coaching of skills to work with people in varying degrees of collaboration. All processes prepare students to work towards a mutual goal or solve a common problem. Interdisciplinary education brings at least two disciplines together, usually in a project-based learning situation, to create innovations or solutions that cannot be compiled in isolation or formed from a single input source (Aboelela et al., 2007; Adler & Flihan, 1997; Giusti, Castelnuovo, & Molinari, 2017; Klaassen, 2018; Klein, 1990). Furthermore, with rapid and unpredictable changes in the future roles of employees, universities have recognised that preparing students for an uncertain future, and training them for the workplace is a priority (Alshare & Sewailem, 2018). Interdisciplinary education is seen as a path to stimulate that type of preparatory learning. However, the new-found ubiquity of ID education is not solely due to the recognition that "two heads are better than one" or that the ID education method is conducive to fostering the development of 21st century skills in students; skills such as critical thinking, collaboration, adaptability, etc. (Wagner, 2008). There are also multiple push factors in the expansion of the interdisciplinary phenomena. Many drivers of what is stimulating the rise of interdisciplinarity have been identified, they range from the knowledge-community's requirement, to societal needs (Repko, Szostak, & Buchberger 2017). Two examples of drivers (i.e. funding and competition) will be focussed upon below. Both factors are putting added pressure upon academic staff and institutions (Musselin, 2018).

Funding. Increasingly, funding bodies are prioritising research that traverses the boundaries of the natural sciences, social sciences and humanities (Callard & Fitzgerald, 2015). Since 2006, The European research council (ERC) has been progressively incorporating interdisciplinary aspects into their guiding principles, starting from the adaption of their review panel structure to the amendment of their definition of excellence to include interdisciplinarity. More noteworthy, is that since 2008, the ERC added an interdisciplinary

field to their three existing research domains (i.e. physical sciences & engineering, social sciences & humanities, and life sciences) and allocated an indicative 13% of the total budget towards it. Other funding allocations for interdisciplinary studies have also been growing steadily; e.g. the ERC's Synergy Grants, although not strictly for interdisciplinary research, are heavily favouring interdisciplinary inclinations. With this generous stream of funding within reach, many universities have expanded their ID portfolios engaging in a so-called "*interdisciplinary arms race*" in order to gain access to this lucrative source of income (Holley, 2009; Rhoten & Pfirman, 2007).

Competition. A further factor that is driving the popularity of ID education is the need for universities to remain competitive and relevant to maintain or increase their student numbers. Competition is viewed as a contest in a given field where each university is motivated by the pursuit of leading innovation (Dimitrova & Dimitrova, 2017). Here, ID education can be viewed as a distinguished selling point (Kleinberg, 2008). Innovation and therefore reputation gained through global rankings, offers high prestige that can help universities to attract more students (Wolf & Jenkins, 2018). Most top universities offer interdisciplinary studies at some level, not including it within the curriculum could be to the university's detriment. The competitive elements (e.g. innovation, attracting students, rankings) at universities are multi-layered and now unfold on a global stage. Institutions not only have to compete for students with local universities, but from international ones too. The quality of education offered, however, is a key factor to set oneself apart from the rest (Musselin, 2018). Therefore, implementing and promoting interdisciplinary courses and research helps universities to remain both relevant and competitive. Universities are compelled to compete with one another by innovating and adapting to the needs of the market, rather than solely focusing on traditional educational excellence (Waśkowski & Jasiulewicz, 2015). From a demand perspective, society is insisting that education become more relevant (Jónasson, 2016; Swora, & Morrison, 1974). Hence, some universities are attempting to supply this relevance, in part, though a range of ID educational offerings.

Despite its popularity, not everyone sings the praises of interdisciplinary education. Some caution that it risks devaluing traditional disciplines and that it might result in students becoming a masters of nothing or a factotum (Byrne 2014, Callard & Fitzgerald, 2015). Furthermore, Nair (2019), suggests it may be a hype, and that superficial knowledge is gained as opposed to deep understanding. A further negative perspective is of it lacking the rigour of rules, checks and triangulations; of it becoming a "*diluted thin science*" (Baker, 2017). These criticisms aside, interdisciplinary education for the meantime, is here to stay. Its prevalence is

only expected to increase in the future (Lyall, Meagher, Bandola-Gill, & Kettle, 2015). Interdisciplinary education, however, is not without its own set of challenges, as most also acknowledge some difficulties in coordinating courses, integrating knowledge and balancing disciplinary integrity (Panaritis, 1995; Holley, 2009; Gantogtokh & Quinlan 2017).

The current study, therefore, aims to describe the challenges that are experienced and the value perceptions of students and academic staff, within interdisciplinary education, at the University of Twente (UT). The particular module of interest (Module 6 Product Design Consumer Products) is a unique example of one of four interdisciplinary modules recruited to STRIPES2021; a Comenius-granted project that aims to support teacher teams in redesigning and improving their interdisciplinary modules in a structured and evidence-informed way.

2. Theoretical Framework

2.1 Interdisciplinary Education and the Act of Boundary Crossing

Interdisciplinary education aims to develop essential 21st century knowledge, skills and attitudes (KSA) that students can apply later, in their future professional lives (Repko, Szostak, & Buchberger, 2017). Usually, these KSA's are fostered through collaborative project-based learning (PjBL) situations, thus exposing students to authentic interactions with a variety of parties and contexts. During this interdisciplinary collaboration, students need to cross the boundaries of their expertise and discover new knowledge and perspectives of their fellow teammates' disciplines. A boundary is a concept often used to explain the limit of one's proficiency (Akkerman & Bakker, 2011; Suchman, 1994). Boundaries at universities are typically explicit because of the specialisations in courses offered. In the past, students at the UT mostly experienced homogenous exposure within their degree specialties. With the introduction of the ID modules, working within teams and the resulting need to practice on how to cross boundaries, became apparent. There are two levels of knowledge construction through boundary-crossing: co-constructions between students from different disciplines, and elaboration between students of the same discipline (Imafuku, Kataoka, Mayahara, Suzuki, & Saiki, 2014).

2.2 Supporting and Scaffolding teamwork

As interdisciplinary education often manifests itself in group project work, the warning that minimally guided instruction is less effective than when students are properly guided, should be heeded (MacLeod & van der Veen, 2019; Stentoft, 2017; Kirschner, Sweller, & Clark 2006). Support throughout the ID process is therefore imperative. This support can be subject related, like supplementary online material, or process related, such as training skills for working within teams or communication competencies. However, very few descriptions of empirically proven pedagogical frameworks that guide educators on exactly how to instruct or support interdisciplinary education exist (Rhoten, Mansilla, Chun, & Klein, 2006). Most of the current literature is composed of anecdotal accounts, opinion papers and definition pieces (Adler & Flihan, 1997). Conversely, fully comprehensive curricular examples are scant, as designing them requires an understanding of human nature and the sensitivity to coordinate teamwork, facilitate the construction of knowledge and manage interpersonal relationships. (Hollmén, Laurila, & Muhonen, 2014). Not all teacher-researchers are endowed with this

appreciation naturally, and as a result, it can be challenging to get the balance right between innovative interdisciplinary education or simply transplanting old formulas to new situations.

2.3 Disciplinary Socialising

The term interdisciplinary, is frequently used by the University of Twente on their website, in their grey materials, and in promotional material. They proclaim the path to practise certain skills (T-shaped professionals, teamwork, etc.), is through interdisciplinary education (University Twente, 2017). However, merely citing interdisciplinary education or declaring that it is the path to reach learning objectives, does not automatically qualify it as being truly interdisciplinary. Neither is interdisciplinarity the pinnacle of integration between different disciplines; there are various other arrangements where disciplines are brought together, that are also valuable. In reality, most so-called interdisciplinary educational undertakings are more likely to be multidisciplinary. The different terms, used inconsistently to describe interdisciplinarity and its variations, causes confusion and can deflect attention to pedantic definitions rather than the actual purpose of the learning experience. The purpose being, advancement of knowledge or improvement of results through contact with others outside of one's expertise. Exactly how the interaction is organised is only secondary to the fact that valuable interaction and knowledge integration is taking place. In order to circumvent the confusion resulting from the misuse of the word "interdisciplinarity", I propose a new phrase to describe any level of disciplinary interaction: *disciplinary socialising* – a phrase coined here for the first time. It is the level to which people from different disciplines acknowledge, apply, and learn from each other's disciplinary knowledge and epistemologies. Taking steps to combine disciplines is primarily a social process, where individuals must communicate and interact often within disparate environments, ideas and bodies of knowledge (Holley, 2009). Once learning interaction between students in different disciplines occurs, or integration of knowledge between disciplines happens, the specific manner can be labelled further. The levels of disciplinary socialising can then be illustrated by the (self-created) *Disciplinary Socialising Continuum,* partially inspired by Adler & Flihan's (1997) interdisciplinary continuum, created for middle and high school cross-curricular integration. *Figure 2*, objectively elucidates the levels of disciplinary exposure within an educational module or programme for tertiary educational institutions. For example, the degree of knowledge sharing between students of different disciplines, the integration of expertise, the type of teamwork arrangement, and their appreciation of epistemologies that differ from their own,

are described. The *Disciplinary Socialising Continuum* is depicted according to four classifications moving from low integrative activities to highly integrative activities. *Figure 2* displays the activities the students undertake during their project work within each classification, as described in detail below:

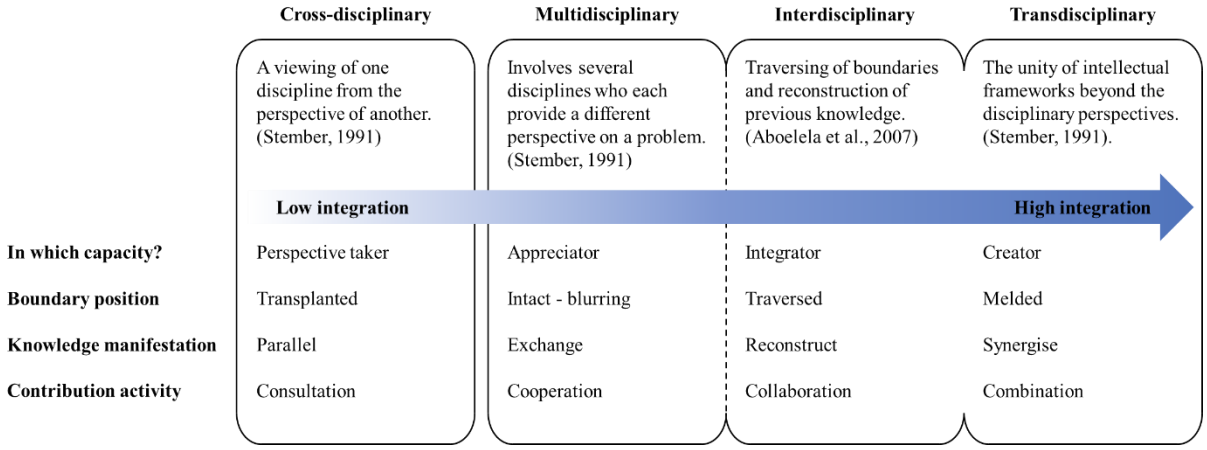

Figure 2. Disciplinary Socialising Continuum: noting the nuances, actions, knowledge acquisition, and roles played by students at each level of interaction within cross-, multi-, inter-, and transdisciplinary education.

Cross-disciplinary activities. The role that the student must play here is one of a perspective taker; having the ability to approach the problem by taking the perspective of a different discipline into account (Boland & Tenkasi, 1995). The student will not actually cross the proverbial boundary, but rather refer to the perspective in a detached but attentive manner. Not necessarily extending their own understanding, but consulting the expertise and applying it to the situation directly. Knowledge is transferred, but not always reciprocally exchanged. For example, when designing a tactile toy for infants, design students may consult a materials scientist to inform them of which toxic materials to avoid. The material scientist will not actually work on the project together with the team, but merely consult and contribute in a limited-advisory capacity.

Multi-disciplinary activities. This arrangement involves two or more disciplines which can each provide a different or complimentary contribution towards solving a common problem. All parties are actively trying to learn from each other in a reciprocal manner. They exchange their knowledge and contribute their expertise at each stage of the process. They mostly stay within the boundaries of their field, but are starting to make connections and have deeper understanding of what the other fields are capable of and what they can contribute (Giusti, Castelnuovo, & Molinari, 2017). Knowledge is exchanged and supplemented between team

members, but not necessarily fused into a novel branch of theory. The different individuals cooperate to work together to contribute their own expertise, concurrently, for the ultimate goal of solving the problem as a team. For example, a study from MacLeod & van der Veen (2019), scrutinised a UT module where mathematics, civil engineering and industrial & engineering management students, jointly designed solutions for motor traffic to-and-from a hospital. Each track had a separate role to play and different expertise to contribute, to complete the group assignment.

Interdisciplinary activities. At this level, integration of knowledge is starting to occur. This should be mainly the responsibility of the course creator or teacher, as students approaching this set-up will most likely be taught new knowledge alongside people from other fields, or a homogeneous group will be learning a newly integrated course. It will then be their responsibility to integrate the new knowledge and methods in the context of their own established expertise. Their classmates will do the same, resulting in a traversing of boundaries and reconstruction of what they previously knew, in light of the new knowledge exposure (Aboelela et al., 2007). The manner of working together to find a solution to the problem, will be more collaborative; where individuals work together towards one single goal, but where roles are not clearly separated by discipline. An example is the TechMed module at the UT, where a homogeneous group of medical students are learning a new synergised topic that materialised due to advances in technology. The problem will then be solved using their newly acquired reconstructed knowledge and the 21st century skills that were facilitated over the course of the programme.

Transdisciplinary activities. Here, the different disciplines are combining expertise to create a novel conceptual, methodological and epistemological invention (Toomey, Markusson, Adams, & Brockett, 2015). The knowledge creation is based upon new synergies and interactions at a high level. Through the combination of expertise and committed teamwork, new synergised types of knowledge that go beyond disciplines, will be created (Stember 1991). For example, a transdisciplinary course could be created at the helm of a new breakthrough-field like ethics of artificial intelligence.

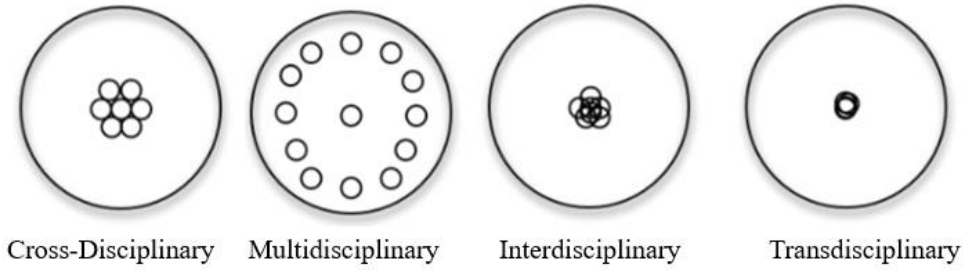

Figure 3. Schematic representation on manners in which disciplines can collaborate (Figure courtesy of Zeigler, 1990; Jensenius, 2012).

From the descriptions above, it is clear that all four approaches are conceptually different, and therefore their structures are too, which is graphically represented in *Figure 3*.

The *Disciplinary Socialising Continuum* can be a useful tool for the classification of a module or programme in an educational science context. Furthermore, it can be used as a reference to describe the actions undertaken by students in each role or context they adopt within the module or programme. Academic staff could use it to pinpoint and then articulate learning goals. This scheme may also be effective to identify "next-steps" if the motivation is present, to increase the level of disciplinary socialising in a given programme.

The different levels of disciplinary socialising may have unique advantages for each institution or faculty's particular circumstances or goals. More importantly, none of the stages on the continuum out-rank each other on effectiveness, they are, simply different intensities of integration that happen to be appropriate for the different contexts they inhabit. This is why the promotion of interdisciplinarity as the apex of disciplinary socialising needs to be curtailed and the value of the other types should be valued as well.

If the knowledge-exchange dynamics of various courses are identified from the *Disciplinary Socialising Continuum*, it becomes obvious that many so-called interdisciplinary exercises are, in fact, multidisciplinary. If true interdisciplinarity is the aim, Klein (2005) posits that genuinely integrated schemes need to arise from an overhaul of the curriculum, not recycling and combining old courses. Here, the point is not to split hairs about definitions but to help faculties chart their interdisciplinary status, and if they choose to do so, take the next step to further integrate and move back or forward, along the continuum.

The need to identify which learning is happening on the continuum, brings the importance of learning objectives to the forefront. Depending on what the teachers want their students to achieve; the desired learning outcomes should dictate at which point on the

continuum they choose to settle. For example, if one wishes their students to be able to work with other disciplines, and integrate and reconstruct knowledge within a collaborative project, multidisciplinary learning is ideal, but if tackling a problem through one's own expertise, taking the perspectives of other disciplines and consulting with them for broader input or relevance, then a cross-disciplinary assignment would be most suitable. To summarise; the desired or intended learning objectives, explicitly stated for each course, dictates the type of disciplinary socialising most appropriate to reach those objectives – they need to be considered first, and cannot be an afterthought. Once disciplinary socialising is underway, it must be noted that each classification can experience a range of challenges. A selection of these are detailed in the next section.

2.4 Challenges Encountered with Disciplinary Socialising

Three challenges, that could be an issue within a disciplinary socialising context, were used as focus for this study. They were generated through a collation of conclusions drawn from Adams (2007), Repko & Szostak (2017), and Borrego et al. (2013). The possible challenges include: communication problems, the presence of prejudice, and teamwork issues. These issues may have the potential to hinder effective learning and goal attainment.

2.4.1 Communication

Generally, poor communication has the potential to result in conflict and frustration (Krauss & Morsella, 2006). The ability to communicate effectively is a fundamental human skill, essential to daily social functioning (Mahajan, 2015). Even within mono-disciplinary environments, where people communicate using the same jargon, issues can arise due to misunderstandings. These types of communication issues can be compounded further when speaking to people from different disciplines. In fact, Adams (2007), claims that scientists are seldom exposed to basic theories or practices of other disciplines, which makes them less likely to fully comprehend their perspectives, or completely appreciate other's knowledge and contributions. Language and terminology can cause confusion. Besides new vocabulary, there is an added complexity in the form of scientific homonyms, i.e. the same vocabulary or phrases being used, but with different meanings for different disciplines (Lélé & Norgaard 2005).

2.4.2 Prejudice between groups or individuals

Perspective-taking: openness to incorporate other methods

Epistemological allegiance to one's own disciplinary practices can hinder recognition of merits in other ways of approaching learning. Moreover, according to Hamzah, Ismail, & Isa, (2012) the attitude of the student determines how they apply their knowledge and skills, either in a siloed or an integrated manner. Unfortunately, members of certain disciplines can foster an intolerance for others, and even claim superiority over them (Mason & Goetz, 1978). This mindset may hinder fully advantageous input from all parties. Referring to the *Disciplinary Socialisation Continuum (Figure 2*, p 11) not appreciating fully, what others can offer may lead to a more cross-disciplinary consultation-type relationship as opposed to a higher level of knowledge integration found in multi or interdisciplinary interactions. The Inclusive Stable Talent Philosophy recognises the strong points of individual team members and aims to bring the best of everyone's expertise and talents together (Meyers, van Woerkom, Paauwe, & Dries, 2019). This theory may be extended and usefully applied to interdisciplinary teamwork projects. This is where individuals of differing disciplines come together to solve a problem, but need to recognise the value of their team mates' knowledge. Moreover, Miller et al, (2008) call for "Epistemological pluralism" which recognises that there are many beneficial ways of knowing. How to teach this appreciation of others' perspectives, will most often not happen naturally, and will need to be supported and scaffolded (Peffer, & Renken, 2016).

Bias

Students need to be cognisant of their biases towards other disciplines, in order to not let them affect the teamwork dynamic and attainment of the learning objectives (Repko & Szostak, 2017; Fussel & Kraus, 1991). Effectiveness of teamwork, and therefore the end result i.e. the project, can be negatively influenced by bias and stereotyping (Meadows et al, 2015; Stoddard, & Pfeifer, 2018; Wolfe et al, 2016). Moreover, it is possible that stereotypical expectations of other disciplines can affect how tasks are allocated and how roles can become entrenched, creating a divvying-up of tasks as opposed to the integration and synergy of knowledge. An additional factor to consider is the possibility that team members could use stereotypes in order to gauge their own level of contribution to the team project (Plaks & Higgins, 2000). Again, stunting optimal contributions for the most advantageous outcome.

Stereotyping is a so-called cognitive schema used by people to organise information about others (Hilton & von Hippel, 1996). It is common in all strata of society, and thus also prevalent in the research and educational realms, where lack of knowledge of practice and methodology can reinforce dismissive attitudes (Lélé & Norgaard 2005). It is common for both students and academic staff struggle to appreciate other disciplines' merits, to the point where they could become contemptuous of them, when their own disciplines' value is questioned (Welch-Devine, Hardy, Brosius, & Heynen, 2014). Furthermore, as hierarchy occurs naturally in society, so too has it developed in the research and education fields (Callard & Fitzgerald, 2015). According to MacMynowski (2007), powerplay in multiple-discipline projects can have a negative impact on collaboration when the participants' perception of hierarchy between the disciplines is not addressed properly. A transformative learning process, taking diverse forms of objective or subjective reframing, is needed to help teams of different disciplines to become more critical of their own assumptions (Mezirow, 1997). Additionally, Social Identity Theory explains that a person's sense of who they are is heavily hinged on their group memberships and may influence how they interact with others (Tajfel & Turner, 1979). Therefore, the students need to be supported to enable them to navigate within their teams; to overcome myriad problems inherent when disciplinary socialising magnifies disparate approaches and epistemologies (Stentoft, 2017).

2.4.3 Teamwork challenges

Disciplinary socialising is commonly enacted through teamwork assignments, specifically through project-based learning. Support on how to perform and collaborate within a team is crucial to reaching task objectives (Hall & Weaver, 2001). Keeping this necessity of support in mind, five challenges that academic staff must consider within a teamwork situation, are: (1) combatting social loafing: when some team members do not contribute fully to a task; (2) workflow interdependence of the task: the degree the members rely upon one another to complete the project; (3) effective conflict management tools: these can be avoidance and confrontational; conflict is not necessarily a bad thing. Yong, Sauer, & Mannix, (2014) found that task-conflict can have a positive relationship with creativity, but relationship-conflict can be detrimental and must be addressed quickly; (4) trust promotion: affective and cognitive trust can be stimulated by various teambuilding exercises; and (5) shared mental models: the ability for team members to have a shared understanding of a task and approaches the different disciplines might apply (Borrego, Karlin, McNair, & Beddoes, 2013). These

teamwork issues are common in both interdisciplinary and homogeneous teamwork settings, however, they may be further magnified due to external factors (curriculum, teacher competencies in interdisciplinary education, etc.) or interdisciplinary communicative or bias problems. As the conduit for disciplinary socialising is the teamwork project, it needs to be scaffolded and supported carefully.

2.5 Project-based Learning

Nowadays, most western tertiary educational institutions have moved from a teacher-focused to a more learner-centred educational model (Schreurs & Dumbraveanu, 2014). Experiential learning and enquiry-based learning, in the form of team project-based learning is one such innovative model. This constructivist approach to education, highlights the need for focus on student discovery, as well as having the added benefit of personal composition of meaning. Furthermore, it places emphasis on understanding in an authentic context, that requires purposeful experimentation by students with their cohorts (OECD, 2018).

Besides hard skills and content-knowledge, the experiential learning pedagogy, PjBL is purported to develop teamwork as well as interpersonal and professional skills (Prabhu, Lim, Wee & Gardner 2018). Included in these skills is communication, where students are forced to not only make themselves understood, but to listen carefully to progress in a project (Magleby & Furse, 2007). Ideally, project-based learning exercises produce novel solutions, combining or synthesising the expertise of all the participants through a collaborative effort. However, in practice, collaborations are not immune to challenges, namely communication problems, prejudices and teamwork issues; all with the potential to influence its level of success (McEwan, Ruissen, Eys, Zumbo, & Beauchamp, 2017). Project-based learning is the archetype of learning at the university of Twente.

2.6 Introduction to the TOM Model

At the UT, teamwork has been common practice for many years. With the introduction of the Twents Onderwijs Model (TOM; Twents Education Model) in 2013, the university's vision was to raise the bar. By restructuring the bachelors programmes with a strong focus on PjBL in a modular thematic-scheme, the UT aimed to provide a better environment that could incubate diversely-skilled graduates. The UT modules consist of 15 European credits, which is equivalent to 420 hours of work. Project-based learning is an attempt to replicate a process of collaboration which happens naturally in the working world, and it exposes students to a

realistic professional environment situation. The overhauled curriculum was aimed at rejuvenating the UT's profile as an entrepreneurial university by advancing sustainable solutions to societal problems. Furthermore, improving the education through research-driven innovations, and boosting student retention in the long run (University of Twente, 2017). According to Craig (2019), TOM has two main focus areas: firstly, the embodiment of interdisciplinarity into the undergraduate curriculum by transmitting the aspects of the UT's interdisciplinary research into the educational programmes, and secondly, by teaching and learning technical and non-technical skills for an everchanging future (i.e. communication, teamwork, organisational skills, etc). Skills that can stand the students in good stead, even as technologies or circumstances change. At the UT, there are three strategies that incorporate disciplinary socialising in education: (1) new study programs that have an ID signature such as TechMed, ATLAS, CREATE, and Advanced Technology; (2) placement of students of different programmes together in minor modules in their third year; or (3) project collaboration by students from different programmes.

The TOM's spirit is intertwined with the UT's motto of *"High Tech, Human Touch"* which, in itself is the epitome of disciplinary socialising. It aims to combine perspectives from social and natural sciences to prepare students for the everchanging working environment, that is constantly altering due to technological advances or environmental uncertainty.

3. Research Questions

The main research question in the context of the Module 6 case study is:

What challenges are experienced by students and academic staff, within Module 6: Product Design Consumer Products, in interdisciplinary education at the University of Twente?

Sub-Questions

i. Which barriers have academic staff experienced within the module?
ii. How do the academic staff perceive the level of interdisciplinary teamwork support provided to students?
iii. To what extent do students experience communication, prejudice and teamwork problems within their ID project group?
iv. To what extent do prejudice issues affect the project work and output?
v. To what extent are the support mechanisms in place, perceived to be sufficient by the students (Workshops, tutor guidance, teacher advice)?

The secondary research question in the context of the Module 6 case study is:

What is the value perception of students and academic staff, within Module 6: Product Design Consumer Products, of interdisciplinary education at the University of Twente?

Sub-Questions

vi. Which drivers of interdisciplinarity are identified by academic staff?
vii. What value do students place in interdisciplinary education?

Assumptions

i. Increasing capacity demands due to the drive to attract more students, will adversely affect academic staff.
ii. Teacher perceptions on student support will be that of sufficient support being offered.
iii. Students will experience communication prejudicial and teamwork problems due to the interdisciplinary nature of the project and module.
iv. Prejudice issues will negatively affect teamwork and output.
v. Students should feel sufficiently supported within the module due to the range of support on offer.
vi. Academic staff will recognise a range of reason as to why interdisciplinary education is valuable and being practised at the university.
vii. Students will have mixed reactions to their perceptions of the value of ID.

4. The Case Description

4.1 The University of Twente: The Enterprising Road to High-Tech Human Touch

The UT opened its doors, for the first time in 1964 (established 1961) as a poly-technical institution. It was seen, in many ways as an experimental undertaking; leading the way with many 'firsts' that were later emulated by other Dutch universities. One such example is the identification of the need to shorten educational programmes and therefore initiate a bachelor of technology degree. So too were their leaders trailblazers with their opinions on education, specifically in disciplinary socialising. For example, in his inaugural speech in 1966 the dean of the Faculty of Electrical Engineering (Breedveld), lobbied against siloing of departments. Stating that *"training in the discipline alone, will never be able to contribute any insights into the way science is interlinked, let alone into the interrelationships in technology… given technology's increasingly multidisciplinary nature, it is the sort of insight that is vital to the engineer"* (de Boer, & Drukker, 2011). It is with this ethos of collaboration, along with the desire to innovate that sets the scene for this study.

4.2 Context and History of the Courses in Module 6

In the early to mid-1990s, project-based learning linked directly to industry, was introduced in the mechanical engineering (ME) faculty at the UT. It was eventually adopted throughout the university in 1999. With the creation of Industrial Design Engineering (IDE) in 2001, a novel combination of mechanical engineering and design, the practice continued.

Upon the advent of TOM in 2013, and with the Industrial Engineering Management (IEM) department lacking in a technical aspect to their course, an opportunity arose. They approached the IDE department to establish a collaborative project to enhance their students' technical exposure. This emerged as a perfect moment, along with Mechanical Engineering, to fuse the three tracks into what is now known as *Module 6: Product Development Consumer Products*. This enabled students to gain exposure to disciplinary socialising through a challenging industrial project, and gain discipline-specific knowledge that could be promulgated to others within the team. The complete timeline of the development of the components that led to the development of Module 6 is shown in *Figure 4*.

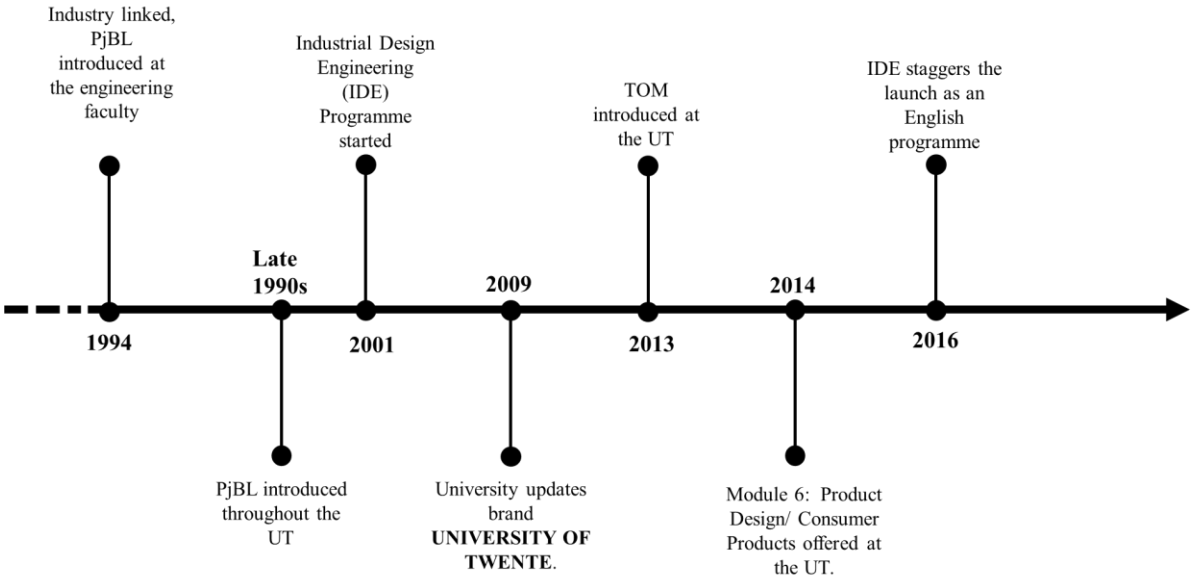

Figure 4. Timeline of the progression of Module 6 components.

4.3 Description of Module 6: Product Development Consumer Products

Module 6: "Product Development Consumer Products" spans a 12-week period, including a two-week holiday break. It is presented in the second quartile for second year students of the IDE, ME and IEM programmes. The module is composed of 15 European credits (ECs), consisting of 420 hours. The credits are allocated as follows: 6.5 ECs for the project, 1.5 ECs for the reflective assignment and the remaining 7 ECs for the three course subjects. The detailed learning objectives for this module is attached in *Appendix A*. The three tracks follow their own disciplinary-specific courses, however, overlap occurs for IEM and IDE students, as IEM students follow two courses that IDE have already completed in their first year, see *Figure 5* below:

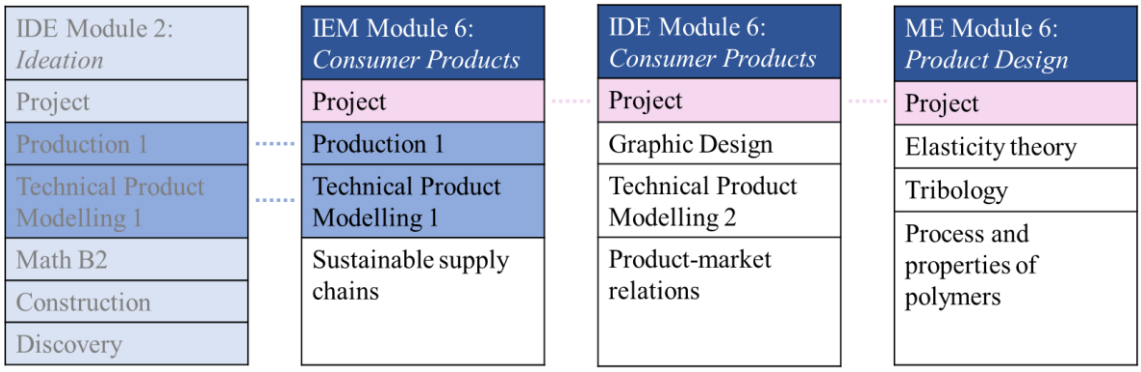

Figure 5. Courses and overlap in Module 6, based on image in Module 6 Manual (2018). Track codes: IDE = Industrial Design Engineering, ME = Mechanical Engineering, IEM = Industrial Engineering Management.

Each year, a different project is linked to an external company where the students of all three programmes, use the knowledge gained from their current courses and past experience, to collaborate to solve a real-life product dilemma. *Figure 6,* shows a representation of the module.

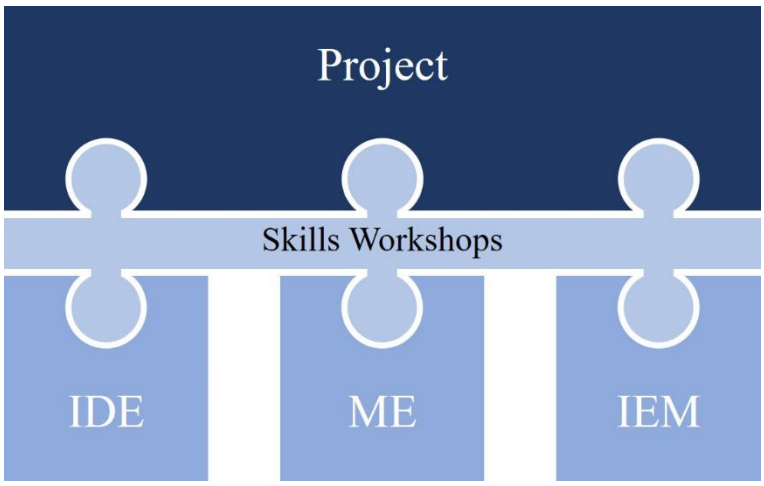

Figure 6. Schematic Representation of Module 6 Product Design Consumer Products. This shows the three separate tracks coming together through skills workshops and project work. Track codes: IDE = Industrial Design Engineering, ME = Mechanical Engineering, IEM = Industrial Engineering Management.

Projects vary each year, some have official non-disclosure agreements (NDAs) attached to them, but all of them aim to solve an authentic dilemma in industry. There are usually 9 or 10 team members in the group; ideally with equal discipline ratios, they are all encouraged, along with working on the product, to instruct each other on their expertise and share their knowledge and feedback throughout the process: "*it is assumed that the members of the project groups take the responsibility to convey acquired knowledge to group members i.e. peer-learning*" (Module 6 Manual, 2018).

A plethora of support and facilitation processes are in place to enhance holistic reinforcement of the intended learning objectives for students. For example: supplementary workshops and activities are planned to develop technical and non-technical skills. Educational support initiatives such as Fraunhofer Project Centre Expertise Student Team (FEST) and Reflection on Science Technology and Society (RESTS) aim to develop professional and metacognitive skills valuable to maturing young students; these are the types of skills that high achievers intuitively know, but on which most need to be instructed (Hartman, 2001).

FEST: "*We do not have learning outcomes or topics we are covering since we are not teaching the students. We are facilitating some guided workshops on (1) brainstorming; (2) deliverables; (3) pitching; and (4) structured design review to the students, where they can use to their advantage and work constructively towards their project goals….Our workshops are based on design thinking principles where we provide some steps on how to tackle the challenges of the project."*

RESTS: "*After the course, the students will be able to describe and analyse their interdisciplinary collaboration by using concepts from interdisciplinarity research, such as 'interaction' and 'integration'."* Three lectures are offered over the 12 week period, a final group report reflecting on the interdisciplinary experience must be submitted near the end of the module, the report is worth 1.5 ECs.

In addition to the workshops providing support, guidance in the form of tutors is provided to each project team. The number and frequency of tutor meetings is at the group's discretion. The tutor is the first contact for the group for questions on the project organisation or content, if technical questions cannot be answered by tutors, students are encouraged to contact the relevant specialist or the module co-ordinators. This personal connection to a mentor offers the opportunity for both process and content related guidance. According to Jordá (2013), tutoring offers multiple benefits in the form of fostering instrumental, interpersonal and systematic competencies in students. Additionally, refresher classes are offered to IEM students to assist them in linking prior knowledge to possible application within the context of the new module. This facilitation of the access of existing knowledge (Förster & Liberman, 2007) was found to be a necessary module addition due to previous years' experience. Moreover, concurrent blocked-time is tentatively scheduled for all three programmes, on their timetables, so that groupwork opportunities are formally facilitated. Assessment takes place on an individual and team basis, where the project outcomes and process are evaluated, as well as individual assignments and exams for each applicable topic or course. Forty-seven percent of the total mark comes from individual exams, the remaining fifty-three percent consists of the project work process and the final deliverable. Here, marks within the team can vary according to peer review scores and the group oral presentation.

Staff to student communication is facilitated via CANVAS, an online learning management platform of the UT. Finally a comprehensive module manual is provided before the initiation of the module to provide all essential information. If further information is needed, it can be accessed on the UT's website, or on OSIRIS, a student information system where students can register for courses, tests, minors, monitor their progress and explore course offerings (University Twente, 2020).

The module is organised by two coordinators (IDE and ME) - each fulfilling complementary administrative and educational roles. Both coordinators are directly involved in the module too, as teachers and/or tutors - enabling them to have real contact with the students and to keep abreast of developments. The module itself, employs strategies of interactive pedagogical methods such as PjBL, peer assessment, and role playing, to name a few. Most academic staff are also researchers, and some are tutors to groups as well. Teaching is done within specific courses, with explicit outcomes, but with a certain amount of teacher-autonomy to tweak materials according to the specific project for that year, although, depending on NDAs this may not always be possible. There are three academic staff within each of the three tracks. Due to time constraints and the absence of integrated courses in Module 6, academic staff do not regularly meet, but rather communicate via the module co-ordinators, the latter acting as conduits for information. This saves time and hands the responsibility of oversight directly over to the co-ordinators.

4.4 Programs participating in the Consumer Products module

4.4.1 Mechanical Engineering – An Inaugural Programme

Mechanical engineering has been offered at the UT, from 1964. It was one of three core departments aimed at educating a population to meet demands from society. It is still loyal to its founding principles and is increasing its intake annually due to the encouragement by the government, to stimulate the training of more engineers. The programme is promoted on the website as:

> "*…Bachelor's programme Mechanical Engineering is a challenging programme for hard workers with strong analytical abilities and plenty of resourcefulness"* (University of Twente, 2019).

4.4.2 Industrial Design Engineering - A True Interdisciplinary Programme

The IDE bachelor's programme, originally launched in 2001, is in fact, the embodiment of interdisciplinarity. It originally structured around four aspects: basics, styling; humanities & business, and engineering.

> *" Knowledge is built up in theory courses; assignments and projects aimed at application, deepening and generalisation. These projects implicitly and explicitly train professional skills"* (Damgrave, & Lutters, 2016).

4.4.3 Industrial Engineering Management

Initially all engineering programmes were made up of two parts; firstly, a three-and-a-half-year programme during which students could earn their baccalaureate diploma and: secondly, a two-year further study to earn one's engineering degree. During the second part, students could select either to continue their engineering studies or gain exposure to business and management. This top-up course in business, which also resulted in students completing their engineering degree, was introduced in 1968. Later, in 1985, a four-year business studies programme with an explicit technical track was introduced, also resulting in an engineering diploma (Posthuma, 2020). In the IEM programme brochure it proclaims

> "*…Become an interdisciplinary 'problem solver of tomorrow' through our 'High Tech Human Touch' approach you will develop a cross-disciplinary vision of companies, organizations, supply chains, and markets - with a keen eye for real results"* (University of Twente, 2019).

4.5 Contextual influences on Module 6

Additional factors that contributed to Module 6's particular context will be described. Three main agents can have an influence a programme's functioning (Honig 2006). Firstly, people i.e. participants, designers, implementors, etc. Secondly, policies, be they national or institutional; and finally, places, the location and context thereof. The individual student, is the first consideration. They have their own knowledge, inherent biases and personal problems over which the institution has little control (Slavin 1994). Next, the discipline that adheres to a certain ethos. It inculcates a culture and propagates discipline-specific methodologies. Surrounding the people and policies are the institutions which have their own conflicts with identity, bureaucratic procedures and educational philosophies. On a macro-

level, governments must contend with financial budgets, complex societal problems, etc. *Figure 7* details some of the relevant factors that come together that influence the running of Module 6 at the UT.

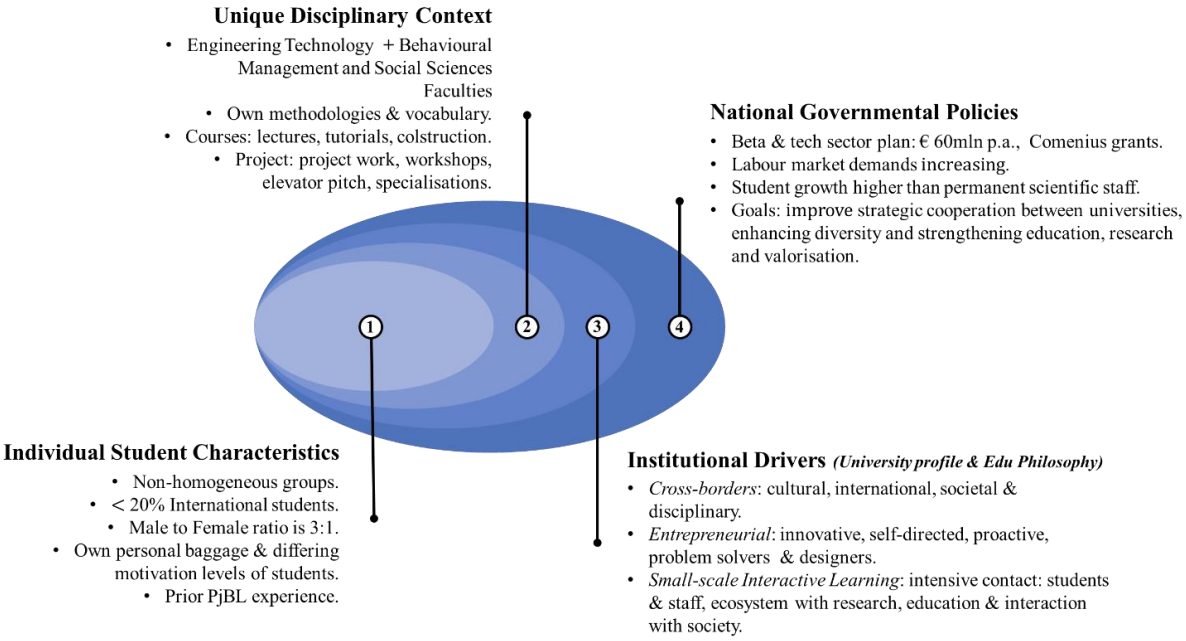

Figure 7. Context of four relevant factors that may influence the running of Module 6: individual student characteristics, unique disciplinary context, institutional drivers, and national governmental policies, respectively.

5. Method

The research is a unique single case study (Yin, 2009), exploring the outcomes of the student experience of the interdisciplinary module 'Product Design Consumer Products'. Furthermore, analysis of the academic staff's challenges within and value perceptions of, the interdisciplinary education in context, is described. This holistic perspective allows for contextual and external influences to be digested alongside the feedback of the students, to sketch a framework on how this module operates. It is a mixed-method approach, utilising two types of data collection procedures with a qualitative and quantitative component (Tashakkori & Creswell, 2007). Specifically; surveys and semi-structured interviews and document analysis. This study was conducted with the consent of the BMS Ethics Committee and adheres to their data handling specifications.

Table 1

Tabulation of Process of Enquiry

Research Questions				
What challenges are experienced by students and academic staff, within Module 6: Product Design Consumer Products, in interdisciplinary education at the University of Twente?	**Document Analysis**	**Teacher Interviews**	**Student Surveys**	**Observations & student comments**
i. Which barriers have academic staff experienced within the module?	X	X	-	X
ii. How do the academic staff perceive the level of interdisciplinary teamwork support provided to students?	-	X	-	-
iii. To what extent do students experience communication, prejudice and teamwork problems within their ID project group?	X	-	X	X
iv. To what extent do prejudice issues affect the project work and output?	-	-	X	-
v. To what extent are the support mechanisms in place, perceived to be sufficient by the students (Workshops , tutor guidance, teacher advice)?	-	-	X	X

(Table continued)

What is the value perception of students and academic staff, within Module 6: Product Design Consumer Products, of interdisciplinary education at the University of Twente?					
i.	Which drivers of interdisciplinarity are identified by academic staff?	-	X	-	-
ii.	What value do students place in interdisciplinary education?	X	-	X	-

5.1 Participants

The participants consisted of students enrolled in the Product Design Consumer Products module (2019/20), as well as academic staff involved in the module, these include academic staff, co-ordinators and the programme director.

Academic staff. There are nine separate courses within the module (three per track). Some academic staff co-teach certain courses and one teaches two courses. In total, eight academic staff were approached (seven male, one female) for a semi-structured in-person interview, which lasted between 16 - 45 minutes. Interview times varied due to the open nature of the questions. All basic questions were covered, however some staff divulged additional information and were more open than others, to discuss and share their reflections. The RESTS instructor was interviewed via Skype. Anonymity was assured to all interviewees. Eight out of the nine interviews were recorded audially. Seven out of the eight academic staff hold a doctor of philosophy degree and one is actively straddling the academic and corporate world.

Coordinator. Two co-coordinators for Module 6 were approached. As one is a teacher, the same semi-scripted interview was used. The second coordinator's interview was open and more exploratory. Both are male, possess doctor of philosophy degrees and belong to the ME and IDE streams. The IEM coordinator, who is not involved in the running of this module was also interviewed in an open manner to gain additional perspective.

Programme Director. The interviewee is female, has a background in educational science and has many years' experience working within the engineering technology faculty as an educational consultant.

Students. The population of Module 6 is 360 students (ratio male/female is 3/1). This module is divided into three separate tracks namely: ME with 157 students (ratio m/f is 138/19); IDE with 93 students (ratio m/f is 72/21); and IEM with 110 students (ratio m/f is 59/51). A digital survey was sent to all students electronically. A total of 70 responded (ratio m/f is 45/25).

5.2 Instrumentation

Academic Staff. Personal interviews were chosen over surveys due to the potential to clarify misinterpretations and to visually identify nonverbal responses (Ponto, 2015). Meeting academic staff in person also helped to amend the open questions according to insights gained over the course of the conversations. The scripted interview was linked to sub questions *i*, *ii*, and *vi* and centred around the following themes: roles within and purpose of the module; drivers of disciplinary socialising (Lyall, Meagher, Bandola-Gill, & Kettle, 2015); teacher opinions on student's experience; teacher's own experience in disciplinary socialising; challenges experienced and an open section, which morphed into a type of "personal reflection segment". The complete interview script is attached in *Appendix B.*

Although there remains, a universal reserve around the reliability of interview data, all efforts have been made to address the three fundamental challenges posited by Bleich, & Pekkanen (2013): (1) representativeness of sample: this was mediated by talking to all of the academic staff involved in Module 6, furthermore both coordinators and the programme director were approached. Consulting with all academic staff eliminated any chance of a non-response bias; (2) Type and quality of information acquired: careful attention to wording by avoiding unconscious bias and follow lines of enquiry that would encourage openness and; (3) Accuracy of reporting: in order to lessen bias or the "seeking of evidence" to support the stated assumptions; consultation with senior supervisors mitigated the risk of such an event (see *Table 2).*

Table 2

Overview of interview details.

Interviewee	Date	Length	Recording
Category 1: Teacher			
ME teacher 1	03/12/2019	23 min	Audio recording
ME teacher 2	17/12/2019	31 min	Audio recording
ME teacher 3 & Module coordinator	19/12/2019	32 min	Audio recording
IEM & IDE teacher 1	11/12/2019	16 min	Audio recording
IDE teacher 2	03/12/2019	40 min	Concurrent notes & supplementary notes
IDE teacher3	10/12/2019	38 min	Audio recording
IEM teacher 2	10/12/2019	43 min	Audio recording
IEM teacher 3	11/12/2019	20 min	Audio recording
Category 2: Coordinator			
Module coordinator	04/11/2019	48 min	Audio recording
Module coordinator	13/02/2020	19 min	Audio recording
Programme director	09/01/2020	37 min	Audio recording
Category 3: Students			
Group no. 30 (6 present)	16/01/2020	12 min	Audio recording
Category 4: Support			
RESTS Instructor	12/11/2019	24 min	Skype call & audio recording

Students. A digital survey from SurveyMonkey was chosen due ease of accesses via the on-line platform. The survey took between 3 minutes to 1 hour 48 minutes to complete, but was estimated to take approximately 7 minutes according to the provider. In order to entice respondents, the aim was to keep the survey as short as possible and to include an incentive (Jones, Baxter, & Khanduja, 2013). Therefore, a total of 15 questions were listed, they consisted of closed questions that were rated using Likert scales, and open questions to gather detailed insights into the students' personal experiences. The closed section of the survey, to gauge value perceptions of ID, bias and communication levels within teams, was based upon parts of the Interprofessional Attitudes Scale (IPAS) (Norris, et.al 2015) and the Interdisciplinary Project Management Questionnaire (IPMQ) (Tormey & Laperrouza, 2019). The evolution of the survey is summarised in *Table 3*, below. The student survey, detailed in *Appendix C*, is aimed at garnering the perspectives and experiences of the students in Module 6. The purpose is to establish specifically, to what extent the students valued the ID

experience, and the level of communication, bias and teamwork issues that were encountered. Furthermore, examples of noteworthy situations that may have occurred were encouraged to be shared. Additionally, their view on the support offered and any teamwork issues were covered.

Table 3

Development of closed questions: Student Survey.

Closed Questions – Student Survey		
Informed Consent Question		
1. Do you agree to participate in this study so that the data gained, can be used to enhance interdisciplinary learning?		
Demographic Questions		
2. What is your gender?		
3. What is your age?		
4. To which track do you belong?		
Themes and Original Question	**Source**	**Module 6 Adapted Version**
Perceptions of ID		
1.1 Shared learning before graduation will help me become a better team worker.	IPAS	5.1 I will benefit in my future career by participating in interdisciplinary educational modules.
1.2. Shared learning will help me think positively about other professionals.	IPAS	5.2 I will broaden my perspectives about other disciplines, through shared interdisciplinary learning.
(Self-created according to literature: consistently repeating ID will solve societal problems)	N/A	5.3 I will be better at tackling complex societal problems, due to my exposure to interdisciplinary learning
1.7 I would welcome the opportunity to work on small-group projects with other health sciences students.	IPAS	5.4 I would welcome the opportunity to work on more group projects, with other disciplines.

(Table continued)

Interdisciplinary Bias		
3.1. Health professionals/students from other disciplines have prejudices or make assumptions about me because of the discipline I am studying.	IPAS	6.1 I feel that students from other disciplines have prejudices or make assumptions about me because of what I am studying.
3.2. I have prejudices or make assumptions about health professionals/ students from other disciplines.	IPAS	6.2 I have prejudices or make assumptions about students from other disciplines.
3.3. Prejudices and assumptions about health professionals from other disciplines get in the way of delivery of health care.	IPAS	6.3 I feel that prejudices and assumptions between disciplines in our group, hinder our ability to work together optimally.
(Self-created, follow up on above theme)	N/A	6.4 My prejudices about other disciplines were changed for the better, after this module and project.
Interdisciplinary Communication		
21. I am good at being sensitive to the way in which different professions may use the same word.	IPMQ	8.1 I am aware that other disciplines may use the same words differently, to my discipline.
1.6. Shared learning with other health sciences students will help me communicate better with patients and other professionals.	IPAS	8.2 I can communicate better across disciplines because of this module and project.
17. I am good at explaining my ideas in ways that other people can understand.	IPMQ	8.3 I have improved the manner in which I explain my ideas, so that students of other disciplines can understand me.
22. I am good at clarifying with people from other professions how their knowledge and skills contribute to each stage of a project.	IPMQ	8.4 I am better at identifying what other disciplines could contribute to a collaborative project.

The open questions then appealed for further information within the above three themes, specifically: personal examples of prejudice, misunderstandings and other problems within the ID teamwork context. Furthermore, any positive outcomes were also requested to be shared. At the end of the survey was an optional section to fill-in any further comments and

one's email address to enter a lucky draw to win one of four vouchers. The "further comments" section also underwent data analysis for further insight on topics the students, themselves, noted as worth mentioning.

5.3 Document Analysis

Document analysis is an organised strategy for scrutiny of both printed and electronic materials (Bowen, 2009). Data gained from this procedure was evaluated, interpreted and assembled in order for insights to be used for triangulation. The motivation to explicitly seek additional sources, beyond the interviews and surveys, was to add further rigour to this study. Triangulation of the data, portrays a more complete picture (Heale & Forbes, 2013). Documents include official media issued publicly from the UT administration and EvaSys summaries obtained from module coordinators, these provided additional perspectives to that of the academic staff and students. EvaSys evaluation surveys are completed at the end of each TOM module and are used to appraise the quality of the educational experience. Furthermore, publications from the Dutch government and the European commission were analysed. A complete list of the grey materials analysed, is detailed in *Table 4.* An enhanced table, including the links to most of the material is included in *Appendix D.*

Table 4

List of documents and data sources analysed.

Documents Selected	**Data Analysed**
University Twente	
The Twente Education Model – TOM Brochure 2017 (hard / soft copy).	Background information about TOM and the basic principles of the model. Specifically interdisciplinarity and the project based education aspects.
Student-Driven Learning at the University of Twente – Information for educational staff (hard / soft copy).	Philosophy of education , skills development of students and structure of the courses.
Quality Agreements 2019 -2024 – Plan of University Twente (hard copy).	The university's profile, specifically the educational profile, the future developments in education for the next six years.

(Table continued)

Critical Self Evaluation Report Institutional Audit - September 2019 (hard copy).	Philosophy and policy providing further background and context. Ambitions and educational policy, internationalisation, "Shaping 2030".
EVASYS Documents (2018/19 & 2019/20) - Evaluations on the students' experience questionnaire (personal copy).	2018/19 - Orientated on the general attitude of students towards the module. 2019/2020 - Acquired supplementary information on the module and project experience.
OSIRIS - Student Information System of the UT (intranet).	Description on courses and learning objectives.
CANVAS - Online learning management platform of the UT (intranet).	Description of courses, incidental information.
University of Twente: Home Organisation: Facts and Figures (website).	Inflow of first year student numbers.
Study tracks	
Industrial Design Engineering; Mechanical Engineering, and Industrial Engineering & Management (websites).	Descriptions on types of learners, activities, attitudes, courses and curriculum.
Workshops	
Reflection on Science Technology and Society (RESTS) and The Fraunhofer Project Centre Expertise Student Team (FEST) (websites).	Descriptions on what it is, what is offered and purpose of the associations.
Other Sources – Websites	
The European Research Council.	Facts and figures on historical and current interdisciplinary funding.
Rijksoverheid, The Netherlands (Sectorplan Commissie Beta en Techniek).	Facts and figures on funding, educational policies and standings.
VSNU – The Association of Universities in the Netherlands.	Facts and figures on funding, educational policies and standings.

5.4 Data Analysis

The framework employed for the analysis of the teacher interviews and open-questions of student survey, is that of Braun & Clarke (2006)'s "Phases of Thematic Analysis". This method was selected due to it being an approach particularly accessible for this context (ibid). In order to gather a rich overall description of the collected data, the data was sorted, themed and analysed from an inductive perspective. This is where no pre-existing coding frame dictates outcomes, but is rather data-driven, allowing for open observance. The theoretical framework was used as reference point, but not as an explicit guide to deducting observance. This thematic analysis is seen as a useful method when employed for *"participants whose views on the topic are not known"* (ibid). The steps were as follows:

1. *Familiarising oneself with one's data:* Transcribing data or extracting data. Reading and re-reading data, make and formulate beginning ideas.
2. *Generating initial codes:* Coding interesting features of the data in an organised manner, sorting data according to each code.
3. *Searching for themes:* Collecting codes into possible themes, assemble all data consistent to each potential theme.
4. *Reviewing themes:* Checking if the themes relate to step one and two.
5. *Defining and naming themes*: Ongoing analysis to refine the features of each theme, develop overall story with clear definitions and names for each theme.
6. *Producing the report:* Final analysis, selection of applicable quotations, final analysis of selected quotes relating back to research questions.

(Braun & Clarke 2006).

Teacher Interview Analysis

The interviews of the academic staff were first transcribed using Amberscript, a speech recognition transcription software. It was then carefully scrutinised to eliminate any machine error. Sorting and analysis was done in Microsoft Excel due to the programme's technical and visual tools. The transcripts were read and then re-read, and initial ideas were formulated. Next, the responses to the interviews were grouped, according to first, questions and then colour coded into themes from within the answers. The themes were then further scrutinised to eliminate overlap. Following that, the themes were re-checked according to the initial ideas gleaned from orientation. Then, responses were physically sorted into themes, the themes'

names were edited for easy comprehension of the reader. Then, responses were tallied under each name. Pie charts were created for visual summation that were to be used for composing of tables later. Pertinent quotes were selected to reinforce the output in the results section.

Student Survey Analysis

Data was exported from SurveyMonkey and sorted in excel format, then divided into the open and closed question sections. The data gained from the open-question sections of the student survey were sorted according to each question. Each of the open questions' 70 responses underwent a thematic analysis and were divided into inducted themes that became apparent during analysis; a minimum number of three responses of a similar vein warranted the creation of a new theme. Totals under each of them were then tallied and pie charts were created for better visual analysis by the researcher. On the very rare occasion that some answers were ambiguous or the questions misunderstood, and where no conclusions or classification could be drawn, the answers in question were not included. For example, in answer to the open question:

> During this module, did you perceive someone from a different discipline in a way that turned out to be true or untrue? Please give an example.
>
> "*This question doesn't make any sense. Do I perceive someone to be true or untrue? What?"*

The data gained from the closed sections of the student survey, underwent recoding for the demographic answers, for example: IDE = 1, ME = 2, IEM =3, etc., however due to the age-range and gender not influencing the outcomes here, these questions were excluded. Next, because the remaining questions were already Likert scales, the sheet could be imported to Statistical Package for Social Sciences (SPSS), where minor recoding and relabelling in "variable view" was undertaken. Due to the reverse phrasing of questions 6.1 – 6.3 , the answers were reverse-scored. *Table 23,* in *Appendix E*, details the negatively worded questions and show how the agreement scores were reversed for factor analysis purposes only. Hereafter, the original scoring is used for means calculations. Computations were undertaken in SPSS to ascertain reliability and gather statistical summaries, as listed in *Table 5*.

Table 5

Data processing calculations undertaken in SPSS.

Test	**Purpose**
Factor Analysis.	Identify whether factors found were similar to original question themes.
Cronbach's Alpha.	A reliability test, to check whether the closed questions are reliable.
Kaiser-Meyer-Olkin Measure.	Check whether sample is deemed sufficient.
Descriptive Statistics: means analysis.	To summarise data and highlight issues.
Descriptive Statistics: means according to track.	Give insight as to how the different tracks answered the questions.

In order to validate the quantitative data gleaned from the student survey, a factor analysis was undertaken. According to the SPSS output, the survey was composed of three subscales as opposed to the original questionnaire which had four. The new groupings according to the factor loading, are renamed below in *Table 6.* The rearranging of the questions according to the new sub-scales does not impact the outcomes of the study, but some constraints will be noted in the limitations section. Evaluating these subscales provides the opportunity for further scrutiny into the reliability of the student questionnaire, and the prospects for it to be used again in other studies, on other modules at the UT.

Reliability. The new subscales defined in SPSS underwent a Cronbach's Alpha calculation to assess the reliability of the student survey. Reliability checks whether a questionnaire steadily reveals the construct it is measuring (Field, 2013). The general rule of thumb is that an α score of 0.7 to 0.8 is acceptable. Field (2013) quotes Kline (1999) and Nunnally (1978) as stating that when measuring psychological constructs, values below 0.7 can be expected. This is due to the range of constructs being measured and that in the early stages of research, scores as low as 0.5 could still be acceptable. With this in mind, the low scores of factor three (detailed in *Table 7*) may not indicate a completely unreliable construct and therefore will still be considered for the study.

Table 6

Reorganising of Factors: Identifying Themes.

Question	Variable	Subscale	Variables Relate to:
5.1	Benefit of ID	One	Outcomes of disciplinary socialising
5.2	Broaden perspectives		
5.3	Societal problems		
8.2	Improved communication		
8.4	Improved understanding of others' offerings		
5.4	Welcome ID again	Two	Working with others
6.4	Prejudice changed for better		
8.3	Improved explaining ideas		
6.1	Prejudice towards me	Three	Prejudicial elements
6.2	My prejudice towards others		
6.3	Prejudice hinder work		
8.1	Vocabulary differences	N/A	

Table 7

Reliability of the new factor loaded groupings for the student survey.

Subscale	Cronbach's Alpha	Cronbach's Alpha Based on Standardised Items	*N*
One	0.75	0.76	5
Two	0.64	0.65	3
Three	0.56	0.56	3

Sample size. The measure of sampling adequacy: Kaiser-Meyer-Olkin (KMO) was found to be over 0.5 and therefore the sample for this study is deemed sufficient. Furthermore, in order to proceed with the factor analysis, some relationship between the variables must exist. In other words, the correlation matrix should not be an identity matrix. Here, a Bartlett's test *(Table 8)* level of below 0.05 is significant and therefore satisfies both of those criteria (Field, 2013).

Table 8

Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Test.

Description		**Value**
KMO		0.71
Bartlett's Test of Sphericity	Approx. Chi-Square	189.76
	D.f.	66
	Sig.	<0.0005

D.f. = degrees of freedom; Sig. = significance.

Synopsis. The means and standard deviations calculated, depict a concise summary of how the students experienced the interdisciplinary parts of the module, these tables are included in the results section, that follows, due to proximity for analysis and discussion purposes.

6 Results

The reactions and outcomes of the student survey, the academic staff interviews, as well as the document analysis are represented here. The various sub questions along with relevant aspects of the gathered data, are organised together according to theme.

6.1 Drivers, Purpose and Value Perceptions on Interdisciplinary Education

Research questions *vi* and *vii* are grouped together to give an enhanced perspective of the interdisciplinary educational interaction (i.e. the project). Here, the supplementary viewpoints from the open questions, of both academic staff and students, as well as the document analysis, generate a more complete picture of the drivers, purpose and value perceptions of interdisciplinary education at the University of Twente.

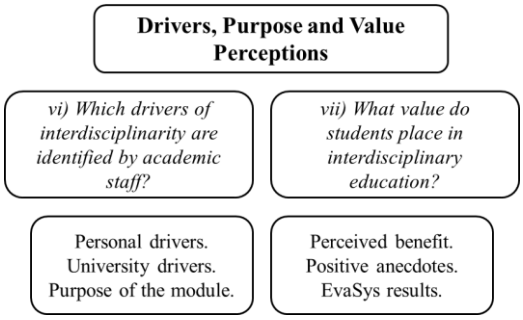

Figure 8. A schematic diagram of the collation of research findings to identify the drivers, purpose and value perceptions of interdisciplinary education. The middle layer includes the research sub questions *vi* and *vii*, while the lower layer lists the processed research data and additional document analysis used to answer to the questions.

Personal drivers academic staff. All of interviewees stated preparing students for real life situations, i.e. employability skills, as their reason for the purpose of interdisciplinary education. In addition to this, 2 out of the 9, gave a secondary driver which was “alignment with complex social issues” – a commonly stated reason in literature. A list was presented (detailed in *Table 9*). Some academic staff consulted the list, but most answered from their own know-how, adding personal anecdotes for context. Interviewees were allowed to note as many drivers as they wished, hence the total count (11) outnumbers the total interviewees (9).

Academic staff’s perception of university-level drivers. As above, interviewees gave their perspective or experience of what is stimulating interdisciplinarity in general at the UT. The list is detailed in *Table 9*. There was a vast range of answers. Two examples of comments are:

"Marketing? Yeah of course, the motto of the university is High Tech Human Touch!"

'I am not sure the UT is pushing it."

Table 9

Drivers of ID at the University of Twente – List was presented and selections were made.

Themes	**Number of interviewees selecting this option**
Alignment with complex social issues	2
Student employability	1
Individual champions	1
Top-down strategy	2
Marketing or Promotional considerations	4
Alignment with research directions	1
Unsure	2
Other: Collaboration	1

Note: N =9.

Academic staff's opinion on the purpose of the module. The responses to this question all followed the same line; to do with student to exposure to different disciplines, experiences and education, culminating in an authentic collaborative project. An extra bonus is the coupling to an external company, with the added gravitas of signing a NDA. Again, the preparation for professional life was repeated as a common factor, but the repeated referral to the project illustrated its central role as the avenue to attain the learning and interdisciplinary experience.

"to learn from each other, also and to do a bigger project – because you can do more when you have more disciplines in one group"

Academic staff as ID practitioners. Without fail, each member of staff confirmed that interdisciplinarity, in research is essential and inseparable from their academic life.

> **"***I have to, because I don't know everything myself, so it's also part of the research field I am in, we need cooperate with a lot of people, it's not one discipline – there are a lot of things happening."*

However, one interviewee offered an alternate perspective on ID by saying:

> *"For research, how on earth would you define where one discipline ends the other one starts? Well let's put it this way... I really don't see disciplines that do not overlap!"*

Students' Perceived benefit (N = 70). With regard to the perception that interdisciplinary education will benefit their future careers and broaden perspectives, over 80% of the students agreed (62 and 57, respectively). An encouraging, 60% (44) would welcome the chance to work on another ID project in the future. However, only 50% (36) thought that the project gave them the skills to tackle societal issues.

Students' positive personal anecdotes. Students were encouraged to share a positive outcome of their ID teamwork experience. Only 6% (4) stated that there were no positive events. The 94% of positive aspects were grouped according to the following themes: complementary knowledge/different perspectives 31% (22); learning from/teaching each other 26% (18); task division/time saving advantages 17% (12); improved quality of product 10% (7); and effective communication 10% (7).

> (IDE student) *"You can work on different parts at the same time and combine knowledge, in such a way that you'll work faster."*
>
> (IEM student) *"When we were brainstorming about concepts every discipline gave their own objective on the concept. This was really beneficial for the project, because everybody has different views on the project."*
>
> (ME student) *"Students specifically chose to try and tackle parts of the project outside their comfort zone in an effort to learn more. These students were then helped by those who already had more experience in that field."*

(IDE student) *"Everyone had different problem solving skills which made the quality of the project higher. The different backgrounds made the project closer to a real life situation in a company."*

(ME student) *"When explaining a concept to other students who have less experience on the subject, the way you need to speak about your idea will be more basic than to people from your own discipline. In our case, their remarks on the concept seeded new ideas. It is useful to have people from different disciplines in your group because of this."*

Document Analysis. Through examination of the EvaSys results, the overall student appreciation of the entire module was made clear. Students were asked to rate various statements, for example: *"As a whole, I learned a lot in the module"*, under the following headings: module; learning; project; assessment; effort put into study; and appreciation. These results were then summarised according to each heading to give an overall indication of the satisfaction levels for Module 6. *Table 10* summarises the results. Here, it is noteworthy to see how the IDE students give slightly higher ratings for most sections (highlighted in bold).

Table 10

EvaSys 2019/20 student satisfaction summary according to track for all parts of Module 6. Highest scores are highlighted in bold.

Category	**Average scores**		
	IDE	**ME**	**IEM**
Module	**3.8**	3.5	3.0
Learning	**3.8**	3.4	3.2
Project	**4.1**	3.5	3.1
Assessment	**3.4**	3.3	3.1
Effort put into study	3.4	3.5	**3.9**
Appreciation	**3.8**	3.3	2.8

Note: N = IDE (16), ME (34), IEM (16).

Summary

Academic staff and students really see the practical benefit of the project work and interdisciplinary education in general. Both parties believe the learning process, through the project work, prepares the students for realistic and probable working situations in the future. Most of the comments from students revolved around gain in knowledge or skill, or an improved output with regard to the project. The academic staff's personal opinions on why interdisciplinary education is important were consistent, showing a clear unity of thought. Conversely, as to why they believed the university was promoting it, showed a range of responses. The outcome that 63% of students (44) would participate in an interdisciplinary team again, reflects a generally positive experience, reiterating the value-perception of the disciplinary socialising encounter. Staff too, spoke positively about the value of the module and usefulness of the skills that students can develop and apply to reach the learning outcomes. The project is seen as a means to put theory to practice and the collaborative process is the vehicle to reach the goals. The EvaSys results, bring added insight to the overall appreciation of the module; it is clear that the even though the students acknowledge the benefit of ID education, they still have problems with the various educational elements of the module itself. Additionally, the academic staff actually work on their own interdisciplinary research - demonstrating that it is not a fabricated construct. They are indeed 'walking the walk' of disciplinary socialising in their professional capacity too.

It must be remembered that the student survey for this study was focusing on interdisciplinary education appreciation. The EvaSys results give a much broader perspective of the students satisfaction with the module as a whole.

6.2 Barriers to Interdisciplinary Education

Sub question *i* focuses on the challenges faced by academic staff. In order to answer this question, results from the data collection were sorted according to themes of student numbers and educational concerns. Furthermore, grey materials supplemented these perspectives by adding contextual information that gave possible reasons for the challenges.

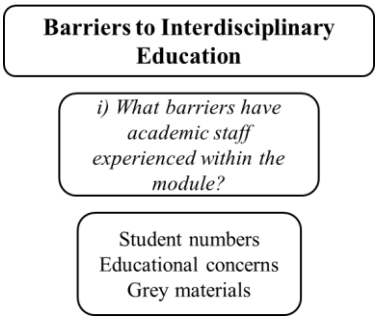

Figure 9. A schematic diagram of the collation of research findings to identify the barriers of interdisciplinary education. The middle layer is comprised of the research sub question *i*, while the lower layer lists the processed research data, as well as the document analysis sources that feed the answers to the question.

Issues for ID delivery. Here, problems from the teacher's perspective, centred around two major themes: firstly, student numbers (64%), and; secondly, educational concerns (27%), the remaining 9 % had no concerns to report. The two prominent categories are detailed further in *Table 11* and *Table 12*, due to their wide range. Number-issues boil down to the same thing; they are reaching their limits. Educational concerns indicate a more varied account.

Table 11

Academic staff's opinions on number of related issues in Module 6.

High Student Numbers – Concerns	**Number**
Pressures on staff and venue capacities	3
Affecting personal interaction with students	2
Approaching limits of time	1
Ratios of students between disciplines	1
Internationalisation complications	1

Table 12

Academic staff's opinions on educationally related issues in Module 6.

Educational Concerns	**Number**
Compression of courses	2
Tutor backgrounds differ	1
External skills support – no autonomy	1
Pre-Master's students adding complications	1
Data available to IEM students to do their role	1

Document analysis. From the Association of Universities in the Netherlands (VSNU) and the Rijksoverheid (national government) websites, as well as leaflets published by the UT, information about student numbers was sought. All three sources note the rise in students numbers. All specified different perspectives however, i.e. national need for more engineers, increasing enrolment of students, active marketing to increase international student numbers. But ultimately, they are all showing a general trend towards increasing numbers or expansive ambitions. *Table 13* details exactly how the student numbers increased at the UT over the period 2015 - 2018.

Table 13

The annual change in student numbers, detailed for each track.

Student Enrolment Numbers from 2015 - 2018				
	2015	**2016**	**2017**	**2018**
Enrolled students per faculty.				
IDE	367	338	346	369
ME	447	422	440	513
IEM	292	319	356	379
Inflow First-year Institution (as of October 1st).				
IDE	84	84	118	120
ME	133	105	142	213
IEM	75	84	100	116
Intake First-year Course (as of October 1st).				
IDE	93	89	122	132
ME	145	116	159	231
IEM	91	110	119	124

Summary

The staff-reported barriers specify a wide range of concerns, but when these concerns are themed together, two main areas of worry appear. Firstly, high student numbers: these have ripple effects on other factors for academic staff. For example organising the logistics of fitting all students into one location. And secondly, small educational concerns that cumulatively may influence the overall quality of the courses, or give unfair advantage to certain students. For example: the background of the tutor having an influence on what kind of guidance they can provide for students. Conversely, from the document analysis

perspective, increasing numbers are not necessarily seen as undesirable (i.e. it is positive that engineering education is increasing). The high numbers are also seen as a challenge to manage or a target to maintain or surpass. Therefore there is misalignment between teachers reaching their limits due to high student numbers, and the continued external stimulation to increase student numbers.

6.3 Student Support for Module 6

The grouping of sub questions *ii* and *v*, as well as the accounts of the academic staff and students on the topic of support are provided. These perspectives are further supplemented by the addition of document analysis in the form of website and grey material scrutiny.

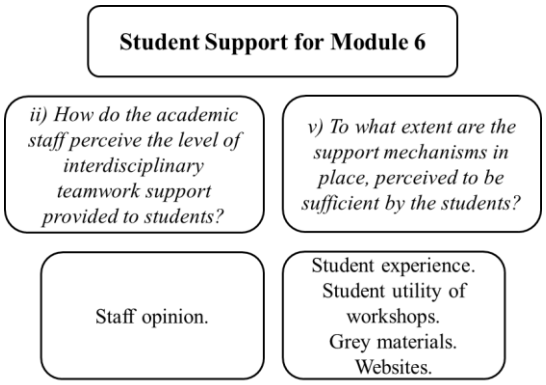

Figure 10. A schematic diagram of the collation of research findings to identify perceptions of the support on offer to students in Module 6. The middle layer is comprised of the research sub question *ii* and *v*, while the lower layer lists the processed headings of the research data, along with the document analysis, they feed the answers to the questions.

Academic staff's opinion on support offered to students within the module. Here the opinions relayed, range from neutral 40% (2) to confirming that the level of support is sufficient or above 60% (3), with some academic staff issuing warnings that too much support could have dire consequences. Only 5 out of the 9 interviewees were asked this question.

> *"Too much!...it's like if you buy a new car and the garage owner helps you for the first 10 miles to get going, and talks about everything that might go wrong. Will you feel confident?"*

Students' support experience. Overall, 77% of students (54) were somewhat satisfied with the amount of support on offer – this does not however, indicate the satisfaction with the type of support offered. Support here, includes the whole package including: academic staff, tutors and workshops. Below are a range of quotes that illustrate the point, the following section gives more detail on the reception of the actual workshops.

> (ME student) "*The university tried, but did not really succeed."*
>
> (IEM student) *"Yes, enough support was available, the tutor played a big role in it."*
>
> (IDE student) *"Yes, we had some workshops and a paper about it."*
>
> (IDE student) *"Yes, there were a lot of workshops organised, maybe even more than necessary."*
>
> (ME student) *"There was enough support, I don't think the skills needed for interdisciplinary collaboration can be taught, but I think it will develop while doing."*
>
> An example of a negative response is:
>
> (IDE student) *"No, our tutor was sometimes of help (the peer-review was nice) but there was no one watching over the concepts and our approach of the product."*

Students' utility of workshops. Two types of skills workshops were provided. One on reflective development (RESTS) and the other on professional and interpersonal skills (FEST) which included collaboration and perspective taking training. For the answers to the question *"Which specific workshops or courses helped you to develop the skills to collaborate on an interdisciplinary project?"* 60% (42) of students answered negatively, i.e. that they did not help at all:

> (ME student) *"No workshops were useful to develop skills to collaborate on an interdisciplinary project. I think just by doing so, you gain experience."*
>
> (IEM student) *"Except the deliverables workshop, which was scheduled after the actual deliverable deadline, the other workshops were a loss of time."*

Some insights on self-discovery or practical development of skills through the project, were shared 12 (17%):

> (IDE student) "*It sounds corny, but regular project meetings or tutor meetings taught me a lot more regarding smooth collaboration than any of the workshops ever did. I guess it's a case where the theory doesn't really sink in unless you see how the interdisciplinarity works in practice."*
>
> (IEM student) *"Not really courses or workshops, more the practice."*
>
> (ME student) *"Honestly, most of the workshops felt like a complete waste of time. We joined them as a project group and often didn't return after the break, and sat together in a project room instead. We were much more productive and learned much more about working together this way, rather than having to sit in a classroom answering very predictable questions for several hours."*

There were also 16 (23%) of students who noted some value in only a few isolated workshops:

> (IDE student) *"There was one workshop with roleplaying which was useful. We all had to look from the perspectives of different stakeholders."*
>
> (IEM student) *"The deliverables workshop made clear what the idea was."*
>
> (ME student) *"The brainstorm session was very much fun. Since having fun together stimulates bonds, this felt like a good teambuilding session."*

Document analysis. The further details on what is on what support was on offer to the students were sought on the RESTS and FESTS websites, the Module 6 manual, and the timetable for the module on rooster.utwente.nl. Unfortunately, some online information was outdated, and therefore the most useful information was ultimately gained through direct contact with the relevant instructor. The timetable, however gave a clear indication of which courses were offered at what stage of the programme.

Summary

Here, the students' opinions align, more or less with the academic staff's, in that enough support is offered. However, not all staff had a clear picture of what support was on offer. The sources of official materials detailing what is on offer to the students is sometimes out of date. Some students felt that their time could have been utilised better, in another way, therefore, although "enough" support was offered, it does not account for their value-perception of which particular support was most useful. Eleven out of the 54 students who responded positively about "enough support", referred to their tutors, it seems that what is most appreciated is a competent and attentive tutor. With regard to the specific workshops' feedback, the common thread that some of them were not directly useful, or that they could be presented in an either a more self-directed manner or in a less time-consuming format. The current format of support workshops is not fully appreciated by students, with only a few isolated workshops receiving sporadic praise.

6.4 Students' Experience with the ID project

In order to gain an understanding of how the students experienced the interdisciplinary project part of the module, sub questions *iii* and *iv* are connected. Data gained from the student survey as well as document analysis fed this enquiry to determine to what extent prejudice, communication issues and teamwork problems hinder collaboration. Although the communication and prejudice questions (from the closed section of the student survey) are also split according to theme, they are summarised together in *Table 17*.

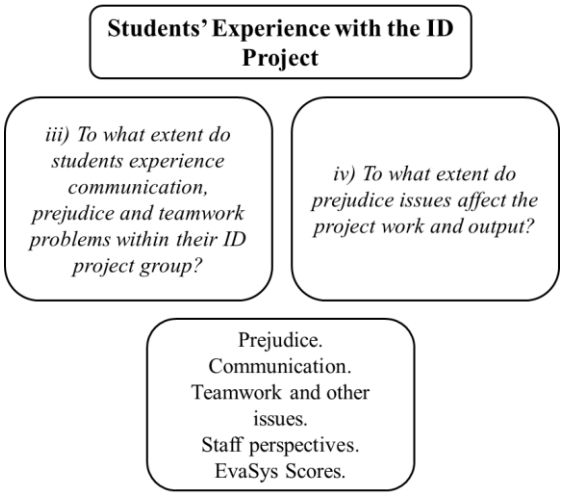

Figure 11. A schematic diagram of the collation of research findings to identify perceptions of the students experience within the interdisciplinary project work. The middle layer is comprised of the research sub questions *iii* and *iv*, while the middle layer lists the processed headings of the research data. Along with the data analysis, they answer the questions.

Personal prejudices closed questions. Approximately 80% of students admit to feeling (59) and projecting (54) prejudice from or against other disciplines. About 39% (29) indicated that they overcame some of their prejudices, while the remaining 61% were neutral or did not agree that their prejudices changed after the project experience. Interestingly though, 89% (61) were neutral or denied that the prejudices negatively impacted their work. See means summary in *Table 17*.

Personal prejudices (anecdotes). This question requested information on an incident over the course of the project, where the individual's prior perception of another's discipline turned out to be true or not true. The majority, 65% (32, $N = 49$) of the answers were of a positive nature; either confirming a positive prejudice or disproving their negative prejudice. For example:

> (ME student) *"I thought that IDE students would be glad to work on the more visually creative parts of the project, such as design of the body of the shaver. This was true. I was however surprised by how they tackle problems in a creative yet systematic way. Before this project I didn't know much about IEM. Now I know a little more."*
>
> (ME student) "*Initially, I expected the IEM students not to do anything, as this I what I heard from other older students (who have done this project already). This however was not true, even though the project is not really related to their discipline. They were very motivated and behaved similar to every other student."*
>
> (IEM student) "*ME students had to do some extra work with regard to their specialization. This was also true for this project and I have always felt their study was a lot of work."*
>
> (IDE student) "*All disciplines were more alike than I initially thought. They were much more overlapping!!"*

The remaining 35% of respondents (18) had a more negative perception of their fellow team members, either confirming a negative prior prejudice or changing a neutral or positive perception to a negative one.

(IEM student) "*During this module, I perceived that IDE and ME students have got different skills and talents than IEM students, especially when it comes to group projects. IDE students have worse language skills and can sometimes be quite amateuristic in their way of forming a project file. This was sometimes quite disturbing and I found it hard to deal with. Also their communication and planning is below the level of IEM students. However, I also learned some things from them in the way of spatial thinking."*

(ME student*) "IDE is, as expected, following the rules a bit too much. As an example, every meeting has an agenda and minutes, even when it's an informal meeting. Also the minutes are very accurate. Every detail is in it."*

(IDE student) "I expected the IEM students to know something about management of product development or project management, or logistics. I still don't know what they can do."

One neutral comment that fitted into neither category, very astutely quoted:

(IEM student) *"No, the prejudices were mostly true and also the perceptions of the people turned out to be quite accurate. Every person has his/her own strengths, disregarding the discipline."*

Table 14, summarises the 18 students' negative comments. Two comments were not directed at a specific track, so were excluded from the table, some students commented on both of the other tracks. Most of the negative comments were directed towards the IEM track.

Table 14

Negative comments directed towards the other tracks.

Tracks	**Scores**		
	IDE	**ME**	**IEM**
IDE comments about:	-	21% (4)	53% (10)
ME comments about:	5% (1)	-	16% (3)
IEM comments about:	5% (1)	-	-
Total:	10% (2)	21% (4)	69% (13)

Note: N = 17.

Communication closed questions. Nearly 75% of students (52) recognised that there are disciplinary homonyms and these have the potential to cause confusion. Additionally, 75% of students (53) also proclaimed that through the project they were better able to identify what the other disciplines could contribute to the project. There was a mixed response as to whether this module developed students' interdisciplinary communication skills. At least 50% of students (35) felt there was some communicational improvement due to working on the project, while 32% (23) remained neutral.

Communication anecdotes. Here the students were prompted to illustrate an occurrence when there was a misunderstanding due to the different disciplinary backgrounds of the team members. Over half stated that there were no misunderstandings. The remaining students noted themes centred around misunderstandings or misalignments with regard to: communication, particularly discipline-specific homonyms caused confusion; perspective taking, which is the ability to appreciate other disciplines' perspective; knowledge gaps; quality of work expectations; and finally just answering "yes", with no further explanation. Exact ratios of these answers are detailed in *Table 15*.

> (ME student) *"No there were not really misunderstandings, that could be due the fact that we worked a lot in group work sessions, so we knew what we had to do and could ask questions to each other all the time."*
>
> (IDE student*) "Yes, during the ideation and conceptualizing phases the ME and IEM students did not deliver the level of work that was expected. The ideas were less worked out and hard to understand."*
>
> (IDE student) *"ME had a hard time understanding why the human factors within a product design needed attention which made the overall project more ME than also IEM and IDE."*
>
> (ME student) *"Yes, about some technical specification on how to solve them. The IEM person didn't understand it and it took a while to explain it to him."*

(IEM student) *"Yes, when a concept or mechanism needs to be explained, there were sometimes misunderstanding because not everybody has the same vocabulary as the IDE people for example."*

And my personal favourite:

(ME student) *"Yes, there was a discussion about the colour foam to be used for a model. I participated in this discussion, only to find out later that the colour of foam specifies hardness and is not about appearance."*

Table 15

Communication anecdotes divided into themes with numeric indicators of prevalence.

Categories of answers	**Percentage**	**Number**
No communication misunderstandings	53 %	37
Discipline-specific homonyms confusing	17%	12
Perspective taking difficulties	11%	8
Knowledge gaps	9%	6
Quality of work (expectations)	7%	5
"Yes" but no further explanation	3%	2

Note: N = 70.

Anecdotes on other problems collaborating. As mentioned previously, normal monodisciplinary teamwork can be a challenge for students. With this in mind, examples were elicited of additional obstacles that were magnified by the new disciplinary socialising dynamic. Forty-three percent had nothing further to add (30). The remaining students had issues with: scheduling and meeting problems; knowledge gaps hindering progress; complaints about IEM's lack of role; differences in how to tackle the project; and unequal distribution of work. Three students, reiterated their communication issues mentioned in the previous communication open question, as the comments were repeated, they were classified as "no further issues." The total as well as the adjusted percentages show the account and classifications of the types of problems that arose, are shown in *Table 16*.

(IEM student) *"Yes, sometimes it was hard to understand all the topics, because you do not have previous knowledge. IEM students almost have no knowledge about any of the topics, so that sometimes was a problem."*

(IDE student) *"Some people are not willing to change their approach to designing a product, because they think their way is the best and most efficient."*

(ME student) *"IEM students did not really know what to do in this project and also seemed to use that as an excuse for not doing anything, even though I think they could also have participated more actively in, for example, brainstorming."*

(IDE student) *"Yes ME and IEM were very unfamiliar with this type of project and it puts an unfair strain on IDE students."*

(ME student) *"Scheduling! Even though we were supposed to have two afternoons in the week free for project time, this was not easy to schedule, as some still had classes during those periods. This limits the amount of group work one can do."*

Table 16

Percentage of other problems that appeared while collaborating on the interdisciplinary project. Classifications are included in brackets.

Categories of answers	**Total Percentage**	**Percentage of problems**	**Number**
No other problems collaborating	**43%**	**0%**	**30**
Problems collaborating:	**57%**	**100%**	**40**
Scheduling and meeting issues (Design issue)	16.0%	27.5%	11
Knowledge gaps hindering progress (Teamwork issue)	13.0%	22.5%	9
Complaints about IEM's lack of role (Design issue)	11.0%	20.0%	8
Differences in tackling the project (Teamwork issue)	10.0%	17.5%	7
Unequal distribution of work (Teamwork issue)	7.0%	12.5%	5

Note: N = 70.

The following tables *(Table 17* and *Table 18)* illustrate the summary of responses by the students to the closed questions in the survey. These questions were directly linked to sub

questions *iv* and *v*. Recall that the questions were posed using a Likert scale from one to five, the responses are their original rating and have not been reverse coded as was the case for the factor analysis. Notable items are the high rating for the perceived benefit of interdisciplinarity and how the students see how the experience has broadened their perspectives.

Table 17

Summary of means - closed questions in the student survey related to this research sub question iv.

	Mean	**Std. Deviation**
Broaden perspectives	4.53	1.03
Benefit of ID	4.24	0.77
Improved understanding of others' offerings	3.91	0.86
Vocabulary differences	3.89	0.96
My prejudice towards others	3.90	0.87
Prejudice towards me	3.77	0.98
Welcome ID again	3.67	1.24
Improved explaining ideas	3.46	0.97
Societal problems	3.46	1.15
Improved communication	3.37	1.02
Prejudice changed for better	3.10	1.13
Prejudice hinder work	2.31	1.03

Note: 1= disagree, 2= somewhat disagree, 3= neither agree or disagree, 4= somewhat agree, 5= agree. $N = 70$.

When the closed survey questions are separated further by track, slight differences become apparent (see *Table 18*). Although not hugely significant, when linked back to the research questions on value perceptions and overall positive perceptions on the interdisciplinary experience, we can see that IDE, overall, responded more positively to questions about the project experience. This is also in line with the EvaSys results depicted in *Table 10.*

Table 18

Summary of means divided per study track. The highest scores are highlighted in bold.

	IDE		**ME**		**IEM**	
	μ	**σ**	**μ**	**σ**	**μ**	**σ**
Benefit of ID	**4.40**	0.71	4.29	0.85	3.94	0.66
Broaden perspectives	**4.64**	0.86	4.61	1.03	4.24	1.25
Societal problems	**3.88**	1.01	3.18	1.25	3.29	1.05
Welcome ID again	**3.92**	1.12	3.50	1.20	3.59	1.46
Prejudice towards me	**4.04**	0.79	3.46	0.96	3.88	1.17
My prejudice towards others	**4.08**	0.70	3.82	0.98	3.76	0.90
Prejudice hinder work	**2.68**	1.18	1.93	0.81	2.41	0.94
Prejudice changed for better	2.96	1.24	**3.21**	1.17	3.12	0.93
Vocab differences	**4.00**	0.96	3.86	0.85	3.76	1.15
Improved communication	**3.68**	0.85	3.14	1.08	3.29	1.11
Improved explaining ideas	**3.80**	0.91	3.29	0.94	3.24	1.03
Improved understanding of others' offerings	3.76	0.97	3.93	0.81	**4.12**	0.78

Note: N = IDE (25), ME (28), IEM (17)

Document analysis. The relevant project-related EvaSys results for Module 6: 2019/2020 (*N* = 66) is summarised in *Table 19*. The appreciation of the project part of the module varies dramatically between tracks. However, all three highly rate "cooperation with others", relative to their scoring of the other statements. This reinforces the finding that most students see the value of ID education, despite dissatisfaction with other course-related factors.

Table 19

EvaSys scores for the project part of Module 6.

Statements	**IDE**	**ME**	**IEM**
"I found the following aspect of the project very valuable"			
The application of previously gained knowledge	56.3%	23.5%	12.5%
The integration of the various subjects learned in the module	62.5%	29.4%	31.3%
The development of new knowledge and insights	50%	61.8%	31.3%
The motivational effect	18.8%	11.8%	0%
The cooperation with other students	87.5%	58.8%	75%

Note: N = IDE (16), ME (34), IEM (16).

6.4.1. Inherent Difficulties within Module 6

There are some difficulties within the construct of Module 6. These hinder equal contributions from each of the three tracks, towards the project work. This may originate from the fact that Module 6 was originally an established IDE course and that the other two tracks (ME and IEM) joined at a later stage. Therefore, IDE appears to be the dominant field within the project; a phenomenon known as epistemological sovereignty (Healy, 2003). The IDE students' roles are easily accessible to them and they feel comfortable within the project. This is demonstrated in the high EvaSys ratings summarised in *Table 10* and *Table 19*, as well as in the reactions gained from the student survey for this study in *Table 17*.

The ME students do have a role to play, but they struggle with a much heavier work load than the other two tracks, resulting in additional time pressures. This factor was referred to by two ME academic staff. The IEM students struggle the most to contribute fully to the project, their roles are often limited to administrative tasks which are not directly linked to what they can offer with their expertise. Below are a selection of comments directed towards the IEM students' lack of role, taken from the 2019/2020 EvaSys comments section (N = 66).

> *(ME student) "In my opinion, IEM contributed little to the project, the current project could have also been done without IEM (translated from Dutch)."*
>
> *(IEM student) "More relevant courses to the IEM study."*
>
> *(IEM student) "The project for IEM was hard. More guidance could be included to give advice on the integration of previous gained knowledge in the project."*
>
> *(IEM student) "With IEM you didn't have a big impact on the project."*
>
> *(IEM student) "(Find) a way for IEM students to be able to contribute more to the project."*
>
> *(IDE student) "Instead of only ME having specializations, all the disciplines should have one."*
>
> *(IDE student) "Some students work harder than others."*

McLeod & van der Veen (2019) and Hung (2011), highlight the importance that each disciplinary track should have the same meaningful input opportunities in interdisciplinary project-based learning. This input, made clear for example, by an easily identifiable role, is

essential to ensure fair distribution of work and to sustain motivation of the students. A recurring complaint, from the students, was the lack of input or ability to contribute from some of the IEM students. The IEM students felt that their role was not clearly identifiable or that the IDE or ME students found their skills were not useful for the project. This lack of ownership is associated with the preventative teamwork issues listed in *Chapter 2.4* (Borrego, Karlin, McNair, & Beddoes, 2013). *Table 14* shows how most of the negative comments about teamwork are directed towards the IEM students. This demonstrates the disillusionment felt by the students about the suitability of roles that IEM can fulfil.

A further administrative factor that may influence the imbalance of the module is that there is no coordinator actively representing the IEM track.

> *(IEM student) "I think that it would be good if IEM also has their own module coordinator. IEM is the study of which most TA's and staff in this module."*
>
> *(IEM student) : "Include IEM tutors and examiners."*

When speaking to one of the academic staff on the topic of the imbalance of roles within the Module 6 project, a solution to Module 6's imbalance was offered:

> "*My ideal situation would be just to start designing (this module) from scratch, because you'll never get these IEM people to...It's my personal belief and I think that is how it works, that you never get a real interdisciplinary team if people have to do different things and if their value to the project is so different. It would be good if they really had this common thing and equally important roles!"*

The coordinating staff are aware of the various issues surrounding the workings of Module 6, and are implementing tweaks annually, to improve the experience of the students. However, as with all iterations or curricular revisions, one change could lead to a new, unforeseen challenge (Reis, 2018).This could be why the balance has not yet been struck, and why IEM students remain disgruntled. Encouragingly, satisfaction ratings of IEM students for this module is improving annually, so small steps are being taken and some progress is being made in improving the experience for the IEM students.

*Academic staff's views on students' ID experience***.** The ability of academic staff to judge the mood and expectations of how their students are experiencing the module, will ultimately aid in the identification of requisite modifications. This could be for the improvement of a course, or enable them to offer ad hoc advice to remedy a problem (Rubio, 2009). For Module 6 staff, however, there appears to be a range of opinions on the students' experience. *Table 20*, details their answers:

Table 20

Academic Staff's view on students' ID experience.

Themes	**Number**
Communication problems	1
Fairness perceptions	1
Collaboration	1
Feelings of superiority	1
Resistance to the utility of some topics	1
Only content issues	2

Summary

Most students hold prejudices and feel others are prejudiced against them. With the feedback gleaned from the open questions too, whether positive or negative, the students reported that their prejudices did not affect their work; they seemed to be able to persevere, to move past their own feelings towards or perceptions of others in order to get their task completed. However, with a reliability score of 0.56 for this set of questions, the possibility exists that the conclusion drawn, may not represent the full picture.

With regard to communication, mixing with the other disciplines not only opened students up to new vocabulary and knowledge, but also exposed them to what others could do, thereby promoting understanding or appreciation of their abilities. With over half reporting no misunderstandings, communication issues seem to depend upon the team and its members. Some that reported "no issues" went further to describe how they pre-empted problems or if they started to become apparent, took the time to alleviate them, investing effort in their team. This occurred, for example by explaining plans and concepts thoroughly, or ensuring all members were present at all meetings and planning sessions; a desirable learning outcome in teamwork situations. The remaining 46% that did admit communication problems, note the disciplinary jargon as an issue. However one student noted that if all

courses were merely followed, students should be able understand the new vocabulary. One of the academic staff noted too, that they had adapted and standardised some of the jargon to enable better disciplinary socialising and communication. The issues arising from knowledge gaps between the subjects caused problems, but these seem to be able to be mitigated if there are good explainers and good listeners in the team, or a willingness to learn. Personal standards of work, or the level of seriousness of the individual can also be explained by personality and not necessarily interdisciplinarity (Ariani 2013). The "other problems" experienced by students can be split into two. Firstly, they revolved around course design issues like logistics or application of roles. The second aspect is to do with teamwork issues like knowledge gaps and attitude. Here, only a quarter of the problems in teamwork are specifically ID.

The means summary, divided into tracks, along with the EvaSys results indicate that IDE and ME have a better overall experience of the module, than the IEM students. What all students do appreciate most about this project, is the experience of working on an interdisciplinary project with people from outside their own discipline. This was confirmed in the EvaSys results as well as the student survey.

Not all academic staff have opinions on student issues. However, academic staff who are also tutors seem to be more insightful and more invested on what is happening outside their classes and within the project and therefore, teamwork situation.

6.5 Teacher Reflections and Insights

The ancillary nature of this chapter provides further insights into aspect of the programme that became apparent incidentally, over the course of the teacher interviews. Although not directly linked to a sub question, it is included as the answers allude to difficulties faced by academic staff that is linked to sub question *i*.

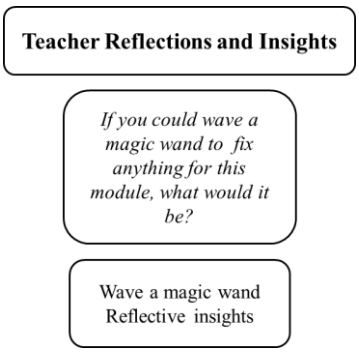

Figure 12. A schematic diagram of the incidental findings of this study. The middle layer is comprised of an interview question for the academic staff, while the lower layer lists the processed headings of the research data.

Wave a magic wand. This questions was aimed to stimulate the fantasy of fixing anything the staff would like to fix; only four staff answered the question. It resulted in answers mostly leaning towards logistical impediments or as mentioned previously, student numbers.

> *"Make sure students are not dispersed over campus…What we actually want is a home-base for students where they can say 'this is where these groups work'."*
>
> *"I always have problems with the digital aspects. Shakespeak interrupts, ruins my PowerPoint – if these things could work that would be very nice!"*
>
> and
>
> *"Double the time, half of the students."*
>
> *"Split the course into two, and separate bachelor and pre-master students."*

Reflective insights on ID. Reflections from accomplished practitioners offer unique and intuitive observations of their personal expertise and experience. These reflections were gleaned incidentally whilst discussing the topics within the interview.

On the path to becoming interdisciplinary:

> *"I mean multidisciplinarity, for me, came over the years. On the other hand, before I started studying I had five or six different options to study: mathematics physics robotics or whatever. And then computational science and then I studied physics, and a few years later I started to do computational science (again) and a few years later I worked with engineers and worked on the real-life problems. So it came over the years and it was also not my own demand; it somewhat came naturally.*"

On keeping the integrity of disciplines:

> *"I would not be in favour of that (complete integration) you lose (integrity)… to start off you train to become engineers or design engineers and that's your final goal. ID is supporting; it's nice if you can work together ID , cause it's also the practise and working practise later on, but it should don't be leading because you train MEs and train IDEs and so on."*

On the existence of ID:

> *"I don't believe it exists. If we look at it very bluntly, In the Netherlands, the majority of students that come in, all the students have, up to their final exams in high school, the same courses, the same topics the same whatever: with that set of courses they're eligible for mechanical, for design and for business here. That means that at the point, when they're 18 years old, they are identical – not in the interests perhaps, but from a high school perspective they're identical… Then we give them a one year of training, and all of a sudden they're specialists? And then we say you're either are mechanical or you're an industrial designer and we put concrete border here separate walls between them. Just because you're different than you and you. Then, after one year we cautiously take away those concrete walls again and say "Let's see if you can work together." But we created those walls!… So I don't get the concept."*

Summary

Interdisciplinarity occurs naturally in the working world, i.e. it is not an idealist learning construct concocted by the university. Not knowing everything leads people to seek answers from experts. Each interviewee had different perspectives and insights to add. Naturally, they had their disciplinary pride, which links to the Social Identity Theory discussed in *Chapter 2.4.2* (Tajfel & Turner, 1979). However, academic staff also had their personal take on the philosophy of interdisciplinarity, which added to an enhanced picture of their contributions to the module.

7 Discussion

The results from *Chapter 6* will be discussed in more detail below, according to the main research questions, sub-questions, and their respective assumptions:

> *What challenges are experienced by students and academic staff, within Module 6: Product Design Consumer Products, in interdisciplinary education at the University of Twente?*
>
> and
>
> *What is the value perception of students and academic staff, within Module 6: Product Design Consumer Products, of interdisciplinary education at the University of Twente?*

i. Which barriers have academic staff experienced within the module?

Assumption i : Increasing capacity demands due to the drive to attract more students, will adversely affect academic staff.

The UT is actively promoting and stimulating the attraction of more Dutch and international students. Therefore it was assumed that increasing numbers would be a negative factor raised by academic staff (e.g. due to increased workload). This assumption was developed during the orientation-reading stage, specifically material gathered from the Association of Universities in the Netherlands (VSNU). They saw a five percent enrolment increase from the academic years of 2017/18 and 2018/19 throughout the Netherlands. This rise in student numbers may initially not appear too alarming, but if it is a trend that continues, it is clear how it can quickly put strain on resources. This expansion was due, in part to increased transfers from higher professional education and the growth of international students numbers: "*This growth is positive for the Netherlands as a knowledge society, but universities are faced with ever-greater challenges in terms of workload and the quality of education.*" (VSNU, 2020). Rising student numbers at universities across the Netherlands are a common trend (ibid). The government too, has forewarned how the engineering student population is growing at a rate eight times that of the lecturers needed to instruct them (Ministerie van Onderwijs, Culture en Wetenschap, 2019). Therefore, with the UT's active policy of internationalisation to attract diverse students, and the Netherlands' government stimulating engineering education, the student numbers appear to be approaching saturation point. The theme of increasing numbers was mentioned explicitly by most academic staff and by a few

students too. The source of high numbers for Module 6 is two-fold: 1) increasing enrolment at the university; and 2) because the three tracks are combined into one large group. Actual numbers of the influx of students is detailed in *Table 13*. The increased numbers have firstly, repercussions with regard to hosting sessions. Availability of rooms with big enough capacity to host all 360 students is rare (the kick-off event was held in a cinema, as it was the only appropriate space, available on that day). Workshops too, become optional, due to space limitations. This immediately eliminates full participation of students from all learning activities, which is ineffective and a waste of resources and learning opportunities. With increasing class sizes, some academic staff also miss the personal contact and deep learning opportunities that occur in more intimate sessions. Perhaps mass-output learning is replacing personal education where students become a number. It is compelling to witness the contrast with governance and practicality at the university. As numbers keep increasing, academic staff have to adapt as best they can, but ideally there should be a nominal limit, so that quality and comfort for all can be maintained. From the academic staff's feedback, this limit has already arrived. Paradoxically, according to the *"Critical Self-evaluation Report: Institutional Audit, the quality agreements of 2019-24"* the UT articulates five core ambitions on which to focus, one of which is "small-scale education". This is in direct contrast to what is happening within Module 6, where numbers have reached 360 students and project groups have a minimum of 9 students. In PjBL, teams consisting of six members is recommended as a maximum number for collaborative learning (Lohman & Finkelstein, 2000). Hindrances of any kind can impede the success of even the most organised and planned curriculum (Livingston, Hayward, Higgins, & Wyse, 2015). Here, large students numbers and the resulting effects are in danger of becoming a hinderance to success.

A further barrier to the interdisciplinary educational aspect of this module, became apparent over the course of the research process. Although not explicitly mentioned by the academic staff of the IDE and ME streams, some did allude to the ill-fit of the IEM track to the module. The epistemological sovereignty of IDE, and therefore the imbalance of the ability of IEM students to identify and claim a substantial role in the project, is a nagging problem (see *Table 14*, *18*, and *Table 19*). Therefore, it is prudent to re-assess possible elements that may influence the success of the course, such as the potential dynamics between fields and their organisational fit with one another. Merely combining random courses will not guarantee an integrated approach from the educators or students (Jacob, 2014). With this in mind, the possibility that IEM may have to look for other interdisciplinary partners, may even have to be considered.

ii. How do the academic staff perceive the level of interdisciplinary teamwork support provided to students?

Assumption ii: Teacher perceptions on student support will be that of sufficient support being offered.

Here, the range of support on offer to the students of Module 6 was explored, and it was concluded that there were numerous and sufficient workshops and scaffolding available to support them (see *Chapter 4.3*). Most academic staff who did answer this question, felt that indeed, there was enough support offered to the students. Some believed too much support would not enable the students to undergo their own "student led education", a type of self-directed learning philosophy that is promoted throughout the UT. The fact that not all academic staff knew exactly what support was on offer, could be due to the lack of integration at subject level of this module, the absence of intra-track communication, or that the skills workshops are externally outsourced. Additionally, this disconnect could be due to time limits and big classes, and therefore lead to less personal interaction and discussion on incidental support-related topics during regular class. Non-integration on a course level allows for the three tracks to only feed into the needs of the project, it saves time on communication, coordination, etc. among academic staff, however, it also creates a disconnect when academic staff are not aware of what else is going on within the module. With this *status quo* of disconnect, I postulate that this may have indirect consequence to the effectiveness of the support offered in Module 6. For example, since the projects change annually, the support and workshops may need to be adapted accordingly. If academic staff is unaware of what is on offer to the students, this may result in missed learning opportunities.

iii. To what extent do students experience communication, prejudice and teamwork problems within their ID project group?

iv. To what extent do prejudice issues affect the project work and output?

Assumption iii: Students will experience communication, prejudicial and teamwork problems due to the interdisciplinary nature of the project and module.

Assumption iv: Prejudice issues will negatively affect teamwork and output.

MacMynowski (2007) posits that prejudice within a team, can have a negative impact on collaboration. The majority of students projected and felt prejudice, however, it did not affect their ability to get on with the task at hand. The motivational perspective on cooperative learning may explain this outcome. According to Slavin (1995), cooperative incentive

structures, here the group project, means that the only way students can reach their own goals is through the group being successful. So, this “need to reach their goals”, may explain how they can get on with the project-work, despite having feelings of prejudice towards one another. A small flaw with the outcome of this prejudice-section, is that it is impossible to measure how much better the project would have been if there were no prejudices present, or if the prejudices were managed more effectively. One could argue that the opinions and response of the students to this question, should be taken at face value. If they really felt the burden of prejudice while working, they would not have selected a positive response to this question; as it would have had a negative effect on their project outcomes.

The other two challenges that were surveyed (i.e. communication and teamwork), were present, but not to the same degree as prejudice. According to the different project groups, the communication and teamwork difficulties varied widely. *Table 15* details how the communication issues are divided. The communication issues that 50% (35) of students acknowledged, may be explained either due to interdisciplinary interaction or personality aspects of the individual. Firstly, this could be due to the ability of individual team members to explain and communicate in a way that is comprehendible to non-experts. Secondly, for the ability or motivational interest of the team members to be receptive to an explanation. This could be down to personality rather than disciplinary epistemologies; Ariani (2013) posits that dispositional factors such as personality, can play a role in motivation and performance.

Of the total respondents, 57% (40) admitted to other problems while collaborating (see *Table 16* for more details). However, when further dissected and scrutinised, 52.5% (21) of the normalised negative responses were true team-work issues, i.e. unequal responsibilities, approach to work, and knowledge gaps. However, of these listed issues only knowledge gaps is related to disciplinary socialising; unequal responsibilities and approach to work are more generic teamwork problems that can affect any team. This may indicate that the disciplinary socialising-dynamic does not have a large effect on teamwork. Furthermore, the specific teamwork issues that were mentioned by students, were compatible with those highlighted by Borrego et.al. (2013), discussed in *Chapter 2.4.* Thus, besides knowledge gaps, there does not seem to be a vast difference between the teamwork issues faced by mono-disciplinary and interdisciplinary groups. An opportunity to pre-emptively focus on knowledge gaps between disciplines, at the early stages of the team formation, presents itself. This could mediate some of the negative consequences of ID ignorance within a group. Taking steps to combine disciplines is primarily a social process, where individuals must communicate and interact

often within disparate environments, ideas and bodies of knowledge (Holley, 2009). The unavoidable factor here are the individuals that make up a team. Personality may explain why some teams work well together and others not, therefore ID differences may show less of an effect than personal differences in teamwork.

v. To what extent are the support mechanisms in place, perceived to be sufficient by the students (workshops, tutor guidance, teacher advice).

Assumption v: Students should feel sufficiently supported within the module due to the range of support on offer.

As a result of previous years' feedback on Module 6 by students, additional workshops and implementations were offered in an attempt to address flagged issues. For example, the IEM students were offered recap and refresher courses on topics that they had already covered in their first year. The goal here was to point students in the right direction in order for them to refresh their knowledge and apply it directly to the project. Additionally, it was the first year the FEST workshops were on offer, these workshops aimed to develop skills (i.e. brainstorming, deliverables, pitching, and structured design review) where students could work constructively towards their project goals. Other support in the form of the REST workshops, teacher support and tutor coaching mostly remained the same. The students do feel sufficiently supported, but surprisingly, not due to the additional FEST interventions. I do postulate, however, that the tutors are where the support is most appreciated. Several of the comments alluded positively to the tutor, but never directly to the teacher or particular workshops. Students find they are supported enough, but the various workshop options were not perceived to be valuable, this indicates an opportunity to trial alternative methods to get the skills education across.

vi. Which drivers of interdisciplinarity are identified by academic staff?

Assumption vi: Academic staff will recognise a range of reasons as to why interdisciplinary education is valuable and being practised at the university.

The academic staff's personal perceptions on the purpose or value of interdisciplinary education were unanimous. They stated "preparing students for the real world" as the key driver in interdisciplinary education. According to Jacobs (2015), employers are searching for recent graduates who are equipped with interdisciplinary skills; the academic staff are acutely

aware of this. As established before, teachers also practise interdisciplinary socialising on a professional level. Therefore, it is reasonable that they would see the direct link between education and practice, and promulgate it to their students, in their teaching. The term "solving complex societal problems" is often cited as the incentive to support interdisciplinarity in education (Repko, 2017; Spelt, 2009; Lélé & Norgaard, 2005; Rhoten et al, 2006). It is a ubiquitous phrase in literature, and is almost a mantra of interdisciplinarity. Surprisingly, societal issues were not ranked highly by either staff or students in Module 6. This could be due to the nature of the project. It is linked purely to industry, and it would take some imagination to stretch the learning outcomes to be relevant to societal issues. It is also possible that the "tackling of societal issues" skills could be nurtured later on in the programme, when the students are more practised in applying their interdisciplinary skills. Furthermore, one could argue that not every interdisciplinary module needs to meet every interdisciplinary learning objective.

The academic staff held a range of opinions as to why the UT is promoting interdisciplinarity (see *Table 9*). A reason for this divergence, could be that the espoused values-message is not trickling down effectively, for example, teachers are not informed properly of the UT's strategic plans. It is, however, common for organisations not to circulate their corporate principles in an easily reachable fashion (Poovathingal, 2014). So, perhaps the promotion of interdisciplinarity within published material, is aimed more at outsiders and not at employees.

vii. What value do students place in ID education?

Assumption vii: Students will have mixed reactions to their perceptions of the value of ID.

The vast majority of students do see the value in interdisciplinary education, and they see how it might help them to develop skills for their future careers. Additionally, students highly rate the module's ability for their perspectives to be broadened. This indicates that despite problems with the project, courses, or workshops, most students could still identify positive learning outcomes from the disciplinary socialising experience. This is demonstrated in the contrast between the EvaSys results focusing on the whole module, as opposed to the student survey which focussed mostly on the interdisciplinary aspects (see *Table 10*, *Table 17*, *Table 18*, and *Table 19*).

A summary of the findings from the research, is detailed in *Table 21* below:

Table 21

Summary of insights gained from research, indicating where students and academic staff's perceptions are aligned.

Student Insights	**Overlap between academic staff and students**	**Academic Staff Insights**
Value of Interdisciplinarity		
Very varied experiences with ID – mostly positive however (not the same as whole-module satisfaction).	Both see benefit for future at work and real life.	Why the UT is driving ID has a range of answers.
-	Both see complex societal issues as not really being practised here.	-
Possible Barriers to Interdisciplinarity		
Most had, and projected prejudices.	IEM may need a more integral role.	Educational concerns.
Misunderstandings were present, but many could be overcome.	High student numbers.	Teacher time is very pressured.
IEM students skills and knowledge is insufficient for them to contribute to the project.	-	-
Supporting Interdisciplinarity		
Workshops were not really appreciated.	Sufficient ID support is provided.	Teamwork practices could also be taught "in house."

8 Limitations

Although every effort was undertaken to conduct an open and reliable study, several limitations became apparent during and after the data collection process. The first grouping of limitations are concerned with some of the wording in the student survey. For the question 5.3 (*I will be better at tackling complex societal problems, due to my exposure to interdisciplinary learning*). The term "complex societal problems" was not clearly defined beforehand, and therefore may have been too ambiguous for different students. Consequently, this could lessen the reliability of the outcome for this question. Additionally, there was a deficiency within question 13 (*Do you feel there was enough support during the module, to enable you to develop the skills needed for interdisciplinary collaboration? Explain, if you can*). After the results were gathered, it became apparent that this question only requested "enough support" and did not prompt the student to further specifically assess *which* support was valuable or not. Therefore, although most students answered that there was enough support, it was unclear which support was most appreciated. In hindsight, a further question breaking down each support activity (i.e. academic staff, tutors, workshops, etc.) with a rating or comments section would have provided a better indication of which support was most valued and why. On the other hand, question 12 (*Which specific workshops or courses helped you to develop the skills to collaborate on an interdisciplinary project? Explain with examples, if you can*) enabled a more specific focus on which specific workshops were valuable.

The second limitation is the low number of personal interviews with students. A brief interview was undertaken with one group of students, but I believe further interviews would have given a more robust representation of how the students perceive the various interdisciplinary aspects of Module 6.

The third limitation refers to the surprising outcome of questions 6.1 – 6.3 (*I feel that students from other disciplines have prejudices or make assumptions about me because of what I am studying; I have prejudices or make assumptions about students from other disciplines and; I feel that prejudices and assumptions between disciplines in our group, hinder our ability to work together optimally*, respectively). Admitting to high levels of prejudice and the feeling of being judged because of one's discipline, turned out not to affect the ability for the team to work together optimally. The limitation here, is that it cannot be measured how much better (or worse) the project would have been if the prejudices were not present, or if they were mediated in some way. Therefore, it cannot confidently be concluded

to what level the prejudices affected the ability of the students to work together optimally. Furthermore, the low Cronbach's Alpha score for this set of questions may indicate a slight flaw in the line of questioning. However, I am still satisfied that the overall essence of the "prejudice conundrum" (i.e. that one can still work well with people they hold prejudices against or if they feel prejudice towards themselves) has been initiated and can be further refined in future research.

9 Recommendations

This study was undertaken to identify the challenges within, and value of, interdisciplinary education for Module 6 Product Design Consumer Products at the University of Twente. Through the interviews, the survey and the document analysis, inspiring examples of expertise and ambition of the academic staff were identified. At the same time some misalignment between the various players did come to light. Further analysis of these misalignments led to identification of opportunities for enhancement of the module:

1. *Alignment of management intentions with current reality*. With regard to the document analysis from the UT's future plans, and the feedback I received from the academic staff, there is a disconnect between the ambitions of management and the realities facing the academic staff. The administration is promoting "small-scale education", whereas academic staff are burdened with large class sizes and lack of time available for quality deep learning. With the promise of funding made by *the Sector Plan Commissie Beta en Techniek Report*, I suggest that the university allocates much-needed funds to alleviate the pressures and work burden put on the academic staff of this module. Additionally, administration and relevant teachers should meet to define a nominal limit to the "mega classes". This is to safely and properly educate students, but more importantly to limit and alleviate the stress of the academic staff.

2. *Opportunities to further enhance scaffolding and support*. Students rated that "enough support" was offered for this module. Due to the feedback received on the skills workshops, it is evident that there is room for improvement. I suggest following the Norwegian University of Science and Technology's (NTNU) model of training and empowering tutors. Add further value by allocating set times within each tutor meeting for skills training and practise, i.e. 15 minutes for each session with a 5 minute instruction and a 10 minutes hands-on example and practice session. However, as is also clear from the study, finding time and suitable tutors is a problem. If budgets were to be allocated to better support the skills development in this manner, I believe this intimate coaching might be an alternative tool for the large scale workshops, which cannot house all students at once. As tutors are already assigned to teams, it will mean they could implement a set, standardised curriculum, with the possibility of further introductory educator-training in psychology and team development. If team skills, perspective taking skills, etc. are really an interdisciplinary educational priority, these may need to be

explicitly taught, practised and fedback to students (Musa & Mufti, 2011). The most efficient and meaningful manner may be through the tutor. This would, additionally, align with one of the UT's aims of "small scale education".

3. *Further refine interdisciplinary goals into active success criteria.* In order to add to the students' access to learning expectations, explicitly break down the 21st century skills learning objectives. For example, not simply stating "be able to communicate across disciplines" but rather giving real and measurable examples such as:
   a) *I am able to identify the gaps in my knowledge and take steps to rectify the deficiencies, either by asking a teammate or by investigating credible sources.*
   b) *I understand that communication requires not only talking, but listening too. Therefore I am able to sum up others' contributions in my own words, checking for misunderstandings, and rectifying them.*

   The abovementioned examples clearly give a direction and action for the students to follow as opposed to vague learning objectives. The first phase in the nine steps of designing of PjBL is to set the goals and objectives for the project (Hung, 2009). Going one step further and explicitly stating the success criteria, along with the learning objectives, can help demonstrate what achievement looks like, for the student (Hattie & Yates, 2013). I believe this will improve the students' expectations of the effort they need to invest in their interdisciplinary learning, and therefore this will guide them on their "student-led-education" process.

4. *Balancing the contributions of all study tracks.* As the coordinators are fully aware, there is an imbalance in the ability to contribute to the project meaningfully, for all study tracks. As steps are already being taken to address this issue, I would like to further encourage the proactive iterations that are already happening within the module (an example of a recent iteration is the introduction of a midterm peer review). After considering the feedback from the students, a recurring issue is the suitability of the project. I therefore suggest that the project be the main consideration, i.e. as the courses are fixed, they should feed the interdisciplinary project. However, I acknowledge the difficulties in coordinating with external companies and the complicated process of wooing potential partners. Perhaps, the two programme coordinators, should include the (non-active) third (IEM) coordinator and work together to first compile a list of what each

track could offer in a given scenario. This list can then act as a guide to identify suitable industry projects, and help eliminate or modify the ones that do not meet all agreed criteria. This may help create a more evenly distributed project for each track.

5. *All informative documentation needs to be checked and updated periodically*. An aspect I noticed incidentally, during my document analysis and interview phase, was that informative documentation available to students was not entirely up-to-date. This documentation includes: the Module 6 manual, for example, which refers to an academic skills course, which is no longer on offer. Additionally, it also does not mention the newly instated mid-term peer review. The RESTs and OSIRIS websites also show outdated information.

10 Practice and Further Research

Over the course of this study, new questions were encountered and other interesting puzzles became apparent. Below some suggestions for further research to explore to these fresh discoveries, are listed:

1. *Solving complex societal issues*. In what way can industry-related projects, such as the one in Module 6, be transferred (or adapted) to stimulate or simulate better the solving of complex societal issues? Furthermore, investigating if "solving complex societal issues" is indeed a necessary learning outcome for all interdisciplinary education, or whether this learning outcome could be satisfied at different stages during the programme's curriculum?

2. *21st century skills.* Students seem to be content with the amount of support on offer to them within Module 6. However, the particular workshops were not fully appreciated. The option to explore whether 21st century skills can be taught via self-managed teamwork settings would be interesting. For example, through blended video-learning in groups; could this be a way to circumvent the tutor limitations and hand agency back to the students.

3. *Unequal distribution of discipline.* Analysing to what extent unequal project-based learning arrangements affect motivation of students might be beneficial. Specifically how the disadvantaged track and the other tracks (i.e. limited role versus others carrying the load due to epistemological sovereignty) cope with the situation. Furthermore, investigations into whether deep learning can still take place, despite unequal role identification is of interest.

4. *Factor analysis of student survey.* During validation of the student survey, the factor analysis identified 3 subscales, and rated the third scale (related to prejudice), via Cronbach's Alpha as a lowly 0.57. Further investigation into how this survey can be improved and refined, may be beneficial for future research, so it can truly measure the prejudice levels within an interdisciplinary group. Also, it would be interesting to delve further into projects where the study tracks are even more disparate. This is in order to ascertain if prejudices affect the outcomes more when the faculties have nothing in

common; as opposed to the Module 6 study, where all participants were engineering students.

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Appendix A – Learning Objectives of Module 6

Learning objectives for the three tracks in Module 6: Product Design Consumer Products.

IDE Consumer Products (**Course Code: 201400117)**

After passing the course, the student can:

a) Apply a multi-disciplinary approach to product development problems.
b) Transfer knowledge to people with different backgrounds (disciplines).
c) Re-formulate the problem specification by a client (formulate the 'real' assignment).
d) Select and set priorities in a plethora of relevant design aspects.
e) Integrate and employ knowledge from different fields of expertise (like marketing, styling, CAD/CAM, intellectual property, packaging, production, research methodology, etc.).
f) Align different phases and perspectives on the product development cycle in respect to the cycle as a whole.
g) Implicitly employ the knowledge and experience that is gained in previous modules.
h) Concurrently pay attention to subject-matters and organisational aspects (project planning and management).
i) Present and market a product in an appropriate way.

Technical Product Modelling 2

a) After passing the course, the student can:
b) Describe development processes and development phases in an interrelated manner.
c) Describe and apply different methods and techniques (curves, surfaces and solids) that are used in CAD/CAM systems.
d) Describe possible ways to exchange data between different software tools (CAD, analysis, manufacturing) and select appropriate methods.
e) Describe and apply rendering techniques.
f) Describe and apply modern methods and techniques in technical product modelling.
g) Apply feature based modelling techniques and employ them to make doubly curved surfaces.
h) Build large assemblies in such a way that they can easily be adapted (e.g. in case of re-design).

Graphic Design

a) Produce well designed and legible visual media such as printed matter, digital report or website.
b) Provide graphic support for a product presentation.
c) Design product information such as usage, safety, and legal aspects.
d) Communicate and collaborate with professional graphic designers.

Product-Market Relations

a) Explain core concepts of marketing theory.
b) Assess the market situation whilst considering the business and brand strategy.
c) Design a marketing plan grounded on customer behaviour insights through and market research.
d) Use research (market and consumer) to inform the product development.
e) Apply key concepts of marketing theory to increase the odds of the market success of a product (e.g., define place, price and promotional strategies).

IEM Consumer Products (Course Code: 201400265)

Project Consumer Products

After successfully finishing the project a student is able to:

a) Apply a multi-disciplinary approach to product development problems.
b) Transfer knowledge to people with different backgrounds (disciplines)
c) Re-formulate the problem specification by a client (formulate the 'real' assignment).
d) Select and set priorities in a plethora of relevant design aspects.
e) Integrate and employ knowledge from different fields of expertise (like marketing, styling, CAD/CAM, intellectual property, packaging, production, research methodology, etc.).
f) Align different phases and perspectives on the product development cycle in respect to the cycle as a whole.
g) Concurrently pay attention to subject-matters and organisational aspects (project planning and management)
h) Implicitly employ the knowledge and experience that is gained in previous modules.
i) Present and market a product in an appropriate way.

Production I

a) Distinguish and describe the various production processes for discrete production.
b) Recognise and explain the (dis)si.milarities between the various production processes
c) Select feasible/applicable production processes for a product while being able to underpin that selection.
d) Relate material characteristics to (the feasibility/applicability of) production processes.
e) Interrelate product geometry, material and production process(es) in relation to a.o. production quantity, batch size, tolerances, accuracy, quality and cost.

Technisch Product Modelleren 1

Learning goals:

a) Analyse a product and can (with that information) model a 3D CAD part model and can redefine it easily.
b) Create assemblies in 3D CAD.
c) Can read a technical drawing.
d) Can apply the technical drawing rules.

Sustainable supply chains for consumer products

Learning goals:

a) Describe the main concept of sustainability and the relation of products and supply chains with the sustainability concept.
b) Apply environmentally and socially sustainable solutions in their projects with companies.
c) Design environmentally friendly and economically efficient supply chains.
d) Identify sustainability niches in products and relate these to circular supply chain thinking.
e) Relate the product design phase to the supply chain design phase and execute these phases simultaneously in their projects.

ME Product Design (Course Code: 201700126)

Project Consumer Products (IDE, IEM, ME)

After successfully finishing the project a student is able to:

a) Apply a multi-disciplinary approach to product development problems.
b) Re-formulate the problem specification by a client (formulate the 'real' assignment).
c) Select and set priorities in a plethora of relevant design aspects.
d) Integrate and employ knowledge from different fields of expertise (like marketing, styling, CAD/CAM, intellectual property, packaging, production, research methodology, etc.).
e) Concurrently pay attention to subject-matters and organisational aspects (project planning and management).
f) Concurrently pay attention to subject-matters and organisational aspects (project planning and management).
g) Implicitly employ the knowledge and experience that is gained in previous modules.
h) perform a patent study about a product concept or about components of the product design.

Specialisation: Designing in plastics

After successfully finishing this specialisation a student is able to:

a) Take the relationship between product design, material selection, production process (injection moulding) and mould design into account.

b) Summarize the properties of the most important plastics.
c) Take the influence of temperature, environment, ageing and use on the properties of plastics and polymers into account.
d) Take into account the influence of the most important processing methods for rubber and plastics on the properties of product and material.
e) Set up a list of demands for material selection for a specific product.
f) Select a material based on a list of demands, and propose an adequate processing method.

Specialisation: Mould design

After successfully finishing this specialisation a student is able to:

a) Take into account the relationship between product design, material selection, production process (injection moulding) and mould design.
b) Name the boundary conditions for product design based on the choice of injection moulding as production process.
c) Construct surface and solid geometries in a 3D CAD system of products with a double curvature and/or thin walls.
d) Design an injection mould using a 3D mould model with the product geometry as starting point.

Specialisation: Simulation of injection moulding

After successfully finishing this specialisation a student is able to:

a) Take into account the relationship between product design, material selection, production process (injection moulding) and mould design.
b) Optimize the product design for the injection moulding process.
c) Optimize the process settings to avoid products out of specification due to inclusions of air, weld seams and product deformations.
d) Minimizing the cycle time of the injection moulding process (and thereby optimizing the cooling time of the product).

Academic skills 6 (replaced by other workshops)

Additionally the student is able to:

a) Works as a member of an interdisciplinary team and reflect on the consequences of interdisciplinarity on the team cooperation and performance.
b) Reflect on his / her own discipline and its unique contribution (added value) to the design process.

c) Apply the basic techniques of the Socratic conversation technique to support the team building process within his / her own interdisciplinary project team.

Elasticity theory

After successfully finishing this part of the course a student is able to:

a) Calculate stresses (force equilibrium, etc.) and use tensors.
b) Explain occurring deformations based on material theory.
c) Apply 3D elasticity theory on components of a construction.
d) Evaluate and understand the results of a calculation.
e) Recognize the problem at hand and simplify it based on the correct interpretation of elasticity theory.

Processing and Properties of Polymers

After successfully finishing this part of the course a student is able to:

a) Indicate how the chemical and physical structure of the polymer chains affect the properties of the polymer.
b) Describe the different phase transitions and corresponding changes in physical structure and mechanical properties.
c) Use existing models for (time dependent) small deformations in plastic components (linear visco-elastic theory including Boltzmann and time-temperature superposition) in the calculation of (time dependent) deformations or stresses.
d) Use the molecular composition of the polymer to explain mechanical behaviour during large deformations and fracture.
e) Explain the behaviour of plastics during production processes and make changes to the design of the production process to prevent undesirable behaviour.

Tribology

After successfully finishing this part of the course a student is able to:

a) Identify a tribological system.
b) Decrease friction and friction phenomena as stick-slip, sliding, etc.
c) Determine the life span of a component using the wear law.
d) Choose an appropriate surface treatment/coating.
e) Adapt a construction in order to minimize friction and wear.

Appendix B – Teacher Interview Questions

1. Which of the following, in your opinion, are your *personal* drivers of interdisciplinarity at the UT? (Why are you doing it?)

□ Alignment with complex social issues	□ Alignment with research directions
□ Student employability for professional / market needs	□ Demand from students
□ Expanding pedagogical practice	□ Other

2. Which of the following, in your opinion, are *external* drivers of interdisciplinarity at the UT? (Why is the UT doing it?)

□ Alignment with complex social issues	□ Top down strategy
□ Student employability for professional / market needs	□ Marketing / promotional considerations
□ Competition with other universities	□ Innovation prestige
□ Individual champions	□ Alignment with research directions
□ Demand from students	□ Other

3. How would you describe the purpose of this module?
4. In your opinion how do you think your students are coping with the ID part of the project – are they supported enough?
5. If you were now to think a bit more about the big issues for ID educational delivery: what is hindering you or holding you back?
6. Do you work on research with other disciplines?
7. How do you think your students are dealing with this year's project? Have you heard any comments or complaints that they are airing?
8. If you could wave a magic wand, to fix anything – what would that be?

(Throughout the conversation, reflections were gleaned and further insights gained)

Appendix C – Student Survey (Exact Format from Survey Monkey)

Module 6: Interdisciplinary Project Experience Survey

Interdisciplinary Experience

Dear Student,

As a Master's student in Educational Science, I could really use your help!
This questionnaire is for students enrolled in the Product Design/Consumer Products (Module 6: 2019/20). The purpose of the research is to explore students' perceptions of their interdisciplinary experience. As a reward for your participation, you will be placed in a lucky draw to win one of four bol.com vouchers, worth €25 each.

Your feedback will contribute to valuable insights for a Master's thesis and the STRIPES2021 Project. Results of this study will only be presented in summary form and individual responses will be kept strictly confidential. The survey only takes 7 minutes. The swift return of the completed questionnaire will be much appreciated!

Thank you for your cooperation.
Yours sincerely,
Coralie Johnson

If you have any questions, please email me at: c.johnson@student.utwente.nl

* 1. Do you agree to participate in this study so that the data gained, can be used to enhance interdisciplinary learning?

Module 6: Interdisciplinary Project Experience Survey

* 2. What is your gender?

- Female
- Male
- Other
- I would rather not specify

* 3. What is your age?

- 18 or below
- 19-21
- 22-24
- 25 and above

* 4. To which track of Module 6 do you belong?

- Mechanical Engineering (ME)
- Industrial Design Engineering (IDE)
- Industrial Engineering Management (IEM)
- Other (please specify)

* 5. Select the most appropriate option for the following statements:

	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree
I will benefit in my future career by participating in interdisciplinary educational modules.	○	○	○	○	○
I will broaden my perspectives about other disciplines, through shared interdisciplinary learning.	○	○	○	○	○
I will be better at tackling complex societal problems, due to my exposure to interdisciplinary learning.	○	○	○	○	○
I would welcome the opportunity to work on more group projects, with other disciplines.	○	○	○	○	○

* 6. Select the most appropriate option for the following statements:

	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree
I feel that students from other disciplines have prejudices or make assumptions about me because of what I am studying.	○	○	○	○	○
I have prejudices or make assumptions about students from other disciplines.	○	○	○	○	○
I feel that prejudices and assumptions between disciplines in our group, hinder our ability to work together optimally.	○	○	○	○	○
My prejudices about other disciplines were changed for the better, after this module and project.	○	○	○	○	○

* 7. During this module, did you perceive someone from a different discipline in a way that turned out to be true or untrue? Please give an example.

* 8. Select the most appropriate option for the following statements relating to your completion of this module:

	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree
I am aware that other disciplines may use the same words differently, to my discipline.	○	○	○	○	○
I can communicate better across disciplines because of this module and project.	○	○	○	○	○
I have improved the manner in which I explain my ideas, so that students of other disciplines can understand me.	○	○	○	○	○
I am better at identifying what other disciplines could contribute to a collaborative project.	○	○	○	○	○

* 9. Were there occasions when there were misunderstanding due to the different disciplines in your group? If so, please give an example.

* 10. Give an example of a positive situation that occurred, due to the different disciplines in your group.

* 11. Did you encounter other problems with regard to collaborating with other disciplines? If so, please explain.

* 12. Which specific workshops or courses helped you to develop the skills to collaborate on an interdisciplinary project? Explain with examples, if you can.

* 13. Do you feel there was enough support during the module, to enable you to develop the skills needed for interdisciplinary collaboration? Explain, if you can.

14. If you would like to add any further comments about your course or about this survey, please do so, below.

15. If you would like the chance to win one of four €25 bol.com vouchers, please fill in your email address, below (winners will notified on the 3rd of February 2020).

Thank you for your time!

Module 6: Interdisciplinary Project Experience Survey

Appendix D – Document Analysis Table (with website links to resources)

Complete table, including links of the document analysis resources in *Table 22*, below.

Table 22

Complete list of documents and data sources analysed (including links).

Documents Selected	Data Analysed
University Twente	
The Twente Education Model – TOM Brochure 2017. (https://www.utwente.nl/en/tom/tom-brochure-2017-definitieveversie15mei2017.pdf)	Background information about TOM and the basic principles of the model. Specifically interdisciplinarity and the project based education aspects.
Student-Driven Learning at the University of Twente -Information for educational staff. (https://www.utwente.nl/en/tom/sdl-brochure-a5-lr-digitaal-def.pdf)	Philosophy of education , skills development of students and structure of the courses.
Quality Agreements 2019 -2024 – Plan of University Twente (hard copy).	The university's profile, specifically the educational profile, the future developments in education for the next six years.
Critical Self Evaluation Report Institutional Audit -September 2019 (hard copy).	Philosophy and policy providing further background and context. Ambitions and educational policy, internationalisation, "Shaping 2030."
EVASYS Documents (2018/19 & 2019/20) – Evaluations on the students' experience questionnaire (soft copy; received from coordinators).	2018/19 – Orientated myself on the general attitude of students towards the module. 2019/2020 – Acquired supplementary information on the project experience.

(Table continued)

OSIRIS – Student Information System of the UT (intranet).	Description on courses and learning objectives.
CANVAS – Online learning management platform of the UT (intranet).	Description of courses, incidental information.
University of Twente: Home Organisation: Facts and Figures. (https://www.utwente.nl/organisatie/feiten-en-cijfers/historie/instroom-en-inschrijvingen-2014-2018.pdf)	Inflow of first year student numbers
Industrial Design Engineering; Mechanical Engineering &; Industrial Engineering & Management: (https://www.utwente.nl/en/education/bachelor/programmes/industrial-design-engineering/) (https://www.utwente.nl/en/education/bachelor/programmes/mechanical-engineering/#why-study-mechanicalengineering) (https://www.utwente.nl/en/education/bachelor/programmes/industrial-engineering-and-management/)	Descriptions on types of learners, activities, attitudes, courses and curriculum.
Reflection on Science Technology and Society (RESTS) and The Fraunhofer Project Centre Expertise Student Team (FEST): (https://www.utwente.nl/en/bms/rests/general-information/) (https://www.utwente.nl/en/bms/rests/bachelor-programmes/io/) (https://www.utwente.nl/en/fraunhofer/FEST/)	Descriptions on what it is, what is offered and purpose of the association.
Other Sources – Websites	
The European Research Council. (https://erc.europa.eu/sites/default/files/document/file/erc_2008_work%20programme.pdf)	Facts and figures on historical interdisciplinary funding
Rijksoverheid, The Netherlands (Sectorplan Commissie Beta en Techniek). (https://www.rijksoverheid.nl/documenten/publicaties/2019/06/14 /advies-commissie-sectorplan-beta-en-techniek)	Facts and figures on funding and educational policies and standings
VSNU – The Association of Universities in the Netherlands. (https://www-vsnu-nl.ezproxy2.utwente.nl/en_GB/news-items.html/nieuwsbericht/497-aantal-ingeschreven-studenten-stijgt-fors)	Facts and figures on funding and educational policies and standings

Note: all websites and links were accurate as of March 06, 2020.

Appendix E – Factor Analysis Reversal Coding

Due to the negative wording of questions 6.1 – 6.3, the Likert scales were reversed for the factor analysis.

Table 23

Reverse scoring of questions 6.1 – 6.3 due to negative wording of the questions.

Question	**Likert Scales**				
6.1 I feel that students from other disciplines have prejudices or make assumptions about me because of what I am studying.	1	2	3	4	5
Recode:	**5**	**4**	**3**	**2**	**1**
6.2 I have prejudices or make assumptions about students from other disciplines	1	2	3	4	5
Recode:	**5**	**4**	**3**	**2**	**1**
6.3 I feel that prejudices and assumptions between disciplines in our group, hinder our ability to work together optimally.	1	2	3	4	5
Recode:	**5**	**4**	**3**	**2**	**1**