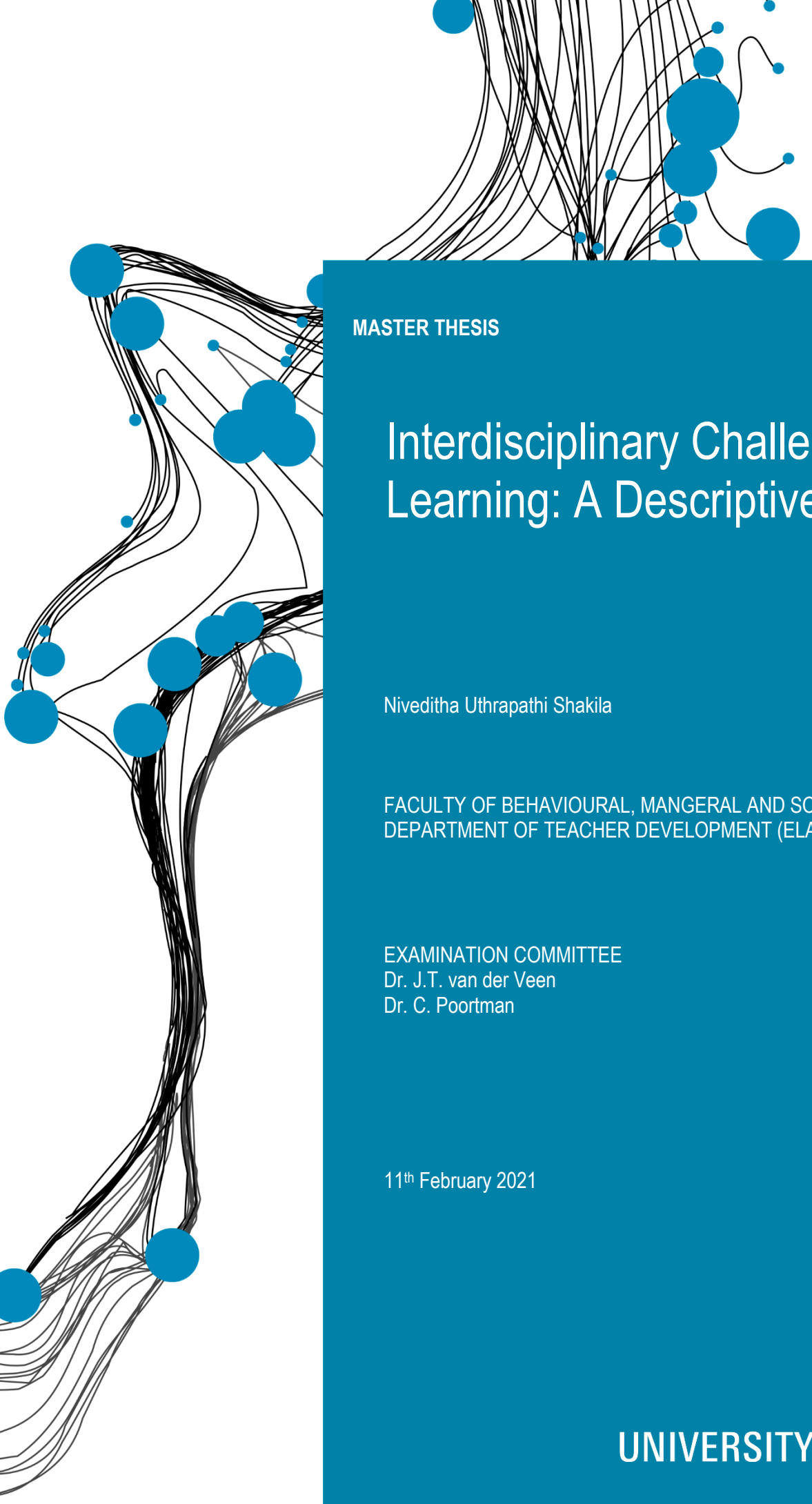

MASTER THESIS

Interdisciplinary Challenge-Based Learning: A Descriptive Study

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Abstract

There is a growing recognition that the complex problems to be addressed in the world require perspectives from multiple fields. As higher education is the pathway to the workplace, it is imperative to develop well-rounded graduates with both, a depth of knowledge in their field and an understanding of the breadth of perspectives from other fields. Although interdisciplinary education has been adopted in many institutions, there are considerable difficulties in implementation such as alignment to vision, teamwork, and support related problems. This study sets out to describe the implementation of an interdisciplinary module, “From Idea to Prototype” that had students from nine study programmes across applied and social science fields who worked on a challenge-based learning assignment. The assignment involved real-world partners in whose organisations the challenges were set. The mixed-methods case study was conducted to examine the perceived value of the module, support for students and staff, collaboration in the interdisciplinary groups, and the competency outcomes. Data was collected through several instruments (observations, focus group studies, document analysis, interviews, survey) from different stakeholders (students, staff) to gain holistic insight.

The results of the study showed that the students and staff valued the interdisciplinary module and especially appreciated the real-world challenges. Regarding support for students, the multiple options were found to be enabling factors while the minimal structure and guidance were the limiting factors. At the staff level, it can be noted that the lack of cohesion within the teaching team and minimal support for guiding student groups in ID are limiting factors. In terms of collaboration in the groups, students recognized the role of the other disciplines, improved their communication, and had varying levels of integration of disciplinary knowledge. The groups faced difficulties such as an unequal distribution of workload and disciplinary differences causing tension. Lastly, the key competencies developed in the module were perspective-taking, communication, collaboration, reflection, and confidence in existing skills and knowledge. Recommendations for improving the module such as scaffolding support for students, developing the ID teaching team, improving peer interactions, and careful recruitment of external challenges are made along with suggestions for future research.

1. Introduction

Contemporary university education is evolving to include interdisciplinarity in research and education to meet the global need for cooperation and integration. Education aimed at developing diversity in backgrounds and skills has been recommended to meet industry demands (OECD, 2018). Additionally, socially relevant, and real-world focused curricula along with integrated approaches have been speculated to be defining trends in guiding the future of university education (Graham, 2018). This ongoing evolution is caused by a demand to respond to so-called societal "grand challenges" (Millar, 2016; Weingart, 2014) which cannot be solved through a monodisciplinary approach (Lattuca et al., 2013; Schmidt, 2008). In order to respond to these challenges, graduates need to have mastery over the depth and breadth of knowledge in their study and be skilled at integrating and employing knowledge and skills from across disciplines (Holley, 2009; Navarro et al., 2016). Interdisciplinary (ID) education is said to be the answer to this need for ingenious solutions to address complex real-world problems (National Academy of Sciences, 2005; Khadri, 2014). Hence, ID education continues to forge its place in higher education.

Essentially interdisciplinarity is "a means of solving problems and answering questions that cannot be satisfactorily addressed using single methods or approaches" (Klein, 2010 p.196). Interdisciplinarity stands out in its approach, in the integration of multiple disciplines, focus on a shared problem that spans across the disciplines, thereby necessitating the collaboration of actors from numerous fields (Holley, 2009; Mansilla & Duraising, 2007; Spelt et al., 2015). Lyall et al. (2015) found that ID education is an existing priority for many institutions. Despite its growing popularity, there are various difficulties in implementing ID education that need to be addressed. The main challenges include non-alignment of vision, goals and learning activities, lack of support and training for teachers and students (van den Beemt et al., 2020), and teamwork-related challenges (Borrego et al., 2013). Although there have been different approaches in implementation (van den Beemt et al., 2017), project-based learning (PjBL) and problem-based learning (PBL) are commonly used pedagogies to develop an environment for solving complex real-world problems (Brassler & Dettmers, 2017; Klaassen, 2018; Klein, 2010). This is aligned with the recommendation by Manathunga et al. (2007) that an active learning pedagogy coupled with student collaboration, and an iterative process designed with milestones and scaffolds is well suited for ID education. While PBL provides students with ill-structured problems to engage with and develop a conceptual final solution, PjBL provides students with specific requirements for developing an end product

that is a tangible artefact (Savery, 2006). The newer challenge-based learning (CBL) is another active learning pedagogy specialized for diverse teams working on solving real-life problems in a systematic method (Kohn Rådberg et al., 2020). It has been said to combine the gains of both PBL and PjBL and is especially applicable to interdisciplinary contexts (Johnson et al., 2009). In CBL, instead of being provided with a problem, students have to define the challenge from general concepts provided by real-world partners. Students are also encouraged to work with peers, teachers, and external partners to devise a solution (Gaskins et al., 2015).

So far, research has focused on outcomes of ID education through PBL or PjBL, while CBL is rather new and has not been studied extensively. As ID education continues to become more mainstream with the growing recognition of the role of universities in shaping well-rounded professionals, this study aims to add to the empirical evidence to guide policy and inform practice. The current research is a descriptive case study conducted on an undergraduate interdisciplinary module, Science to Society 'From Idea to Prototype' at the University of Twente. The module has adopted the CBL approach to facilitate ID education for students from nine diverse disciplines from across applied and social sciences. Since the context includes very distant disciplines unlike previous studies mainly focused on engineering disciplines, the results can encourage and guide broader ID education.

This study is part of the multiple case study design of the Comenius STRIPES2021 research and development project. Through this project, this module was selected as one of a series of educational modules under examination with the overall aim to support teachers to improve interdisciplinary education. This study aims to examine the implementation of interdisciplinary challenge-based education in this module in terms of the perceived value of this module, the support for staff and students, the collaboration with the interdisciplinary group, and the competency outcomes. The outcomes will in turn inform the recommendations drawn for the module staff to consider to further strengthen the design and delivery of interdisciplinary education.

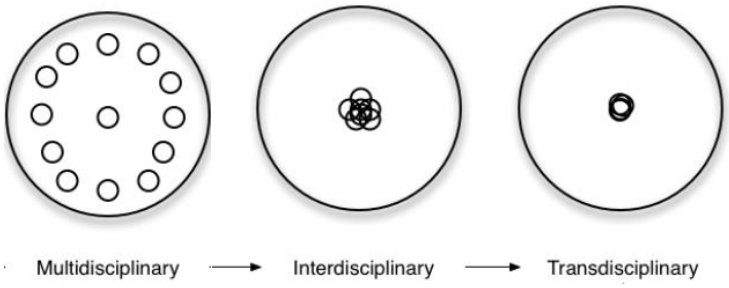
2. Theoretical framework

2.1 Typologies of interdisciplinarity

Interdisciplinarity is a term with multiple connotations from the educational, sociological, and philosophical dimensions. An early definition coined by Klein and Newell (1997 p.393) referred to it as "a process of answering a question or solving a problem or addressing a topic that is too broad or complex to be dealt with by a single discipline". The mere development of insights and knowledge from a variety of disciplines is not enough to be characterized as interdisciplinary, the ability to integrate these forms of knowledge is essential (Mansilla & Duraising, 2007; Spelt et al., 2015). It is important to note that integration is a key aspect of interdisciplinarity which makes it particularly distinct from the confines of independent disciplines and other levels of disciplinary association. Adler and Flihan (1997) proposed the interdisciplinary continuum (Figure 1), wherein the different stages of disciplinary blending ranged from knowledge being, correlated in stage one (multidisciplinary) to shared in stage two (interdisciplinary) and reconstructed in stage three (transdisciplinary). Multidisciplinarity is characterized by approaching a subject under study using different disciplinary perspectives with no integration of the theory or findings. While interdisciplinarity produces more coherent and integrated results owing to the creation of its own theoretical, conceptual, and methodological identity (van den Besselaar & Heimriks, 2001). Trans-disciplinarity is said to transcend disciplines to form a common methodology (Dezure, 2017; Huutoniemi et al., 2010; Klein, 2010). Multidisciplinarity is typified as a juxtaposition of disciplines with less integration and focus on the problem. While interdisciplinarity intends to address 'real-world' problems thereby forcing participants to cross boundaries and create new knowledge. Trans disciplinarity combines interdisciplinarity and participatory approaches bringing together non-academic actors as well in a true systemic fashion, focused more on the problem than the disciplines involved (Klein, 2010; Klein & Newell, 1997; Stock & Burton, 2011).

Figure 1

Typologies of Interdisciplinarity



A wide variety of literature is focused on research in these non-disciplinary approaches (Huutoniemi et al., 2010; Stock & Burton, 2010) and is increasingly being extended to teaching and learning (Spelt et al., 2009; Spelt et al., 2015). Within interdisciplinarity, distinctions can be made to identify sub-categories such as 1) a dominant discipline driving the study leading to unidirectional interdisciplinarity; 2) disciplinary interaction guided by the project, leading to goal-oriented interdisciplinarity; 3) links between distant disciplines called broad interdisciplinarity; 4) links between similar sub-disciplines called narrow interdisciplinarity; 5) instrumental interdisciplinarity which focuses on pragmatic approaches, and 6) critical interdisciplinarity which is driven by value and reason to question existing epistemologies (Huutoniemi et al., 2010; Lattuca et al., 2001; Newell, 2001; Stock & Burton, 2011; Repko, 2007; Welch, 2011). Therefore, as Huutoniemi et al. (2010) pointed out, the goals (why is it integrated?), type (how is it integrated), and scope (what is integrated?) of interdisciplinarity depend on multiple contextual factors and design decisions.

2.2 Interdisciplinary education in Higher Education

The term ‘discipline’ is a wide concept. However, in the context of academic education, there is a generally accepted understanding. Disciplines are characterized as having distinct epistemological factors such as an accumulated body of knowledge, theories, language, social factors such as an acquired culture, and constituent practitioners and researchers (Miller & Mansilla, 2005, Krishnan, 2009; Reich & Reich, 2006). Disciplines themselves are often categorized based on their roots and purpose. Social sciences concern humans in relation to society, Natural sciences concern natural occurring phenomena, and Applied sciences apply existing knowledge towards practical goals such as engineering sciences (Biglan, 1973). Despite this, it is important to note that the so-called boundaries between the disciplines are artificial and, considerable overlap and commonalities exist between and across disciplines (Krishnan, 2009; Abbot, 2001).

Traditionally, universities are based on the structural framework of the disciplines (Clark, 1986; Weingart & Padberg, 2014) and typify not only students, researchers, and staff within the boundaries of the disciplines but also knowledge and study programmes (Holley, 2009). Jamison et al. (2014) note three focus modes for universities namely, the academic mode focused on scientific and disciplinary knowledge, the market-driven mode focused on developing employability, and the hybrid-learning and responsibility mode focused on supporting the sustainable development goals (SDGs). It can be argued that ID education

aligns with all three modes. Firstly, it aligns with the academic mode because of its holistic view on theory and knowledge development stemming from post-modern critiques of disciplines and specializations (Klein, 1990; Frodeman, 2014). Secondly, the increasingly complex labour market has heightened the interest in ID competence to effectively contribute to the workforce (Frodeman, 2014; Newell, 2010). Thirdly, concerning the responsibility mode, its growing recognition that the 'grand challenges' which are the world's current problems concerning SDGs, cannot be solved through perspectives from a single discipline (Brassler & Dettmers, 2017; Holmwood, 2010; Klaassen, 2018; Millar, 2016; Moore, 2011; Ouda Khadri, 2014; Schmidt, 2008).

Tackling these challenges requires students to develop depth and breadth of knowledge cutting across disciplinary boundaries (Holley, 2009; Navarro et al., 2016). Therefore higher education is increasingly called on to develop students' ability to address these issues in both the scientific and professional domains (Jensen et al., 2019). The belief that interdisciplinarity can enable a comprehensive understanding to address these issues has led to increased interest in interdisciplinarity (ID) in higher education (Newell, 2008). The gradual but consistent evolution of the role of universities and higher education stems from this need for interdisciplinarity in higher education (Gero, 2017; Millar, 2016). Spelt et al, (2009) contend that, while traditional higher education focuses on domain-specific knowledge and development of generic skills, ID higher education aims to foster boundary-crossing skills to change perspectives, synthesize knowledge and deal with complexity. Hence, the inherent aim of ID in higher education is to facilitate disciplinary integration at educational and research levels towards creating integrated theories of knowledge, developing well-rounded students with a holistic perspective, and ID competencies.

2.3 Pedagogies for Interdisciplinary education

In higher education, ID takes the form of activities, courses, and entire programmes founded on the integration of disciplines. It is interesting to note that ID stems from a constructivist paradigm and hence concerns the interrelations between concepts and how the learner constructs knowledge in complex situations (Stentoft, 2017). Active learning is frequently proposed as pedagogy to facilitate ID in higher education (Lyall et al., 2015; Navarro et al., 2016; Spelt et al., 2009). Active learning pedagogies tend to be suitable for ID education due to their focus on fostering critical thinking (Klein, 2006) and other higher-order thinking skills like problem-solving, reflection, and self-direction (Brown Leonard, 2012; Haynes & Leonard 2010; Lattuca et al., 2004). Moreover, these can bring much-needed

relevance for students by developing a deeper understanding and learning to apply knowledge to real-life problems in a holistic manner (Czerniak et al., 1999). Moreover, researchers in this field also recommend the combination of active learning and an iterative learning process with milestones and scaffolds as being suited for ID education (Manathunga et al., 2007; Spelt et al., 2015).

Problem-based learning (PBL) and Project-based learning (PjBL) are two active learning pedagogies that meet this recommendation and have been previously studied in the context of ID higher education (Brassler & Dettmers, 2017; Jensen et al., 2019; Warr & West, 2020). These pedagogies enable students to apply and develop their knowledge and skills in authentic scenarios along with the development of 21st century and metacognitive skills (Stentoft, 2017) and is aligned interdisciplinary learning (Savery, 2006). The newer challenge-based learning (CBL) model is comparable to these active learning pedagogies and is designed for ID teams working on solving real-life problems in a systematic method (Johnson et al., 2009).

Challenge-based learning is a relatively new learning approach (dating back from around 2011) envisioned to build off from PBL and PjBL towards furthering these active learning pedagogies for the 21st century. CBL creates a rich learning environment wherein students' professional skills are fostered by engaging in interdisciplinary, real-life, multi-stakeholder situations towards solving complex problems (Kohn Rådberg et al., 2020). As the real-world challenges are inherently multidisciplinary, CBL is designed for interdisciplinary teams working along with the partners from the 'challenge' context to collaboratively address the challenge (Magnell & Högfeldt, 2015). CBL is touted to bring together the best aspects of PBL, PjBL, contextual teaching and learning, and a focus on real-world problems (Johnson et al., 2009). A key difference is in the opportunity for students to choose and define the challenge from the offered general concepts as opposed to being provided with a challenge/problem. Other developments such as the involvement of non-academic partners, problems tied to an idea of global importance, and emphasis on self-directed pathways and reflection make this approach desirable. (Alexander et al., 2019; Gaskins et al., 2015; Kohn Radberg et al., 2020). Furthermore, Pisoni et al. (2020) point out that experts and teachers play a crucial role as mentors and in monitoring the development of students' skills and competencies. They may also facilitate collaboration among stakeholders and continuously adapt the methods of guiding according to the students' needs.

CBL provides a hands-on framework (Figure 2) with three essential phases, Engagement, Investigation, and Implementation (Johnson et al., 2009). The engagement

phase is characterized by moving from the abstract big idea to a concrete actionable challenge through the essential questioning process. In the next phase, the students conduct research to create a foundation of sustainable solutions. Finally, in the last phase, evidence-based solutions are implemented and evaluated with an authentic audience (Nichols et al., 2016)

Figure 2

Challenge-Based Learning framework (Johnson et al., 2009)

Despite CBL's potential benefits in fostering 21st-century skills, providing a framework for enabling students to address real-world challenges, and facilitating collaboration between learners and non-academic partners, it does have some difficulties in implementation. These include a perceived increased time commitment in comparison with traditional approaches, faculty's expertise to guide without controlling the process, and developing authentic assessments to evaluate learning outcomes (Nichols et al., 2016). Besides, at the learner level, the openness of undefined problems coupled with non-traditional guidance can prove to be a struggle in open problem contexts (Jensen et al., 2019). This can be said to especially be the case for novices who have not been exposed to the demands of self-directed active learning (Clark et al., 2012).

2.4 Collaboration in interdisciplinary groups in CBL contexts

ID teams set a unique context for students to interact and learn together with students from other disciplines. In a challenge-based learning context, there is the added complexity of defining and solving an open-ended challenge from multiple disciplinary viewpoints. Jensen et al. (2019) point out that the student group is responsible for taking ownership of their learning processes. Students have opportunities to integrate new knowledge with existing knowledge thereby making learning more effective (Gero, 2017) and improving their

motivation to learn (Zhou & Krogh, 2019). However, Yueh et al. (2015) suggest that this creates a complex learning model that can be challenging for diverse student teams to manoeuvre effectively. These challenges have been found to stem from differences in language and meanings across disciplines (Hall et al., 2002; Schaddelee & McConnell, 2018), varying focus due to differing interests and logic (Brandstädter & Sonntag, 2016), and unequal distribution of responsibilities (Cotantinto et al., 2010; Helle et al., 2006). Richter & Pareti (2009) in their study about barriers to ID coined the term 'disciplinary egocentrism' to refer to students' inability to relate their discipline to an ID problem and recognize the value of contributions from other fields. Moreover, biases and stereotyping of other disciplines can hinder effective ID teamwork (Meadows et al, 2015; Stoddard & Pfeifer, 2018; Wolfe et al, 2016).

Zhou and Krogh (2019) found that collaboration in interdisciplinary teams is influenced by peer arranged group formation which can create a conducive support system. They also highlighted that task diversity within the group fosters intrinsic motivation of the students and self-managed groups pave the way for shared responsibility. However, they caution that students need to be supported with developing project management and leadership skills (Zhou & Krogh, 2019). Merely bringing together students from various disciplines with a common assignment does not pave the way for integration, which is the crux of ID education. Miller & Mansilla (2004) outlined four stages of integration of disciplinary knowledge in groups. The first stage is mutual ignorance and is followed by stereotyping, perspective-taking, and merging. Amey and Brown (2005) developed the ID collaboration model outlining the stages of collaboration which also highlights integration as a key factor along with the inclusion of stakeholders, teamwork, and leadership in the group. Besides, researchers warn that when the problem analysis has been performed too well, a multidisciplinary way of working may be adopted to solve individual components and combine them (Jensen et al., 2019). The stages of integration may occur over time within the same group and can be influenced by student characteristics, such as previous experience in ID (Lyall et al., 2012). Moreover, supervision received from tutors or teachers also affects collaboration and an interdisciplinary supervision group is recommended (Zhou & Krogh, 2019). Support to foster collaboration is elaborated in an upcoming subsection (see section 2.6). Overall, there are internal and external factors that can influence collaboration in ID teams.

2.5 Competencies developed through ID education

A significant highlight of ID education is the opportunity for nuanced skill development, while traditional higher education focuses on domain-specific knowledge and development of generic skills. Spelt et al. (2009) point out that, ID higher education aims to foster boundary-crossing skills to change perspectives, synthesize knowledge and deal with complexity. Moreover, Stanton et al. (2017) noted that ID education is aligned to the 21st-century skills of critical thinking and problem solving, communication, collaboration and teamwork, and creativity, and innovation. Since communicating across disciplines necessitates the ability to simplify and articulate complex ideas which in turn requires expertise in students' disciplinary knowledge, McNair et al. (2011) reason that disciplinary expertise is an outcome of ID teamwork. As metacognitive competencies are both a pre-requisite and outcome of ID learning (Ivanitskaya et al., 2002), students need to be supported to apply and further develop their skills. Furthermore, due to the active and self-directed learning models utilized in ID education, students need to go beyond academic competencies and master skills such as defining learning objectives, adapting to uncertain contexts, reflection, evaluating performance, and receiving and giving feedback (Jensen et al., 2019). However, competency development is not a default outcome of ID contexts, it has to be designed for and supported at the curricular and teacher level as elaborated in the next section (Section 2.6). Overall, students need the ability to absorb and process new knowledge coupled with the skills needed to navigate ID, manage individual learning, and group processes.

2.6 Supporting interdisciplinary learning in CBL contexts

Support for staff

Academic staff facilitating ID require support to cater to the needs of the established curriculum and the students towards achieving the learning outcomes. Academic staff can take the role of designers, teachers, supervisors, and mentors in ID programmes. In terms of facilitating ID education, staff members need support to scaffold their guidance (Gardner et al., 2014; Schaddelee & McConnell, 2018) and move out of the comfort zone of their disciplines into the uncertain arena of ID (Jensen et al., 2019). Training has been suggested to focus on approaching non-traditional and open-ended problems (Ding, 2014) and a conceptual understanding of ID (Gardner et al., 2014). Moreover, structuring the mentor role to facilitate appropriate interaction for students engaged in open-ended problem solving is crucial (Gómez Puente et al., 2013). Jensen et al., (2019) further recommend that supervisors with research qualifications are best suited, as they are trained in diverse scientific practices and can apply

different approaches based on the subject matter. The course design has been recommended to be a collaborative process among the staff involved (Gast et al., 2017) with a combination of disciplinary backgrounds and a stable teaching team (Hannon et al., 2018; Jensen et al., 2019). Spelt et al. (2009) concur about the importance of teaching teams and emphasize that professional development towards building a shared understanding of ID, each other's disciplines, and integration are necessary to create a conducive space for students in ID. Moreover, it is important to note that the prior ID experience of staff influences the vision, their willingness to implement, and their facilitation of effective ID education (Spelt et al., 2009). Overall, staff involved in ID at various capacities need to be adequately supported to use and develop their skillset and understanding of ID to effectively facilitate ID learning for students.

Support for students

Students in ID programs are confronted with a novel way of working and the open-ended problem-solving component further necessitates scaffolding to meet the learning outcomes. Support can be in the form of infrastructural resources, supervisor and teacher support, and the structure of the curriculum. Firstly, infrastructural resources include space for the groups to work together, the materials required for developing the solution to the given problem, and access to experts (Redshaw & Frampton, 2014). Secondly, regarding support from teaching staff, research has shown that students require guidance to: (a) transition from well-defined assignments to self-managed group work; (b) approach ID; (c) communicate across disciplines; (d) effectively collaborate; (e) integrate their disciplines; (f) encourage engagement; (g) help resolve conflict; and (h) apply peer-related skills (Fleming & Stanway, 2014; Jensen et al., 2019; Redshaw & Frampton, 2014; Warr & West, 2020). Moreover, role modelling ID teamwork to value other disciplines and apply interdisciplinary thinking skills has been emphasized as an important aspect of support from staff (McNair et al., 2011; Schaddelee & McConnell, 2018).

Thirdly, regarding the curriculum, in their systematic review of ID higher education, Spelt et al. (2009. p.32) found that "a gradual, linear, phased pattern" with the learning outcomes serving as milestones were important conditions for facilitating ID. The principle of constructive alignment which is the intentional coherence between the learning outcomes, learning activities, and assessment has been applied to analyze ID teaching (Spelt et al., 2009; Stanton et al., 2017). Support can take the form of scaffolding structures to guide students towards the learning outcomes and ID thinking (Borrego et al., 2013; Drezek et al., 2008;

Jensen et al., 2019; McNair et al., 2011; van den Beemt et al., 2020; van der Veen & MacLeod, 2018; Vogler et al., 2018).

Several strategies have been suggested in previous research to scaffold instruction for students in ID education. Inclusion of checkpoints for progress and structural elements to meet the students' needs for more guidance and a strict timeline is advocated by McNair et al. (2011) in their study of ID self-managed teams. Stentoft (2017) adds to this and emphasizes the importance of signposting and clarifying expectations to support metacognition. Feedback conversations with students have been highlighted as an important scaffolding strategy to support motivation (Fleming & Stanway, 2014), support the realization of learning outcomes (Manathunga et al., 2006), foster personal and academic development (Jensen et al., 2019). Oberg (2009) suggested the use of a discourse framework to guide students to discuss their assumptions about the problem, to build awareness of disciplinary perspectives. Towards fostering ID teamwork and collaboration, the use of evidence-based group structures and formation strategies are recommended (Borrego et al., 2013). Lastly, ICT tools are recommended for facilitating and supporting group interactions (Klein, 2013; Makrakis & Kostoulas-Makrakis, 2012). Overall, from these studies, it can be said that support for ID needs to target the three aims of an ID pedagogy which Spelt et al. (2009) highlighted as, promoting ID, achieving active learning, and realizing collaboration.

2.7 Difficulties in implementing ID education

As the idea of interdisciplinary education continues to gain widespread interest, the growing literature is shedding light on the difficulties in implementing ID education within a university. These difficulties include institutional barriers to implementation, effective teaching in ID, constructive alignment of learning goals, activities, and assessment, stakeholder management, and teamwork challenges (van den Beemt et al., 2020). In terms of institutional barriers, many researchers attribute the disciplinary departmental regime at universities to be a significant limiting factor (Amey & Brown, 2004; National Academy of Sciences, 2005; Sá, 2008). These rigid structures have been suggested to offer significant resistance for ID programs (McNair et al., 2011). Thereby, the development of a common vision for ID is hindered, which can be a hurdle for the organisation of such a programme and limit students' disciplinary boundary crossing (van den Beemt et al., 2020).

Staff members have to confront the uncertainties of ID and open-ended problems. These include planning and designing for unknown scenarios, finding themselves in a non-expert role, the possible discomfort of being on par with the student group in some areas of

approaching the assignment, and potential conflicts within teaching teams (Jensen et al., 2019; Warr & West, 2020). Furthermore, Jensen et al. (2019) pointed out that teaching in ID settings requires much more than disciplinary knowledge and known teaching strategies as the teaching and learning processes are starkly more complex in ID open-problem contexts. Moreover, the contextual factors of an ID programme can be said to influence the difficulties and support needed, such as the pedagogical model adopted and the type and scope of ID. For instance, active and discovery learning models recommend unguided open-ended problems and reduced hands-on support from staff (Jensen et al., 2019). On the other hand, broad ID involving distant disciplines has been suggested to be more difficult to support (Spelt et al., 2015).

At the student level, the novelty of working with peers from other disciplines can lead to problems with teamwork, communication, prejudice, and conflict (Campos et al., 2012; Schaddelee & McConnell, 2018; van den Beemt et al., 2020; Warr & West, 2020). Besides, students struggle with integrating disciplinary perspectives with diverse group members and sharing the workload (Contantinto et al., 2010; Warr & West, 2020). The autonomy associated with self-directed learning in groups can add to the difficulty especially when students transition from spaces with highly defined disciplinary identities and expectations (McNair et al., 2011). Furthermore, Jensen et al. (2019) pointed out that changing the perspective from viewing teachers as the source of all knowledge to supervisors who are also confronted with the uncertainties of open-ended problem solving is an added difficulty. Notably, Sores et al. (2013) highlighted that the support required for students to navigate ID is possibly underestimated by the course designers. In concurrence, Stentoft (2017) notes that teachers need to play an even more active role than in disciplinary contexts to support the diverse processes that lead to achieving the learning outcomes.Lastly, the design and development of the educational module are met with difficulties in setting a holistic and inclusive vision, constructive alignment, and catering and clarifying the expectations to all the stakeholders involved (Borrego et al., 2009; Nowacek, 2009; Stentoft, 2017; van den Beemt et al., 2020; Vogler et al., 2018).

3. Case description

3.1 Science2Society Minor: From Ideas to Prototype

Science to Society is a minor offered to third-year bachelor students as part of the High-Tech Human Touch minors at the University of Twente. Bachelor students from different programmes across the five faculties in the UT participate in this minor. The minor has two-part 15 EC modules, the first part titled “From Ideas to Prototype” is offered in quartile 1A and the second part, “From Prototypes to Society” is offered in the quartile 1B. Students can choose to enrol in one or both modules. This study is set in module 1: From Ideas to Prototypes in the academic year 2020/2021. The module aims to engage students from multiple disciplines to collaborate and address real-world challenges in diverse fields of Energy, Health, Learning, and Robotics that require an interdisciplinary approach through the integration of knowledge from different domains (OSIRIS, 2020).

> *“These challenges require us to learn how to design solutions and utilize knowledge and research methods from not a single, but multiple scientific domains. To be successful, robotic solutions in healthcare for example have to be approached from a technical, psychological but also an ethical, business, and philosophical standpoint.”* (OSIRIS, 2020).

The students work in groups to analyze the state of the art of the science behind a challenge provided by an external partner and devise novel ways to apply their knowledge in an extensive and agile design process (CANVAS, 2020).

“The learning objectives of this module were:

1. Collaboration and communication with multi-disciplinary team members and stakeholders.
2. Addressing the challenge by:
    a. Analyzing and breaking the challenge down to several specific research questions.
    b. Applying design-based research and other appropriate research methods.
    c. Composing requirements that integrate the needs of different stakeholders and different domains.
    d. Designing several concepts and compare them based on the composed requirements.

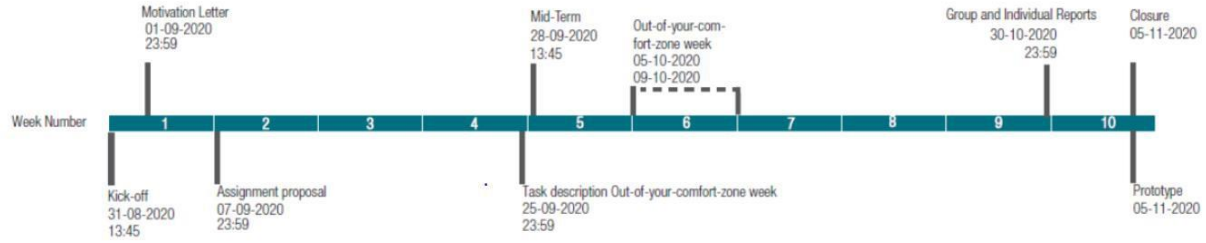
e. Using resource management to construct a prototype that considers the trade-off between various requirements in multiple domains (time, costs, personnel, facilities, marketing, etc.)

3. Validate and demonstrate the designed solution and elaborate on the design rationale.
4. Evaluate and critically reflect:
    a. On the impact of the chosen prototype solution on its target group and society.
    b. On their own contribution to the team, based on their disciplinary knowledge and academic skills." (OSIRIS, 2020)

The module is organized across the 10 weeks of the quartile at the University of Twente (Figure 3). The schedule had few milestones and activities that were mandatory for all and several options for need-based support.

Figure 3

Schedule of the module (OSIRIS, 2020)



At first, the enrolled students formed their groups via a 'speed date' approach wherein they get to know each other and are introduced to the challenges. The available challenges were pitched by the respective challenge provider which were diverse and multidisciplinary open-ended challenges from external companies and internal departments at the UT (see Table 1). The students were encouraged to form groups based on diversity requirements (disciplines, nationality, gender) and the groups were asked to submit choices for their top three challenges through a motivation letter. Once the challenges were allotted to the groups, they were expected to meet with their assigned process tutors and set out to define their exact problem in an assignment proposal to be submitted in week 2.

Table 1

Overview of challenges and the challenge providers

Challenge provider	Title
University of Twente	Human-machine cooperation and societal impact in the development of a chewing gum removal robot
Saxion University of Applied Sciences	Reliable hand force measurement for people with hand impairments
VolkerWessels	A Platform approach to Design for Manufacture and Assembly in construction
Gemeente Enschede	Twente Energy Transition towards Gasless Domestic Heating & Cooking (Biogas)
Gemeente Enschede	Twente Energy Transition towards Gasless Domestic Heating & Cooking (H2 Fuel Cells)
Green Grid Consultancy	Disabled people inclusion at the neighbo**u**rhood level
Medisch Spectrum Twente	GetWell: helping elderly to regain control over their health after hospital stay
HR department, University of Twente	High-flex working at the UT

Through this module, students are introduced to various scientific disciplines and their skills development is fostered through lectures and interactive workshops. These were aimed at providing the student groups with a shared background knowledge and skills to address the given challenge. The topics of these structured spaces were generic so that they are useful for the various challenges the student groups worked on (as outlined in Table 1). The content was focused on design, research, programming, and targeting competencies through workshops on ID, CBL, and reflection (see Table 2). Week 5 had a mid-term presentation where the teams presented their work and were evaluated based on their work by their process tutor and module coordinator. Week 6 was termed the 'out of comfort zone' week wherein the students worked on a task for another group's challenge. The group and individual reports were expected to be submitted in week 9 and the module ended with the final presentation of results and prototypes.

Table 2

Schedule of planned activities

Content	Type of activity	Week in the module
Research Methods	Lecture	1
Design Requirements	Lecture	1
Multi & interdisciplinarity	Workshop (non-content)	1
Challenge-based learning	Workshop (non-content)	2
Design Approaches	Lecture	2
Design Thinking	Lecture	2
Value Proposition	Lecture	2
Iterative Design	Lecture	3
Stakeholder Analysis	Lecture	3
Arduino & Programming	Workshop	3
Behaviour Change Tools	Lecture	4
Reflection	Workshop (non-content)	4
Ethics of Design	Lecture	8
Final presentation	Assessment	10

The expected end-products of this module were one or more scientifically and practically grounded prototype(s) addressing the challenge. In part 2 of this minor (Module 2: From Prototype to Society), students will elaborate on this prototype into a tested and evaluated solution. It is important to note that due to COVID-19 pandemic regulations, a blended learning approach was adopted for the module wherein most of the activities occurred online through the in-built conferencing tool in the Learning Management System, CANVAS. The lectures and workshops took place through online sessions and there were project workspaces reserved in the DesignLab at the University of Twente campus for optional group work weekly on all Fridays.

3.2 Challenge-Based Learning in this module

This module followed the pedagogical approach of challenge-based learning wherein the interdisciplinary student teams worked on identifying, analyzing, and designing a solution for a sociotechnical problem (Kohn Radberg et al., 2020). The learning is also characterized by the collaboration between the students and the challenge provider, the partner who has requisitioned a solution for their context. The 48 students across eight teams each worked on a unique challenge along with the stakeholders towards developing a prototype of their

solution. As this is a novel pedagogy for most students and staff members involved in this module, educational specialists from the Centre for Expertise in Learning and Teaching (CELT) at the University of Twente who also helped design the module, conducted sessions for students and staff members. These sessions served as an introduction to CBL, the framework, process, and roles of those involved. Also, resources outlining the same content were available for perusal on the Canvas page of the module.

3.3 Assessment

This module employs multiple assessment methods at different points of time in the module to evaluate the students' work based on the learning objectives. Several subgrades together make up for the final grade of this module. Moreover, there are also formative assessments which aim to provide feedback and are not graded. Assessment rubrics and guidelines were provided to the students and staff members. The alignment of the learning objectives to the various assessment components are outlined in the assessment scheme in Figure 4.

Figure 4

Assessment scheme (OSIRIS, 2020)

Learning Objective	Assessment						
	Formative Assessment			Summative Assessment			
	Motivation Letter	Assignment Proposal	Midterm Presentation	Report (60%)	Individual Reflection (10%)	Final Presentation (30%)	
						Peer Assessment (10%)	Expert Assessment (20%)
1	x	x	x	x	x	x	x
2		x	x	x			
3				x		x	x
4	x			x	x		

3.4 Stakeholders and their roles

This module not only brings together students from different study programmes but also academic staff from multiple disciplines at various capacities support the implementation of this module. The partners, their roles, and functions are briefly explained in Table 3. Two of the challenge facilitators were employees of NovelT, an entrepreneurship and business

development consultancy within the University of Twente campus. They also supported the recruitment and orientation for the challenge providers.

Table 3

Staff involved in the Science2Society module.

Role	Functions
Module coordinator	Responsible for the organization and coordination of all activities in the module. The central point of contact for challenge facilitators, providers, students, and lecturers
Lecturer	Responsible for facilitating the corresponding lecture or workshop.
Process Tutor	Responsible for guiding and supporting the students during the design process. Students are advised to have a weekly meeting with their tutor.
Challenge Facilitator	Functions as a link between the groups and the challenge provider (stationed at the UT campus).
Challenge Provider	The partner who commissioned the challenge. Students are encouraged to contact them weekly and work together towards a solution.

4. Current Study and Research Questions

The goal of this research is to describe the implementation and outcomes of an interdisciplinary CBL module at the undergraduate level. Outcomes in terms of, value of ID, collaboration in teams, and competency outcomes are to be examined. To achieve this goal, the following research questions are formulated:

1. What is the value of interdisciplinary challenge-based learning in this module?
   1.1 What is the attitude of students and staff towards the module?
   1.2 What are the highlights of this module?
   1.3 What are the difficulties in this module?
2. What are the enabling and limiting factors of support for interdisciplinary education?
3. How do interdisciplinary teams collaborate in a CBL assignment?
4. What are the competency outcomes of interdisciplinary education for the students?
   4.1 What are the anticipated competency outcomes?
   4.2 What are the perceived competency outcomes?

5. Research Design

This study has a pragmatic research approach intending to inform practice and add to theory (Salkind, 2012). It employs a case-study design (Rowley, 2002) as it suits the holistic examination of the unique features of the module, 'From Idea to Prototype'. It is a fully mixed concurrent study wherein both qualitative and quantitative phases are conducted and is mixed from the data collection stage (Leech & Onwuegbuize, 2009).

5.1 Participants

Students

There are 48 students enrolled in the minor (50% female) and divided across eight teams of six members with a heterogeneous mix of study programmes. The students represent the following programmes: Psychology (18), Mechanical Engineering (11), Industrial Design Engineering (8), Technical Medicine (2), Chemical Science and Engineering (2), International Business Administration (1), Electrical Engineering (1) Computer Science (1), and ATLAS (1), Overall, they can be classified to represent the disciplinary groups of Social Sciences (19) constituting of students from Psychology and International Business Administration and Applied Sciences (26) with all the students from all the other programmes.

Academic Staff

There are 17 staff members involved in the delivery of this module (41% female) across various roles: lecturers responsible for facilitating the planned content (9); module coordinators responsible for organization and coordination (3); process tutors responsible for guiding the student groups (8); challenge facilitators acting as a communication bridge between the challenge providers and the groups (5); educational specialists who guided the design of this module (3); and challenge providers representing the partner organizations (8). Among the staff interviewed, 85% had previous experience in interdisciplinary education or research.

5.2 Instrumentation

Typical of the case study design, multiple sources of evidence were collected through various data collection instruments. Table 4 shows the alignment of the instruments to the corresponding focus research areas. Both, methodological and data triangulation were applied, as multiple methods of data collection are employed for the same research question(s) and the data is sourced from students (individual and groups) and staff are the participants (Carter et al., 2014). At the student level, a survey, focus group studies, and observations were conducted while at the staff level, semi-structured interviews were used.

Also, a document analysis of module related documents and group project reports was conducted to ascertain the answers to the research questions posed. Table 2 shows the alignment of the research questions to the corresponding data collection instruments. This study is conducted with the BMS Ethics Committee's approval (Request no. 201167) and observes the prescribed data handling guidelines.

Table 4

Alignment of research questions and instruments

Research Questions	Instruments				
	A	**B**	**C**	**D**	**E**
1. What is the value of interdisciplinary challenge-based learning in this module?					
1.1 What is the attitude of students and staff towards the module?		☑	☑		☑
1.2 What are the highlights of this module?	☑	☑	☑	☑	☑
1.3 What are the difficulties in this module?	☑	☑	☑	☑	☑
2. What are the enabling and limiting factors of support for interdisciplinary education?	☑	☑	☑	☑	☑
3. How do interdisciplinary teams collaborate in a CBL assignment?	☑	☑	☑	☑	☑
4. What are the competency outcomes of interdisciplinary education for the students?					
4.1 What are the anticipated competency outcomes?		☑	☑	☑	
4.2 What are the perceived competency outcomes?			☑		☑

Note. A - Observation, B - Survey, C - Focus Group, D - Document Analysis, E – Interview

Survey

An online survey administered through SurveyMonkey was used to collect self-report data from the students about their experience in the module. A survey was chosen due to its efficiency and the need for holistic understanding (Cohen et al., 2011) of the overall value of the module, views on collaboration, support, and competencies developed. The survey was kept short and an incentive was used to encourage responses (Jones et al., 2013). Before the questions, information about the survey and voluntary participation was shared. In all, 15 questions were presented with ten closed-ended Likert scale questions and five open-ended

questions to gather qualitative comments. The survey design is outlined in Table 5 while the survey items and their sources can be found in Appendix A.

Table 5

Survey design in alignment with the research questions

Research Question	Questions	Example
Value	**Five Likert scale questions** • Benefit for future • Interest in ID • Usefulness of ID • Motivation • Future participation in ID	5.1 The learning from this module will help me in my future study/career.
Group collaboration	**One multiple options question** • Nature of teamwork **Six Likert scale questions** • Group formation • Recognizing the role of other disciplines • Other's prejudice • My prejudice • Broadening of perspectives • Awareness of difference in language **Two open-ended questions** • Positive groupwork experience • Negative groupwork experience	7.2 I recognize the role that the team members from the other study programmes played in the project.
Support	**Two Likert scale questions, question** • Types of support • Rating overall support • Remote experience **One open-ended** • Improvements needed	8.2 Overall, how would you rate the support you and your group received in this module.
Learning	**Five Likert-scale questions** • Communication • Relatedness • Connections to other disciplines • Reflection • Critical thinking **One open-ended question** • Overall learning	13.2 I was able to make connections between the challenge and my prior learning from my study programme.

The survey starts with obtaining consent for voluntary participation and questions concerning the demographic characteristics. Students were asked to choose their faculty

instead of their study programme to preserve anonymity as there were some programmes with only one student. The closed section of the survey was adapted from Lattuca et al. (2013) measures of ID competence, and previous studies (Gero, 2017; Johnson-Veldhuis, 2020; Richter & Pareti, 2009). Items related to the value of the module and prejudice were retrieved from the work of Johnson-Veldhuis (2020) adapted them from the Interprofessional Attitudes Scale (IPAS) (Norris, et.al 2015) and the Interdisciplinary Project Management Questionnaire (IPMQ) (Tormey & Laperouza, 2019). In addition, there were some self-created items based on the literature. The open section of the survey is intended to collect qualitative comments from the students about their experience in the module. Careful wording was considered to avoid vagueness, double barrelling, and negative phrasing (Cohen et al., 2011). The actual survey administered can be found in Appendix B.

The survey was shared with all students in the last week of the module by email. A reminder was shared on Canvas with the module coordinator's support. A final reminder was shared during the final presentation wherein the survey link and a QR code to access it were shared. The survey received a response rate of 81.3% with 39 out of 48 total students completing it. On average, the survey took 7 minutes to complete.

Focus group study

Focus group studies were conducted with students to obtain a fine grain picture of their experience. A collective view was sought in this contrived setting of participants chosen from the different project groups. This instrument was specifically chosen to gain insight into the group work experience and to encourage the participants to speak out (Cohen et al., 2011). Moreover, it suits the triangulation of the data required in this study design (Breen, 2006). A focus group study protocol (see Appendix C) with prompts aligned to the research questions was used to guide the discussion. The focus groups were intended to have students of the same discipline from different project groups. However, scheduling difficulties owing to the COVID19 regulations led to having two focus groups with different sets of Psychology students and 2 individual interviews with students from a technical background (see Table 6). The focus groups began with sharing the purpose of the study and seeking informed consent for voluntary participation and audio recordings. The researcher facilitated the space by sharing the questions and asking follow-up questions when needed. The focus groups were for 25 minutes on average.

Table 6

Focus group studies

No.	Role(s)	Week in the module	Length
1	PSY Student 1 PSY Student 2 PSY Student 3	6	33 min
2	PSY Student 4 PSY Student 5	6	29 min
3	IDE Student	7	25 min
4	ATLAS Student	7	35 min

Semi-structured interview

Semi-structured interviews were conducted to elicit the perspectives of the academic staff involved in the module. The dialogic nature yielded well to the purpose of understanding the participants' experience in the module and their views on the challenges and highlights of the module, and on the skills developed by the students throughout the module. The scope of the semi-structured interviews with a broad schedule was developed to be sufficiently open-ended so that the sequence could be reordered, digressions and expansions made, new avenues included, and further probing to be undertaken (Cohen et al., 2013). Concerns about the validity and reliability of interviews have been echoed in research (Bleich & Pekkannen, 2019). Therefore, steps were taken to mitigate these concerns: 1) triangulation of evidence is prioritised to reduce bias and improve validity, 2) all members of the academic staff approached to be interviewed to improve the representativeness, 3) using consistent and neutral wording of the questions for reliability, 4) analysis and inferences to be consulted with supervisors to reduce reporting bias (Cohen et al., 2013).

Before the interview, the aim of the study and information about anonymity and voluntary participation was shared. Further, informed consent was sought to make audio recordings for further analysis. The interviews started with basic questions about demographic information and their role in the module, this was followed by the interview prompts. Broadly, the interview scheme consisted of 10 – 15 questions focused on the experience in the module, and opinions about student collaboration and competency outcomes (see Appendix D). The scheme was modified according to the role of the staff member. Overall, 22 out of the 25 staff members were interviewed across many different roles in sequential order through the

course of the module, as outlined in Table 7. The interviews were on average for 26 minutes and were conducted through video calls on Microsoft Teams or Google Meet platforms.

Table 7

Academic staff interviews

No.	Role(s)	Week in the module	Duration
1	Educational Specialist 1	5	25 min
2	Educational Specialist 2	7	55 min
3	Educational Specialist 3	6	29 min
4	Module coordinator 1 (Challenge Facilitator, Lecturer)	6	48 min
5	Module coordinator 1 (Challenge Facilitator, Lecturer)	11	20 min
6	Module coordinator 2 (Challenge Facilitator, Lecturer)	5	33 min
7	Lecturer 1	5	43 min
8	Lecturer 2	5	24 min
9	Lecturer 3	5	15 min
10	Lecturer 4	5	16 min
11	Lecturer 5	5	20 min
12	Lecturer 6	8	27 min
13	Process tutor 1	11	20 min
14	Process tutor 2	10	17 min
15	Process tutor 3	10	13 min
16	Process tutor 4	10	19 min
17	Process tutor 5	10	19 min
18	Process tutor 6	-	Notes
19	Process tutor 7 (Previously module coordinator)	11	33 min
20	Challenge Facilitator 1	7	55 min
21	Challenge Facilitator 2	7	12 min
22	Challenge Facilitator 3	9	22 min
23	Challenge Provider 1	9	16 min

Observation

To gain an in-depth understanding of the functioning and collaboration within student project teams, qualitative observations were conducted. This took the form of semi-structured non-participant observations in the natural setting (Cohen et al., 2013) i.e., during the weekly project group workspace in the DesignLab. The purpose of the observation was to elicit evidence about the functioning of the student groups and their interactions with the staff for

support. LeCompte and Preissle's (1993) guidelines for directing observations were employed to focus the scope on the team behaviours along with operational details.

Document Analysis

Document analyses were performed on files related to the module, Canvas course, and the Osiris page. Document analysis is defined as a systematic procedure for reviewing and evaluating documents (Bowen, 2009) and is an unobtrusive and efficient method to elicit exact and non-reactive information. The data from these files will be examined to interpret information specifically about the support organised in the module and the intended learning outcomes. In addition, the student groups' project reports were accessed of those who had opted to share their work for educational research through an informed consent form they signed and attached to the final submission. The sections concerning the group process and the team compositions were analysed and formed supplementary evidence about the interdisciplinary collaboration in this module. Six out of the eight groups had consented, out of which only four had the group process report section which was the focus of the analysis.

6. Data Analysis

6.1 Quantitative data

The survey had a response rate of 81.3% and the closed-ended items from the survey are converted to quantitative data by recording the Likert scale and multiple-choice options in SPSS (Ex: 1 = Strongly Disagree, 2 = disagree, 3 = Neutral, 4 = Agree, 5 = Strongly agree). The direction of the labelling was checked to ensure reverse phrased items are not overlooked. Items 6.1 and 6.2 were hence recoded to counter the negative phrasing. Descriptive statistics (mean and SD) for each item were computed according to the disciplinary classification of Applied Sciences and Social Sciences to obtain an overview of the dataset and look for possible differences. Additionally, demographic characteristics (gender and age) were compared and no influence was found.

Factor analysis could not be performed owing to the small sample size. The small sample size of 39 is not comparable with the recommended sample sizes of at least 100 - 300 (Costello & Osborne, 2005; Field, 2009; Tabachnik & Fidell, 2001). In studies with a lower number of samples (<50), it is recommended to have a high number of variables, a low number of factors, and high communalities (de Winter et al., 2009). Communality is the proportion of a variable's variance that can be explained by the factor and therefore, when communalities are low, the corresponding variable does not load significantly on any factor. For this questionnaire with 16 variables, the communalities of the variables ranged between 0.35 and 0.80 with an average of only 0.50. Hence, factor analysis was deemed inapplicable.

Reliability analysis of the original groupings was performed to measure the consistency of the questionnaire (see Table 8). Students' perspectives about the value of the module, and the competencies developed through the module had acceptable reliabilities of 0.76 and 0.79 respectively while, students' perspectives about collaboration had a relatively low reliability of 0.59 (Field, 2013). This is still considered for this study as the rule of thumb used can be extended to accept values as low as 0.5 for measuring psychological constructs (Field, 2013).

Among the responses to the Likert Scale type questions, to ascertain if there were significant differences of opinion between students from Applied Sciences and Social Sciences disciplines, statistical tests had to be performed. Students from the faculties of Engineering Technology, Science and Technology, and Electrical Engineering, Mathematics and Computer Science were classified into Applied Sciences (N=23). Whereas students from the Behavioural and Managerial Sciences faculty were classified under Social Sciences

(N=16) for the sake of this analysis. Towards this, normality of the sample was first tested with the Shapiro Wilk test, which yielded a *p* value less than 0.05, hence the normality assumption was not confirmed. The data is ordinal due to the Likert scaling and was assumed to be independent. The Mann-Whitney test for independent samples was used to compare group means between the Applied Sciences and Social Science data sets.

Table 8

Original groupings in the questionnaire and their reliability

Component	Cronbach's alpha	Likert Scale question
Value of ID	0.76	Benefit in the future
		ID interesting
		Better understanding due to ID
		Real challenge motivating
		Participation in ID again
Collaboration	0.59	Group formation
		Role of other disciplines
		Other's prejudice
		My prejudice
		Broadening of my perspectives
		Use of different language
Competency outcomes	0.79	Communication
		Connecting challenge and prior learning
		Connection to my discipline
		Reflection
		Critical thinking

6.2 Qualitative data

The qualitative data from four sources were of two formats, namely audio recordings from the interview and focus group studies, and text data from the responses to open-ended survey questions, notes from the observation, and the documents. All audio recordings were transcribed using AmberScript transcription service and were further verified manually to ensure accuracy. Thematic analysis was chosen as the approach to analyse the transcripts as the research questions focused on understanding people's experiences and opinions (Braun & Clarke, 2006). Furthermore, it combines the systematic aspect of content analysis along with

the rich and nuanced account within the context (Guest et al., 2014) which is desirable for this study. Braun and Clarke's (2006) phases of thematic analysis were applied, along with recommendations by Nowell et al. (2017) to improve the trustworthiness of the analysis.

The analysis began with familiarizing self with the data, the transcripts were repeatedly read and actively engaged with to become immersed in the data and to actively look for meanings and patterns (Nowell et al., 2017). Reflections about the data and preliminary ideas for coding also based on the literature were documented at this point. An Excel spreadsheet was used to manage the data sources, through a naming system and tracking of the analysis progress. Next, initial codes were generated by identifying significant sections of the text and attaching a label to them with a 'code' corresponding to the interview question. Next, hierarchies were created to group-specific codes together under a category. Analysis software Atlas.ti version 9 was used for this phase to code and create code forests for representing the hierarchical codes. To improve trustworthiness, reflections were documented, and a coding framework was developed to keep track of the codes used and their definitions. This serves as an evidence trail for the credibility of the study (Nowell et al., 2017).

Next, the codes generated were perused to identify themes. Braun and Clarke (2006) emphasize that themes do not emerge from the data but is conceptualized through reflective analysis of the codes. The research questions and their sub-questions along with literature about the focus areas influenced the themes. Phase 4 involved reviewing the themes, wherein the coherence between the themes was checked and discussed with the supervisor. The data was revisited to ensure referential adequacy, ensuring each theme has a grounding in the data (Lincoln & Guba, 1985). The uniqueness and the relation between the themes were further examined in phase 4, the themes are named and defined. This process was followed for data from different sources and participants and the preliminary codes expanded to include nuanced and specific codes relevant to the sources and the research questions. The overarching trends across the themes were mapped and compared to corroborate the findings.

6.3 Interpretation

The qualitative and quantitative findings from various instruments and participants had to be compared across the methodological and the data level. This involves identifying convergence, complementarity, and dissonance among the findings for relevant research questions (Adams et al., 2015). Table 4 in the Instruments section (section 5.2) outlined the alignment between the research questions and the instruments used. The triangulation

protocol developed by Farmer et al. (2008) was employed for triangulating the results from the qualitative data (focus groups, interviews, document analysis, observations) and quantitative data from the survey. This followed the process of sorting the findings by research focus and convergence coding to identify the level of alignment, silence, or disagreement between findings from different sources and methods (Farmer et al., 2008). The quantitative data is specifically from the survey responses of the students, these findings are from a larger sample size as compared to the relatively small sample size in the focus group studies with student participants. However, the focus group studies allowed for a deeper understanding of student perspectives while the survey was kept short to improve the response rate. Hence, the survey data added representativeness while the focus group studies added nuanced understanding through extensive data. Similarly, the triangulation of the findings from the qualitative instruments and integrating these with the findings from the quantitative section where applicable helps to overcome the limitations of the individual methods and paint a holistic picture of the module under examination. The transferability of the findings is aimed for by rooting the interpretation in theory and by providing thick descriptions of the setting.

7. Results

The main findings from the study are discussed below. This section is organized in subsections according to the research questions and the results from the analysis of the data from the various participants and instruments are presented and summarized. Each subsection begins with an overview of the research focus and the corresponding instruments used. For the qualitative data, in keeping with the thematic analysis, the key themes are described, and quotations are used to substantiate the findings. Frequencies are mentioned in parenthesis where applicable to highlight the density of a theme.

7.1 Value of interdisciplinary challenge-based learning

What is the attitude of students and staff towards the module? What are the perceived highlights of this module? What are the perceived difficulties of the module?			
Instrument	Student questionnaire	Teacher interview	Focus groups
Corresponding item	5.1, 5.2, 5.3, 5.4	5, 8, 9, 10, 11, 16	1, 2, 11

Attitude towards ID

Staff

Overall, staff members across the many roles in the module indicated a positive attitude towards ID education. They pointed out several strengths of ID from their perspectives and some cautioned about the possible difficulties and negative effects especially during implementation. The most popular opinions (shown in Table 9) were that ID education is relevant for the future, broadens perspectives of other fields, helps enhance key competencies in students, and fosters learning from other disciplines. Also, the staff observed certain key challenges such as lack of concrete learning, the challenge of differentiation in teaching students from diverse disciplines, balancing support and fostering independence, and group formation and composition. The following quotes represent this conundrum well:

> *"It's way more motivating for students to see and to apply what is learned in real life, because that's what they have to do after graduation as well. So the best thing with is it makes it more relevant for them and they see the purpose of what they are doing."*

> *"I think it also poses new challenges for the educational programmes and the teachers because we all need to get out of our comfort zone. The students also*

need to but…., it is easier to work with other disciplines because they are more eager to share knowledge, as they are less of an expert. "

Table 9

Staff's attitude towards ID education

Attitude towards ID education	Occurrence
Enhances competencies	11
Relevance for future	10
Broadens perspectives	9
Learning and knowledge from other fields	4
Possible lack of concrete learning	3
Importance of group formation and composition	3
Challenging for teachers	3

Students

The students' perceived value towards this interdisciplinary challenge-based module was examined through five Likert scale items, 4.1 – 4.5, and qualitative comments from open-ended item 14 in the student survey. Overall, the statements received rather high agreements among the survey participants (Table 10).

Table 10

Value perceptions according to the students

Faculty	Applied Sciences (n = 23)	Social Sciences (n = 16)	Total (n=39)	Significance of Mann-Whitney test
	mean (±sd)	mean (±sd)	mean (±sd)	*p* value
Benefit in the future	3.74 (± 0.75)	3.38 (± 0.88)	3.59 ± 0.82	0.17
ID interesting	4.17 (± 0.72)	3.81 (± 1.05)	4.03 ± 0.87	0.27
Better understanding due to ID	4.22 (± 0.74)	4.06 (± 0.99)	4.15 ± 0.84	0.72
Real challenge motivating	4.09 (± 0.51)	**4.46 (± 1.06)**	4.24 ± 0.79	0.01*
Participation in ID again	4.26 (± 0.62)	4.07 (± 1.10)	4.18 ± 0.83	0.85

1 (Strongly disagree), 2 (disagree), 3 (Neutral), 4 (Agree), 5 (Strongly agree)

Note. $*p < 0.05$. Significantly higher score is highlited in bold.

The statement about improvement in motivation due to the inclusion of a real-world challenge was most positively regarded which is aligned to findings from the staff as well. It is interesting to note that the staff had highly regarded the relevance of ID for the future which

received an almost neutral response from the students. Furthermore, the results of the Mann-Whitney test for comparing the means of Applied Science and Social Science disciplines per item are also outlined in the table. The results indicated that there was a significant difference between the two groups only for the item concerning the motivation of real challenges. The students from Social Science disciplines were more motivated by the real-life challenges than the students from Applied Sciences.

Highlights of this module

Staff

The module coordinators implemented the changes in the module this year concerning the integration of challenge-based learning (See section 3.2). On the purpose of this change, they viewed it as a natural next step for this minor and remarked that this has increased the freedom for student groups to define the challenge and the involvement of the challenge providers. One coordinator added that,

> *"(CBL) it's in line with the interdisciplinary nature of the minor, it fits with a lot with what we had in mind already. For example, we had project-based learning where the students were able to define and redefine the problem. And challenge-based learning comes with this amazing idea that says, well, the challenge is fully defined by the students. Keeping in mind that we have students from eight or nine different programs able to define the problem, the challenge is based on their expertise. What challenge-based learning does, actually works pretty good for an interdisciplinary minor. So, it's not so much of a forced change. It was more of an evolution, I would say."*

The educational specialist who supported the design of the course noted that the organization of the course by the module coordinator as a highlight. Also, the rigour of the learning objectives and the availability of support were highlighted. The challenge facilitators (n=3), who worked as a liaison between the student groups and the challenge providers, shed light on the usefulness of this module for the providers. One of them shared how this experience could be useful for the students to get insight into real-world domains and hoped that the staff appreciated the interaction as well. The following comment about the added value for challenge providers exemplifies this aspect well:

"The other thing is the companies can get a glimpse of what design thinking is about, what multidisciplinary challenges is all about and hopefully will get new insights about the innovations they want to achieve."

The sole challenge provider interviewed also resonated with this and mentioned that the interdisciplinary approach to the challenge was valued. In addition, they appreciated the organisation and support from the challenge facilitator through the course of the module. The process tutors (n=7) pointed out the highlights from their perspective of supporting the students through the process of developing the prototype in this challenge-based module. The exposure to real-world problems with the challenge provider and working with students from other disciplines was shared as a strength in this module. Also, the scheduled moments for support such as the out of comfort zone week and the presentations were appreciated as a highlight of this module. The following comments from the tutors are examples of these,

On real challenge experience:
"I think having the challenge provider was very nice because they (students) got to interact with the real-life company or a real-life case. Normally if I look at my own courses, for instance the challenges and assignments that I provide are things that come from me. So they don't necessarily have this interaction with the world and get to develop this idea of stakeholders and that, I think it's a very good experience. The interdisciplinary team is again a huge strength. So being able to work with people from different fields and get to know how to speak to people from different fields."

About the out of comfort zone week:
"I very much like out of comfort zone week. I think that's a great idea to give students the experience of being the one that sets the assignment. They then understand what goes into setting an assignment, I think that it fits the challenge-based learning well… That was also a scheduled moment for them to involve other resources."

Students

Students (n=4) appreciated the opportunity to work together with other students from different study programmes in this module. Secondly, students (n= 3) mentioned that the difference between this module and the others they had taken before was the inclusion of a real challenge and client. This is in line with the staff's perspectives of the challenge provider being a highlight. They noted this as a motivating factor because the solution could hopefully be used in real life by their target clientele. The following comment by a student explains this aspect well:

> *"(In previous projects) I often had the feeling that we are working several weeks on one problem and then we come up with a solution. But like nobody cares about the solution because it's just on your paper and you get a grade and that's nice, but that's it. And with the (challenge provider), we can actually do something that they can use. So, you are more motivated to work because, you know, they really want to use it."*

Furthermore, it was pointed out that this module will help them in the future as working on the challenge and working with people from other fields aligns to the real-world context.

Difficulties of this module

Staff

The lecturers' (n=7) involvement was found to be limited to the lecture or workshop facilitated by them. Most of them shared that they did not have insight into the whole module and the work of the student groups (n=6). Although lack of time was mentioned as a reason for this (n=3), willingness to be more involved was also a common trend (n=4). Lecturers' responses about the design of the module shed light upon their perspectives about the position of their lectures/workshops within the module. Uncertainties about the integration of their lecture within the organization of the module and alignment to the assessment were also raised (n=7). An example of a lecturer's comment about this is:

> *"(Students might think) 'oh, I don't know why is he saying this for our project right now, at this moment in this way?' Because they sort of feel that I don't know either."*

This concern is further echoed by the module coordinators (n=2) who pointed out difficulties from their overarching perspective such as, alignment of learning objectives with

the lectures and the assessment components. Specifically, the dilemma of having the module focused on developing a prototype but having the learning objectives mainly rooted in collaboration and other ID skills was brought up. Secondly, recruiting and preparing the right challenges was unanimously mentioned as a weakness right now. The support from NovelT was appreciated and it was suggested that challenges had to be recruited in advance so they may be selective and set the expectations with the providers adequately to avoid problems. This sentiment about the need to quality check the challenges recruited for the module was also echoed by an educational specialist interviewed. The following comment from an interviewee explains the resulting difficulty well:

> *"One thing that definitely needs to be improved is how to involve the challenge providers more into their group composition and the assignment of the challenges, because we had a lot of complaints this year that said "well, the student profiles are not what I would like to have for my challenge", and we're like, "yeah, but when we asked you what kind of students you want, you didn't say anything." So that was a miscommunication between us and them."* (Module coordinator)

Challenge facilitators also pointed out that the fit of the student representation with the challenge provider (n = 2) was amiss in certain groups. They attributed this to cultural differences and lack of local knowledge among international students. The following remark by a challenge facilitator explains this aspect well:

> *"I think one group has more problems with understanding how society works. So especially with this challenge, it's not technical. It has a lot of social aspects on it, and that's very hard to grasp if you're not from the Netherlands, because it's a different country."*

Lastly, lack of access to specific learning resources was brought up by challenge facilitators and module coordinators (n=4). They shared that although the challenge is open-ended, the solutions are restricted to the disciplinary expertises available within the groups. Specifically, when a group's prototype in this module requires knowledge and skills that the group does not possess, it might get difficult to be able to implement that in the next module due to their lack of expertise. For example, one interviewee said:

> *"They have cases that really require many different type of inputs. That we don't have that available. And I don't know, I think the main handicap basically is that*

we don't have that many resources to offer. So there is no money, there are no software or, you know, devices."

Suggestions such as providing on-demand workshops through NovelT and bringing in practically trained students from Saxion were raised along with acknowledgement of logistical limitations. Process tutors (n=6) shared that difficulties in the module were around the clarity of expectations, pandemic regulations leading to reduced interaction, and students being prepared for CBL. These aspects are further elaborated on in the next sub-section (Section 7.2).

Students

In the focus groups, students unanimously echoed that working with students from other disciplines was difficult at first in this module. This is further explained in the subsection on ID collaboration (see section 7.3). Students (n=4) also resonated about the lack of alignment of the lectures to the work they engaged in. In addition, students (n=3) found the minimal structure in the module, especially concerning feedback and accountability difficult. This is further elaborated in the next subsection (see section 7.2).

7.2 Support for interdisciplinary education

What are the enabling and limiting factors of support for interdisciplinary education?			
Instrument	Student questionnaire	Teacher interview	Focus groups
Corresponding item	10, 11, 12	6, 7, 8	3, 4

Support for staff

The module coordinators shared that the tutors received one workshop facilitated by a CBL expert from CELT and a module coordinator noted that process tutors "*mostly had prior tutoring experience and a somewhat limited role this year*." The lecturers were found to receive the least support limited to communication about the schedules. Regarding support for organizing this module, the CELT team's support in the design stage, and NovelT partners support with the recruitment and engagement of external challenge providers were recognized by the module coordinators. The educational specialists from CELT also added that discussions were facilitated with another lecturer who had incorporated CBL within their module. They further emphasized the importance of the tutor role in guiding without steering too much and *"giving away the answers"*. Although leaving the expert role and taking on a coach role is possibly difficult for the staff, it was said to be crucial by the educational specialists and was emphasized in the workshop for process tutors. Lastly, the need for

professional support for facilitating interdisciplinary education for all staff members to guide CBL and foster integration in the groups was shared by the coordinators and specialists (n=3).

The lecturers' (n=7) mentioned that they were in contact with the module coordinator only and updated their content before the lecture/workshop. In terms of support, they (n=4) mentioned that it was minimal and confined to coordination and information sharing but expressed general satisfaction with it. Through the course of the interviews, a few of the lecturers (n=3) pondered about and suggested that staff meetings in the beginning and end of the module can enable collaborative planning and help solve the lack of interaction between the staff. This is best supported by the following quote from a lecturer who highlighted the need for interdisciplinary staff collaboration:

> *"That's (meeting) also the interdisciplinary thing because you can't just go into this. Because teachers too should definitely speak each other's language]. So that kind of stuff is not really happening."*

The challenge facilitators (n=3) also remarked that they were satisfied with the communication with the module coordinator for support. Besides, one of the facilitators added that they would have liked to join the workshops and lectures to be informed about what the students were learning and emphasized the importance of alignment of expectations among the different actors. Another facilitator remarked that some of the workshops could be offered for the facilitators and providers along with the students.

The process tutors were also happy with the communication with the module coordinator and the CBL workshop at the beginning of the module. As mentioned in the previous subsection, they pointed out that the expectations from their role were not completely clear. For instance, they shared their dilemmas about drawing the line between the process and the content, and difficulty in balancing the right amount of support for the students. Moreover, the COVID19 pandemic regulations led to reduced opportunities for interaction within the group and with the tutor (n=4). In addition, role clarity was brought up, tutors (n=3) shared that their groups were not aware of the different support roles in the module at first and had to be prompted to initiate meetings. This is supplemented by an announcement on Canvas in the second week of the module by the coordinator encouraging students to meet with their process tutors.

Support for students

Staff's perspectives. The module coordinators (n=2) mentioned that the change in structure to include industry facing challenge facilitators was said to add *"valuable experience of the real world"* as all the other staff members were from the academic domain. Module coordinators (n=2) and challenge facilitators (n=3) emphasized the importance of the partnership between the student groups and the challenge providers who were involved a lot more this year and served as content expertise as well. The tutors were specifically chosen from Ph.D. candidates or assistant professors as they were thought to be more experienced in tutoring and familiar with project management. Their role was to oversee the group's work and collaboration. However, it was also noted that the role of the tutor is changing as other staff are becoming more active and relevant.

The process tutors shared that their role in supporting students was focused on sharing feedback on updates (n=4), guiding the design process (n=4), brainstorming ideas (n=2), encouraging disciplinary integration (n=2), encouraging morale (n=1), and clarifying expectations (n=1). Few of the tutors shared that they felt they were not needed as much and the meetings with the teams were sparse (n=2) while others mostly had weekly meetings (n=5). Also, tutors pointed out that the students struggled with understanding what was expected from them. It was also shared that there was a gap between the intention and the practice in the module specifically in terms of the freedom for the students to design their learning. They suggested that students could be better prepared for this jump to challenge-based learning module as they are used to getting more guidance in their previous modules. The following comment from a tutor is a good representation of this aspect:

> *"(In the CBL workshop) it was mentioned that students would bring in their own criteria for assessment or that they would be the ones that decide they have met the objectives and found a way to show that. When I got into conversation with the students, they were very much looking towards me to tell them that."*

These tutors suggested that providing students and tutors examples of previous groups' work and trajectory in this module could help them understand the breadth of the freedom to design and ways to support in CBL, respectively. The challenge facilitators (n=3) shared that they saw their role as the intermediary contact point between the challenge provider and the students, guiding students through the process, and managing expectations and supporting the provider. All the lecturers (n=7) mentioned the constraints of online learning due to COVID-19. While some (n=3) attributed this to reduced attendance and

engagement in the online lectures, others (n=2) said they were satisfied with the engagement and response from the students despite the online version not being ideal. Lastly, the lack of resources and non-alignment of lectures to the students' work as mentioned previously are other factors that were pointed as potentially influencing the support students received.

Overall, the module was said to work on the principle of student-driven learning, wherein the onus of accessing and using the available support options lies with the students with very little structured support. Talking about this an interviewee said:

> *"In this initial part, they need seamless support so that you not like a parent, it's like you're not normative and point fingers……But I was not going to tell them what to do, but they were coming to me to discuss it. And that's what we want to cultivate, that they come to you with questions…. So I think this aligns well with the role of teachers in CBL, that you just need to be there to support students from the background and let the students experiment, let them go nuts, let them explore their limitations."*

Interviewees (n=4) across different roles added that while some students appreciate this openness, some others struggle and get confused by the number of people involved. In addition, an educational specialist interviewed remarked that students need support to build their CBL skills in the beginning and that this will enable them to become self-starters for the rest of the module

Students' perspectives. The students' perspectives of the support they received in this module were captured through the survey and focus group studies and are presented below.
Survey. Among the students who participated in the survey, 77% regarded the support they received as adequate or more based on responses to item 11 from the survey which concerned the overall quality of support. Moreover, 56% positively regarded the remote learning experience in this module due to COVID19 regulations based on responses to item 15 (see Table 11).

Table 11

Student perspectives of overall support and remote learning experience

Item	Mean (±sd)	Inadequate	Needs improvement	Neutral	Adequate	Very good
Overall Support	3.94 (±0.97)	-	12.8%	10.2%	46.3%	30.7%
Item	**Mean (±sd)**	**Highly negative**	**Negative**	**Neutral**	**Positive**	**Highly positive**
Remote Learning experience	3.51 (±0.97)	-	15.3%	38%	26%	18.7%

Note. N = 39

Items 10.1 – 10.5 provided information about the students' perceptions of the different options for support (as shown in Table 12). The responses to the latter set of items showed that the challenge providers and facilitators were the most supportive for the student groups (in bold), while other groups, and lectures & workshops are the least utilized forms of support. Lastly, the students were also asked to rate the remote learning and working experience in this module and a little more than half of the students regarded it as positive.

Table 12

Students' ratings of the different support options

Source of support	N	Mean (±SD)
Process Tutor	39	2.85 (±0.93)
Challenge facilitator	39	**3.23** (±0.84)
Module coordinator	36	2.76 (±1.16)
Lectures & workshops	39	1.92 (±0.87)
Challenge Provider	39	**3.28** (±0.76)
Other groups	38	1.84 (±1.01)

1 (Very little support), 2 (Neutral), 3 (Moderate support), 4 (Major support)

Note. The highest scores are in bold. Total N = 39.

Furthermore, qualitative comments from the survey also add to the understanding of enabling and limiting aspects of support according to the students. Regarding the enabling aspects of support, students (n=6) appreciated the multiple available options for support in the

module and were satisfied with the support they received. On the other hand, in terms of the limiting aspects of support, four large themes emerged from the codes. Firstly, clarity of expectations specifically in terms of the project report and the roles of the support staff in the module was pointed out as an aspect that could have been better. Secondly, the need for more structured interaction was a recurring theme pertaining to more; lectures for content support, feedback moments, time at the DesignLab, and with other groups. Students acknowledged the COVID regulations and shared their difficulties with online work and collaboration and suggested more structure to the module with possibilities to interact with other groups and each other to stay on track. The following comment from the survey response is a good representation of this:

> *"More lectures/planning and structure of the module (would be good). Especially with corona measures, it's difficult to keep track and to know in what stage of the module we are. It's easier to stay motivated when there is more interaction with other students/groups and lectures."*

Lastly, support for effective group work was found to be a theme. Specifically, students (n=4) shared that the group composition in terms of balancing the disciplines and aligning them to the challenge was crucial. Regarding the group formation, students (n=3) acknowledged that the online version made the process more difficult and pointed it out as an area of improvement. In addition, a student remarked that more guidance for group collaboration would be a valuable improvement.

Focus group study. During the discussion about the support provided in this module, students (n=3) appreciated the availability and accessibility of the support of staff and external partners in various capacities through involvement in their projects. It was clear that the groups had different primary sources of support among the process tutor, challenge facilitator, challenge provider, and the module coordinator. Discussions with the coordinator during Friday DesignLab meetings were highlighted as being useful for clarification by students (n=2). Specifically, the involvement of the challenge provider was indicated to be a highlight, and participants (n=2) shared instances of the challenge provider sharing information and resources.

A recurrent topic of discussion among the students (n=7) was about the lectures. While some students (n=2) found some of the lectures useful for their challenge, others (n=4)

mentioned that the content of the lectures was redundant as they had already learnt them in their study programmes. A student aptly pointed out that,

> *"Lectures and workshops should provide a good foundation, I guess, for every group. So, every project group has to select the lectures that are a little different for each project individually."*

Three types of perspectives capture this problem, represented by these quotes from students from different project groups, namely:

a) not seeing the purpose of the lectures as it was not connected to their project:
"*Some of the lectures were very unconnected and in my opinion, a bit useless…. For example, we had a four-hour statistics lecture where I don't know, I do not really see any value in the project because we didn't have to do anything with statistics. So I went afterwards wondering why I was listening to that. I just think some of the lectures, it was not really clear how it is connected to the project, but maybe I just didn't get it. Maybe they can just make it more clear. But I also felt like they taught us something, but it never showed up in the project."*

b) not seeing the purpose as the students from the other disciplines in the group possessed the knowledge and were able to share:
"I did not feel that any of them were very useful for our project. But we also have three industrial design students who know a lot about the whole design process. So, I think maybe we did not have to all gain from the lecture because they already knew everything and just did it or explained it to us."

c) acknowledging that it helps level the knowledge gaps among the disciplines involved:
"I just remember the behavioural change lecture we have for psychology students in our group, so we don't really need that lecture. But the other students came from technical background, and it was very useful to them because we apply the behavioural change mechanism. So it was very useful for them to have a basic understanding and then we were able to build on that."

The turnout in the lectures being very low was brought up by the participants (n=2), one of them expressed that it was demotivating for both the teachers and the students present.

Another student suggested short, targeted lectures that were related to the challenges along with the general lectures can be useful and encourage student participation. Support in the form of guidance and feedback was opined to be inadequate among the students (n=3). They specifically pointed out that the lack of structure within the module for project activities and tasks apart from the mid-term and final presentations, left them confused and yearning for clarity at many moments. An example of this dilemma is this conversation from a focus group.

> Student A: *"We are very free in our structure. On the one hand, I like it because in this way you can learn from the other disciplines because we have to discuss. But, I think it makes it very difficult….. But in the last modules we've always had this kind of I was it called module manual where you have like these steps. This week you were going to write that and next week you should hand in that. Now there are no like deliverables in between everything. So, you just have to come up with the whole part in the end."*
>
> *Student B: "I also think because we aren't getting much feedback and yet in the end, it's the report that counts."*

Another student suggested that cohesion in the form of interaction with other groups could serve as ongoing feedback and formative moments that could help them learn from each other and stay on track. Thirdly, several students (n=4) indicated that the non-alignment of expectations between the various stakeholders was a struggle their group faced. While one student shared an example of, challenge providers already having a premeditated direction for the solution, two others from different groups mentioned the language barriers with the challenge provider. Moreover, misalignment about expectations between challenge facilitator, process tutor, and coordinator was also shared by students of one group.

Document analysis. The module manual accessed through the Canvas course of the module showed three aspects of support for students: facilities, supporting roles, and deliverables. The DesignLab facility was the intended foundation for this module with its spaces and resources available. Besides, the larger UT community is mentioned as an available resource for students to access as needed. However, it is important to note that access to both facilities was limited by the COVID19 pandemic regulations. Role descriptions and advice for contact and collaboration for the different actors in the module (challenge facilitator, module coordinator, challenge provider, lecturer, process tutor, and project group) are explained. The learning objectives, activities, and assessment methods were briefly

specified on the Osiris page of the module and the objectives and assessment methods were further explained in the module manual and the Canvas course along with the timeline of the module.

Information about the learning activities could be found in the course schedule on the Rooster and all session material including video recordings were made available on the Canvas page. The motivation letter, assignment proposal, mid-term presentation, and the final presentation were the graded deliverables in this module. Also, regarding the assessment methods, there was supplementary material in the form of evaluation criteria and rubrics for the formative and summative assessment components. The Canvas announcements feature seems to be the primary mode of communication in this module, information necessary for the lectures, weekly updates for three of the ten weeks, logistical and safety information for DesignLab use, and information about the deliverables were shared here. Among all the announcements, three of them seem to be reactive to reset expectations and/or prompt students towards available support structures within the module. These are regarding encouraging meetings with process tutors, attendance in lectures, and referring to the rubrics available for the assignments.

Problems with alignment of the learning objectives, learning activities, and assessment became evident in the analysis of the module as well. The structured learning activities within the module were the lectures, workshops, and mid-term presentations. The focus primarily seems to be on the learning objectives two and three concerning the process to develop and evaluate the prototype solution for the challenge. There was only a workshop each focused on the first (communication and collaboration) and second (reflection) learning objectives. Overall, there is limited evidence of support through learning activities and feedback for developing the collaboration and reflection in the student groups. In addition, although the first learning objective (communication and collaboration) was to be evaluated in the final presentation, the rubric shows no alignment to this objective.

Observation. The project group workspaces at the DesignLab were scheduled for every Friday, wherein groups A, B, C, and E could choose to be present in the morning, and groups D, F, G, and H could use the space in the afternoon optionally. The observation notes showed three themes relevant to support namely, use of space, interaction with staff, and inter-group interaction. Firstly, on average two groups were present in each session (morning and afternoon) across the five weeks of observations. While some groups were present every week until the COVID19 pandemic regulations became stricter in the fifth week of the module, others were intermittently present with some or all group members. Secondly, these

project workspaces were available for all the staff members involved as well to interact with their respective student groups. It was observed that the module coordinator who was also the challenge facilitator for two of the eight groups was present and interacted with all students. The students shared updates and asked questions specific to their project or in general about the module with the coordinator. In addition, two challenge facilitators and one challenge provider were also observed engaging with their student groups in this DesignLab space. Lastly, during the observations, it was noted that there was minimal interaction between the different groups present except for the week before and after the out of comfort zone week. During this time, the paired groups discussed clarifications in the task descriptions and outputs from the out of comfort zone week together.

Summary

Overall, support for the staff members differed according to their role in the module. Staff were satisfied with the organisation and communication aspect within the module and expressed their interest to be more involved. Lecturers suggested teacher collaboration towards integrating the learning activities towards the outcomes and assessment. Challenge Facilitators shared their interest to join the lectures and workshops to be aware of the educational aspects. Process tutors shared that they would like more clarity on their role and expectations for guiding the student groups. Module coordinators suggested that professional support for guiding ID education would be beneficial for all.

Regarding enabling factors of support for students, the multiple options for support in this module were appreciated. Students were largely positive towards the support they received. Planned support was in the form of content support from lectures/workshops and challenge providers, supervisory support from process tutors and challenge facilitators, infrastructural support in the form of Canvas for online education, DesignLab for in-person Friday meetings, and Arduino kits for programming. All participants specifically pointed out the involvement of the challenge provider to provide contextual support for the challenge at hand as an enabling factor. Besides, the group members supported each other to navigate this ID module. On the other hand, the limiting factors of support had an overarching trend among the data from the different participants and instruments about the incoherence between the learning objectives and learning activities in the module. Next, the minimal structure through the module can be regarded as a limiting factor of support.

Also, the staff pointed out the lack of material and challenge specific resources in the module as a possible hindrance. While students brought up aspects around lack of interaction with other groups, struggles with group formation and finding the ideal composition, and

suggested additional support for group work. It is interesting to note that although the structured interactions were minimal, process tutors (n=3) added that student groups did not make use of their optional meetings regularly. It is important to note that the ongoing COVID19 pandemic and the resulting regulations played a factor in the online learning design and hence, reduced interaction.

7.3 Interdisciplinary Collaboration

How do interdisciplinary groups collaborate?			
Instrument	Student questionnaire	Teacher interview	Focus groups
Corresponding item	6, 7.1, 7.2, 7.3, 7.4, 7.5, 7,6, 8, 9	17, 18	5, 6, 7, 8, 9, 10, 11

Staff

The interviewees in the roles of module coordinators, challenge facilitators, and process tutors shared insight into how the teams collaborated in this module and what influences this collaboration. Trends that came up were centred on the unequal contribution from the disciplines (n = 8), different levels of integration (n=5), differences in perspectives among the disciplines leading to tension (n=4), reduced interaction due to online learning (n=3), and prejudice about other disciplines (n=2) especially not seeing importance of non-technical disciplines. The following quotes from the staff exemplify these findings well.

On the unequal distribution of work:

"I think for the psychology students are really doing well and know what to do and have things that they feel comfortable with. But the other two, I think that they until now have the feeling that they really can't bring anything from their discipline. Because I think it's much more about psychology, so they feel a bit left out or underused basically"

On a low level of integration:

"They kind of have two camps now and it's very difficult to really get those integrated because they say, 'Well, I'm working on this and you are working on this. And if you just do that and I just do this and we get together and then it's fine'…. they actually kind of split up the assignment in a technical part and a social part."

On a high level of integration

"After some time…. you see the engineer talking using psychology terms, you see the psychology student talking, using engineering terms."

On difference in perspectives:

"So, psychology and other social science students are confronted with engineers with a different mindset and different way of thinking and solving issues and vice versa."

On reduced interaction:

"Because of the online education….students are not sitting as much together... I think it's really about sitting together and having a look at someone else and seeing that person working with SolidWorks or something when you have never seen it….(and you try and realize its use and you can do it too.)"

On stereotyping and prejudice:

"They will have some prejudices, some stereotypical expectations of what a typical social scientist can't do or will do, vice versa. I hope that to some degree, those stereotypes will be…nuanced a bit more so that they will become more positive attitude towards the other disciplines and discover that they also know useful stuff that."

Students

Student perspectives about the interdisciplinary collaboration within their groups were studied through the survey, focus group studies, and document analysis of the project report and is presented below.

Survey. The survey had one question with multiple checkboxes (item 6), five Likert scale type questions (items 7.1-7.5), and two open-ended questions (items 8, 9) regarding the collaboration within the ID teams. In terms of the nature of teamwork within the groups, multiple forms were adopted (Table 13) with 'dividing tasks based on expertise' being the most popular one.

Table 13

Nature of collaboration in the ID groups

Nature of collaboration	Percentage
We divided the tasks based on our expertise	87%
We formed sub-groups to tackle the challenge	77%
We worked on tasks individually and coordinated our work in the meetings	46%
We engaged in group work most of the time and shared our expertise	36%
Students of certain disciplines had more or less work in our project	28%
We all had an equal role in the project	26%

Next, the responses to the Likert scale questions measure the collaboration aspects. The responses were analyzed according to the disciplinary groupings of Applied Sciences and Social Sciences students to identify potential differences (table 14). The ratings were almost identical across the two groups for most statements, Mann-Whitney test confirmed that the differences were insignificant. Students were mostly neutral towards the way the groups were formed. There is an overall agreement in terms of recognizing the role of students from other programmes in the project. On the other hand, students claim relatively little to no prejudice towards students from other disciplines. Overall, students somewhat agree to having broadened their perspectives about other disciplines and being aware of language differences among the disciplines.

Table 14

Student perspectives about collaboration.

Faculty	Applied Sciences (n= 23)	Social Sciences (n= 16)	Total (n=39)	Significance of Mann-Whitney test
	mean (±sd)	mean (±sd)	mean (±sd)	*p* value
Group formation	3.30 (± 1.18)	3.12 (± 0.96)	3.23 (± 1.81)	0.64
Role of other disciplines	4.00 (± 0.43)	4.12 (± 0.62)	4.05 (± 0.51)	0.43
Other's prejudice	3.26 (± 1.18)	2.87 (± 1.20)	3.01 (± 1.19)	0.32
My prejudice	3.00 (± 0.95)	3.44 (± 1.15)	3.18 (± 1.05)	0.16
Broadening of perspectives	3.82 (± 0.71)	4.00 (± 0.76)	3.89 (± 0.73)	0.37
Use of different language	3.52 (± 1.08)	3.87 (± 0.80)	3.67 (± 0.99)	0.35

1 (Strongly disagree), 2 (disagree), 3 (Neutral), 4 (Agree), 5 (Strongly agree)

The qualitative comments from the survey add to these findings about collaboration. In terms of positive examples of working in the ID group, widening of the scope of the project and learning were two themes that emerged. The former corresponds to comments (n=14) about improving the depth of understanding the challenge from diverse perspectives and realizing the value of the different disciplines. The following comments are a good representation of this:

> *"Tackling both technical and social challenges and combining both."*

> *"We can have different points of view. Therefore, we can discuss different approaches to the problem and decided which one should be the best."*

> *"Understanding of psychology and its impact to how people's behavior and perception can impact the feasibility of an engineering project"*

The latter, the theme of 'learning' had comments about new learning about other disciplines, ideas generated through brainstorming with other disciplines, recalling and applying old learning, and skills developed through working in an ID team. This is further elaborated in the next subsection (See section 7.4).

Examples of negative experiences in group work were along the themes of disciplinary differences (n=8), misunderstanding (n=8), problems with dividing responsibilities (n=5), difficulties with decision making (n=5), and communication problems (n=4). The following quotes are comments from students that are representative of these themes:

> Disciplinary differences: *"We have a different way of starting the research process. The more technical disciplines started already with the design when we did not even have the problem analysis complete"*

> Misunderstanding: *"We had a disagreement when someone wrote in the midterm presentation that psychology students know a lot about the design process, as an example of a strength that psychology students have. I feel quite insulted when someone else from a quite unrelated study claims to know a lot about the topic that I study, when I know they don't."*

> Dividing responsibilities: *"some people had more to do and I felt useless."*

Decision making: *"We didn't work always together and sometimes decisions were made that not everyone was aware of."*

Communication: *"Words mean different things sometimes, which can lead to confusion"*

Focus group study. The analysis of the focus group discussions adds on to and align with the findings from the survey. Prominent aspects that emerged from the analyses were communication, decision making, division of responsibility, integration of the disciplines, and the impact of the pandemic regulations. In terms of communication, a notable feature that was mentioned by the students (n=7) was that open communication was adopted in the group so that everyone is on the same page. A good representation of this was the following comment by a student:

"(Explains an instance of a difference of opinion), but as long as you keep listening to each other, you try to understand the perspectives of the others. It's quite helpful."

Another feature of communication that was echoed among the students (n=3) was regarding language. Students pointed out the differences in disciplines made it harder to communicate at times as they had to explain what they mean, and the terminology to students of other disciplines. A student reflected on this and said,

"Sometimes, if we have a certain idea, it's hard for others sometimes to understand what you mean with it. So, the other Industrial Design students understand but like a Computer Science student doesn't understand what exactly you mean. And it's difficult to explain what you mean and then have some kind of discussion and then try to figure out."

Regarding the project work, decision making, division of responsibilities, and disciplinary integration were the themes that stood out. The first two are closely related and all students attributed decisions as being made democratically and discussed during meetings. A recurring topic that students (n=6) pointed out was, the differences in perspectives and focus areas among the group members from different disciplines. They attributed this to creating the need for open communication (as mentioned above) during decision-making

processes and to build trust. The following quotes by students are representative of this aspect.

On different approaches:

"We all have different approaches and for example, like the psychology students' approach is more like scientific. So, you start with working on your theory and you start working on the analysis of the problem…. The engineering students' approach is more practical, they wanted to start right at the beginning with the prototyping and everything."

On different focus areas and trust:

"It's sometimes it's really difficult to get to agree on what's important because everyone puts a different emphasis on it because we are really developing a prototype….. you have to trust your other group members even more because they have to apply the knowledge that you don't have and you can't check."

Furthermore, students (n=3) mentioned that frequent in-person meetings were very effective for their group to stay motivated and clarify communication. The division of responsibility was mostly based on disciplinary expertise as reported by all the students (n=7) but is also said to be influenced by other factors like availability and personal choice. However, some students (n=3) added that although tasks were divided, they always shared the updates and discussed everything together in the meetings, so they all were on the same page. This excerpt from a conversation from a focus group shows this aspect well.

Student A:" Since the beginning, we're trying to make our solutions, arguments so everybody pose their arguments on certain decisions and then we try to find similarities and to convince the others by our arguments and I guess it worked out quite well.

Student B: "Yeah, I think you also just talk everything out so it does take a bit longer, but then we all know that we are on the same page and so everyone has reached that point and said what they felt is needed."

Hence, disciplinary integration can be seen as the outcome of these discussions about decision making and division of responsibilities. A student explained how they started with psychology to understand their target population and their needs and included these findings

in the design interface. Another student attributed this form of integration as one of the biggest highlights of this module and added that:

> *"It's kind of nice that it all comes together after some time. So you start with an idea or with different perspectives. And when, like time has passed, it kind of the idea gets better and feature all the perspectives."*

This aspect of starting with differences and the development of integration and cohesion was a recurring trend (n=4). The following is a conversation between two students who discussed this:

> *Student A: "We didn't know each other well. So we now know each other's background and weaknesses, individually and from the studies, so we know how to to go by a task. So you can talk about it."*
> *Student B: "I agree and that it's a lot more easy to predict what the others would want to do. So you can already adapt a little bit.."*

Overall, the students echoed the opinion that although group work in the ID teams was more difficult at the start, they are getting better at understanding how to manoeuvre this novel way of collaboration.

Document analyses. The analyses of the project reports brought out some of the same themes as above and a few unique ones. Firstly, groups (n=4) recognize the disciplinary inputs from the students of different programmes and appreciate their contributions to the whole. An example of this is the following text from a report:

> *"The group has the opportunity to analyse the needs of all stakeholders and implement those into a technical solution to solve the given challenge. Consequently, the report gains in terms of professionality and coherence due to the combination of different theoretical knowledge on how to report the development of a prototype."*

Secondly, all reports discussed the division of responsibilities among the group members from the different programmes. Largely, tasks were divided based on disciplinary expertise, and psychology students primarily contributed towards connecting to the theoretical background and scientific writing while students from engineering disciplines were said to contribute to the technical aspects of the prototype. Regarding the integration of the

disciplines, the reports showed that attempts at integrating disciplinary insights were done after individual or sub-group tasks were performed to consolidate the different elements of the prototype. For example, the following are excerpts from two group reports.

> *Group X: "Finally, around the seventh week of the module, when the prevention and correction part were largely finished, more communication between the members was visible as they decided to start working on the user interface and campaign. Due to that, the group had more frequent online meetings on Teams to discuss each other's needs for the joined parts and also to gather some ideas."*

> *Group Y: "One psychologist and the industrial design student did the usability tests together, so that both have learned from each other to some extent. The latter learned more about a psychological usability test and a think-aloud protocol due to the observation of the psychology student, who conducted the test. Further, the psychology student was able to broaden their technical skills on how to develop a prototype and share it online and they were able to observe a part of the usability test that was more design and function-oriented. This enabled both students to switch perspectives and to be open for new styles of interviews and usability testing."*

Thirdly, a trend among the reports analysed was, learning resulting from the collaboration in this module. The varying perspectives and insights from the different disciplines were acknowledged as bringing about opportunities for new learning and deepening prior knowledge. The following comment from a group's report shows this aspect well.

> *"Together, as a team, there were a lot of discussions with different types of viewpoints due to the various disciplines. These discussions enabled everybody to have minimal basic knowledge of each other's disciplines and corresponding skills."*

Lastly, all the group reports examined (n=4) mentioned the various staff members involved as primary support for their group's work. Specifically, support from the challenge facilitators, challenge providers, and tutors was acknowledged. Each group seems to have gained different aspects from the stakeholders such as content knowledge, information about the target group, and feedback on the design process and report.

Summary

Overall, among the data obtained from different participants and instruments, there was consensus about the nature of collaboration largely being driven by dividing tasks within the ID group based on disciplinary expertise. It was also unanimously noted that the contribution to the project varied among the disciplines involved in a team. Next, the aspect of differing perspectives across the disciplines and some prejudice about students of other disciplines was shared by both teachers and students. Within the data collected from students through the survey, focus group study and the documents show alignment about the learning that came through collaborating, communication struggles among students of different disciplines, and difficulties in making decisions as a team.

7.4 Competency outcomes

What are the anticipated competency outcomes? What are the perceived competency outcomes?				
Instrument	Student questionnaire	Teacher interview	Focus groups	Documents
Corresponding item	13, 14	12, 13	2, 3	Module manual

The competency outcomes of this module are organized into the anticipated outcomes and the perceived outcomes. The anticipated outcomes were determined by analyzing the module documents and the interviews with the lecturers as they did not interact with the student groups and had no insight into the actual outcomes. Their inputs were based on their understanding and expectations from ID education. On the other hand, the perceived outcomes were ascertained through the data from the students, other staff members who were involved in student supervision, and the analysis of the project reports.

Anticipated competency outcomes

Staff. According to the interviewed lecturer's opinions (Table 14), the potential skills students could develop through this module are perspective taking (n=5), communication (n=2), collaboration (n=2), willingness to acknowledge and learn from other perspectives (n=2). An interesting take by one lecturer was, "*isn't working interdisciplinary, not already a skill?*", while another opined, "*I think, it's more of an attitude developed.*".

Table 14

Lecturers' perspectives about skills developed

Skills	Occurrence
Perspective-taking	5
Communication	2
Collaboration	4
Willingness to learn from other fields	2
Confidence in self	3

Document analysis. The module manual outlined the intended learning outcomes from this module (see section 3.1), which are focused on the areas of collaboration and communication with multidisciplinary team members and stakeholders. Next, addressing a given challenge by using design principles, and validating the design solution and demonstrating it with rationale are focused on. Lastly, evaluation, and critical reflection of the solution and on individual contribution to the team is an intended outcome.

Perceived competency outcomes

Staff. The challenge facilitators, module coordinators, and the process tutors worked first-hand with the student groups in various capacities through the course of the module. Hence, they had insight into the actual skills developed by the students (Table 15). An interesting caveat shared by one of the interviewees was*:*

> *"It's hard to assess if it's the effect of this module or if they were already kind of developed in that area. For psychology students, they are much more open to working with other people from day one. So also for those, it's tougher to assess if it's us who make a difference or if it's their susceptibility."*

Table 15

Staff's perspectives about skills developed

Skills	Occurrence
Collaboration	5
Confidence in existing skills	4
Perspective-taking	3
Ownership	2
Problem-solving	3
Applying prior knowledge	3
Professional skills	2
Dealing with uncertainty	2
Reflection	1
Communication	1
Leadership	1

Students. The student participants in the focus group studies reflected that communication (n=4), teamwork (n=2), organizational skills (n=3), being able to apply prior knowledge (n=2), perspective taking (n=1), and intercultural working (n=1) are the skills they have developed and used in this module. Also, students (n=3) realized that they became more aware of the skills gained from their disciplinary background. The following comment is an example of this:

> *"I did learn a thing that compared to the other studies in my group, that we are a bit more organized when it comes to putting things in a report….. making it more readable for multiple readers."*

In the survey, the skills developed and employed in interdisciplinary learning was examined through the self-reported responses to Likert-scale items 12.1 – 12.5 and open-ended item 13 in the student survey. Overall, the statements concerned the competencies of communication, ability to draw connections between disciplines, reflection, and critical thinking and were highly rated by the students. Table 16 shows a summary of the student responses grouped into applied sciences and social sciences. Results from the Mann-Whitney test showed that the means of students from Applied Sciences (which was higher across all five items) are not significantly different from the means of the Social Science students.

Table 16

Student perspectives about skills developed

Faculty	Applied Sciences (n = 23)	Social Sciences (n = 16)	Total (n=39)	Significance of Mann-Whitney test
	mean (±sd)	mean (±sd)	mean (±sd)	*p* value
Communication	3.74 (± 0.69)	3.56 (± 1.03)	3.67 ± 0.84	0.60
Connecting challenge and prior learning	3.96 (± 1.06)	4.25 (± 1.00)	4.08 ± 1.04	0.30
Connecting to my discipline	3.87 (± 0.81)	3.69 (± 1.01)	3.79 ± 0.90	0.54
Reflection	3.91 (± 0.56)	3.69 (± 1.01)	3.82 ± 0.79	0.71
Critical Thinking	4.00 (± 0.79)	3.75 (± 1.06)	3.90 ± 0.91	0.56

1 (Strongly disagree), 2 (disagree), 3 (Neutral), 4 (Agree), 5 (Strongly disagree)

The open-ended responses from the survey add to the findings about the learning from this module. Students shared about varied learning gained through participation in this module such as: disciplinary knowledge, collaboration, communication, research, perspective taking, professional skills, leadership, knowledge about the industry, confidence, application of prior knowledge, reflection, problem-solving, leadership, approaching ID projects, and research skills. The following comments from the student responses illustrate some of the perceived competency outcomes:

On perspective-taking:
"Not having 'tunnel vision' on the problem by only looking at it from your own discipline. I learned to look at it from multiple perspectives"

On knowledge about the industry and other disciplines:
"I gained a lot of knowledge about the construction industry, how the inner structure works and how psychological factors and communication can be a heavy influence on productivity and progress, independently from the domain"

On Communication:
"How to communicate with people from different disciplines"

On research skills:

"Helping to write the report, I never wrote an extensive report or did proper research for my study."

On connecting challenge to prior learning

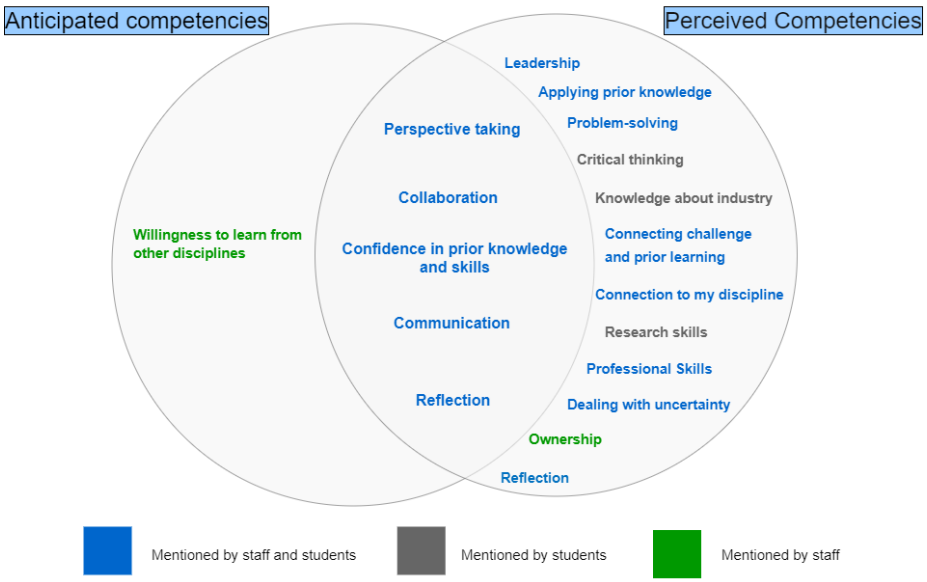
"Become creative in finding ways how to include my discipline in a challenge which does not seem to include that"

Summary

The competencies developed through module were determined based on what is anticipated by the lecturers and in the intended learning outcomes, and what was perceived by the students and the staff who worked directly with the student groups. There was concurrence between what was anticipated, and the perceived outcomes and the outcomes exceeded the anticipations (see Figure 5). It is important to note that the density of these comments are not equal and vary between being occurred once by one type of participant to multiple times by many types of participants. Keeping with the thematic nature of the analysis, they are included towards creating a thick description. For the perceived outcomes, it can be noted that there is internal coherence between the findings from the different participants (students, staff) highlighted in blue in Figure 5. The overall key trends are collaboration, communication, confidence in self and their disciplinary knowledge, reflection, and perspective-taking.

Figure 5

Competencies developed



8. Discussion

The findings are discussed further along with interpretations from existing literature towards answering the posed research questions of this study.

8.1 Value of interdisciplinary challenge-based learning

Staff members and students predominantly shared a positive attitude towards this unique module. The module was valued due to its relevance to the future workplace and as it supported the participants to broaden their perspectives. This is a crucial factor because, a positive attitude can influence the outcome of interdisciplinary education according to previous studies (Borrego et al., 2013; Hattie, 2008; Koch et al., 2017; McNair et al., 2011; van den Beemt et al., 2017). Furthermore, staff members highlighted the potential for competency development in this module as a value add, which is in line with literature that states that ID education contributes to the development of key 21st-century skills (Stanton et al., 2017; Wagner, 2008). They also cautioned about the potential barriers in implementation such as lack of concrete learning, the importance of group composition, and the challenge for teachers to cater to students from multiple disciplines. These aspects align with the theory about the difficulties of ID education (Borrego et al., 2013; McNair et al., 2011; van den Beemt et al., 2017; Welch-Devine et al., 2018) and were also observed through this study as elaborated in the subsequent sections. Students positively regarded the value of the module and shared that despite the difficulties they had a fruitful learning experience. Specifically, 95% of them attributed that working on the real-world challenge motivated them. The finding that real-world problems improve student motivation has been discussed in literature about ID education (Brundiers et al., 2010) and challenge-based learning (Kohn Rådberg et al., 2020). Moreover, the involvement of the external challenge provider in the project was remarked as a highlight by different types of staff interviewed and students. This crucial element of partnerships with real-world problem owners has the potential to deepen the rationale for ID education (Hannon et al., 2018) and allows for more diversity in solutions (MacLeod & van der Veen, 2020).

The document analysis and observations revealed information about the design of the module and several aspects of which can be highlighted as a strength in the design. Firstly, concerning the pedagogy employed, challenge-based learning has been incorporated which aligns with the problem-centering strategy for interdisciplinary teaching which has been suggested to suit the context of broad interdisciplinarity (Nikitina, 2006). Secondly, in accordance with theory stating that group composition is a key factor for successful ID

collaboration (Jæger & Jensen, 2019), the group formation process was guided and regulated in this module with a speed-date session and diversity requirements. Lastly, the assessments in this module were in line with theoretical recommendations for improving integration through assignments requiring solving for an authentic problem. Rubrics for each assessment were shared for enhancing clarity for students and staff members (Schaddelee & McConnel, 2018).

Regarding the difficulties perceived in this module by the staff and the students, aspects related to the structure of the module and support for students and staff for interdisciplinary education and collaboration surfaced. The latter aspects are elaborated further in the following subsections (see section 8.2 and section 8.3) as they are directly relevant to the research questions two and three. In terms of the structure of the module, due to the diversity and distance between the constituent disciplines, it is a case of broad interdisciplinarity. Teaching and developing curricula for broad ID is characterised by more difficulties than narrow ID (Spelt et al., 2009). A recurring trend among the data was the lack of alignment of the series of lectures with the content required for the challenges and the learning objectives. Moreover, the module documents showed that structured learning activities were predominantly focused on the learning objectives concerning the problem definition and prototype development with less focus on collaboration and reflection. This shows that the module has a shortcoming concerning the constructive alignment principle of outcome-based education which has been said to support the ID learning environment and improve the clarity of expectations for the students (Spelt et al., 2015).

8.2 Enabling and limiting factors of support for interdisciplinary education

The academic staff received varying types of support based on their role within the module. The lecturers received no formal support and were concerned only with their individual lectures/workshops and had limited insight into the rest of the module and how their topic fits within it. The challenge facilitators, who were involved in recruiting the challenge providers and acted as their liaison with the student groups, expressed interest in being more involved and getting the providers involved in the workshops and progress of the module. The process tutors participated in a workshop about CBL and supporting student groups through the CBL framework which was facilitated by an educational expert from the Centre for Expertise in Learning and Teaching (CELT) at the University of Twente. The module coordinators appreciated the support from CELT for the design of the module and the NovelT staff (two of the challenge facilitators) for the challenge provider recruitment and

suggested that support for fostering integration in the groups would be beneficial. Collectively, all the staff members appreciated the communication with the module coordinator and remarked that the online learning situation due to the COVID19 pandemic regulations is limiting interaction with students and other staff. Overall, it can be concluded that the staff predominantly worked individually and interacted primarily only with the module coordinator. This was noted by some staff members as a potential limitation to having a coherent and integrated module.

In terms of enabling factors of support, the workshop for the process tutors was regarded positively among all the process tutors interviewed and is aligned to the theoretical recommendations for training supervisors (Schaddelee & McConnel, 2018; Spelt et al., 2009). Another positive support factor is that 85% of the staff interviewed had prior experience in interdisciplinary education or research as previous studies have suggested that ID experience can increase their investment and ability to guide the students (Gardner et al., 2014; Lyall et al., 2015; Spelt et al., 2009). On the other hand, the lack of cohesion among the staff team, and limited training for staff members can be said to be limiting factors of support. As McNair et al. (2011) and Spelt et al. (2009) highlighted, the multidisciplinary staff team's role-modelling of valuing other disciplines and integrating disciplinary perspectives can be crucial for encouraging interdisciplinary collaboration and learning among the students. Moreover, Hannon et al. (2018) also pointed out the importance of a stable teaching team for sustaining ID courses. As highlighted before, training was limited to one CBL workshop for process tutors. Previous studies have argued the importance of training for supervising interdisciplinary teams and guiding teams towards integration and open-ended problem solving (Gardner et al., 2014; Lyall et al., 2015; Spelt et al., 2009).

At the student level, they had access to multiple available options for support regarding content, feedback, and information through the module ranging from the diverse staff members, lectures and workshops, and the wider UT ecosystem. Students were largely satisfied with the available support and pointed out various enabling and limiting factors of support. Together with the staff's perspectives and the document analysis, it can be concluded that the multiple options for support, DesignLab workspace, availability of assessment information, and relevance of some lectures can be classified as enabling factors. On the other hand, lack of guidance and clarity of expectations were the limiting factors of support. The module had minimal structured activities with deliverables in the first, fifth, and tenth week and lectures (two per week) primarily in the first four weeks. Students expressed frustration with the openness of the module and the staff also pointed out that the lack of structure was a

big jump from the structured education 2nd-year bachelor students are trained with. The online learning situation also contributed to this lack of structure, as the students had very limited interaction with other groups and staff.

The course demands the students to be self-directed in their learning with limited guidance. Although the intention is to develop students' professional competencies and self-regulation through this design, it is important to note that scaffolding is crucial to support the transition from learning with well-defined expectations to self-directed ID group work (Manathunga et al., 2006; Stentoft et al., 2017). Previous studies have also reported students suggesting that they lack support (Macleod & van der Veen, 2020) and asking for more checkpoints for feedback (McNair et al., 2011). However, a fine balance must be reached in terms of structure as too much structure can negatively impact ID collaboration. Therefore, instead of prescribing the approaches or outcomes, students may be supported by including activities that encourage and guide integrated problem-solving (Borrego et al., 2013; McNair et al., 2011). Lastly, in terms of guidance, the students received feedback on the deliverables and were expected to gain ongoing feedback from their respective tutors and facilitators. From the module documents, it can be noted that although the four intended learning objectives have equal weightage in the assessments. However, the students predominantly received support for the problem definition and prototype development and there is little guidance for their collaboration and reflection skills. This adds to the need for intentional guidance for competency development to navigate the ambiguous context of ID challenge-based assignments (Jensen et al., 2011).

8.3 Interdisciplinary collaboration in Challenge-based learning

This study sheds light on the nature of collaboration, the students' perceptions about the collaboration in their groups, and collaboration problems. Interdisciplinary collaboration was found to take various forms in the groups, with differing levels of integration. Dividing the tasks based on disciplinary expertise was a dominant theme in the way the groups collaborated as evidenced by the survey responses, analysis of project reports, and staff opinions. Previous studies have been critical of this approach of tackling disciplinary components and combining them as they lead to multidisciplinary and pluridisciplinary (cooperation without coordination between disciplines) learning (Jensen et al., 2019; Vogler et al., 2018). Another related finding is the unequal contribution of the students in a group to the prototype which was evidenced by data across instruments (survey, project report) and participants (students, process tutors, challenge facilitators). This could be caused by the

division of responsibilities by disciplines so certain disciplines do not have as much to add from their disciplinary knowledge and the usual problems of social loafing in group projects. Managing and distributing workloads among disciplines in groups are said to be common problems in interdisciplinary contexts due to unequal disciplinary grounding and sequential order of involvements of the disciplines (Cotantinto et al., 2010; Warr & West (2020). In the current study, the root cause can be hypothesized to be the distance from the individual disciplines and the defined problem as pointed out by staff opinions. This also relates to the perspectives about the group formation and alignment between the disciplinary composition of the groups and the challenges available. As Do (2013) pointed out, understanding the content of the project is of crucial importance for participation in interdisciplinary contexts. Owing to the challenge-based learning principle of groups defining the problems, the onus of defining the problem from the perspectives of the disciplines involved rested on the student group.

Regarding the collaboration experience, staff members alluded to prejudice and failure to recognize the importance of non-technical disciplines by especially students of technical disciplines as a barrier to collaboration. Literature refers to this inability to see the relevance of other disciplines' in an interdisciplinary problem as 'disciplinary egocentrism' (Richter & Pareti, 2009). However, students mostly responded positively about recognizing the role of other disciplines and reported having little to no prejudice about other disciplines.

Communication was found to be a key factor in interdisciplinary collaboration within the groups. Students recognized that language differences exist among different disciplines and explained how they had to adapt their communication style to explain ideas to students of other disciplines. Effective communication is a crucial element in interdisciplinary groups as they negotiate meanings and find common ground (Repko, 2007; Woods, 2007), and is a key learning outcome of interdisciplinary education in general (Borrego et al., 2013) and in this module particularly. Moreover, communication problems have been widely discussed in literature, the use of significantly different vocabulary among disciplines necessitates simplistically articulating one's ideas (Epstein, 2005; Warr & West, 2020). Other collaboration problems include disciplinary differences causing tension and struggles with decision making. The inherent differences in theory, methodologies, and epistemologies across the disciplines can be an area of struggle for students to navigate learning in interdisciplinary groups (Peffer & Renken, 2010; Spelt et al., 2017). Moreover, Öberg (2009) pointed out that students new to interdisciplinarity do not prioritize overcoming disciplinary differences to create a common ground. This further adds to the need for scaffolded support.

8.4 Competency outcomes

The skills of *communication, collaboration, reflection, perspective-taking, and confidence in prior knowledge and skills* were the competency outcomes that were anticipated and confirmed based on student and staff perceptions. There were unforeseen outcomes that the students reported such as, *leadership, research skills*, *understanding how to approach ID projects*, *knowledge about the industry*, *report writing*, and *professional and organization skills*. Students' developing the competencies of drawing connections to prior knwowlegde and between disciplines is notable. Lattuca et al. (2012) categorized the skill of being able to see connections across ideas in other disciplines as a key interdisciplinary skill. This is aligned to findings from Spelt et al. (2009) wherein the student characteristics of curiosity, respect, and openness were related to the attitude of appreciating other disciplines, lack of which can be a barrier to interdisciplinary collaboration (Peffer & Renken, 2017). In addition, the staff pointed out *ownership* as an additional competency developed by students.

Overall, the findings are similar to other studies that have highlighted the development of competencies in interdisciplinary education and active learning pedagogies (Costa et al., 2019; Miller et al., 2019; Spelt et al., 2009; Vogler et al., 2018). However, there is little evidence about the development of metacognitive competencies which have been highlighted as both a pre-requisite and outcome of ID education (Ivanitskaya et all., 2002). Metacognitive competencies can be broadly defined as one's awareness of their cognition and ability to monitor and improve their progress through deliberate planning and reflection (Blakey & Spence, 1990). Moreover, these competencies are crucial for, student-driven learning as they guide self-regulation, self-appraisal, and management of cognition and ID education as they influence integration (Brooks et al., 2019).

Competency development in students can be attributed to both the interdisciplinary and challenge-based learning elements of the module which offer them the opportunity and demand to expand their repertoire of skills. However, in this study, it is important to note that there was minimal guidance for developing these competencies and the outcomes are self-reported. Moreover, the staff emphasized that students might have already possessed these skills to some extent and further developed pre-existing skills through this module. Vogler et al. (2018) found that scaffolding is necessary for guiding the development of soft skills and noted that they tend to be overlooked due to the importance given to hard skills. This relates to the finding about the need for scaffolding discussed previously.

9. Limitations

Despite the efforts taken to conduct a reliable study, it is pertinent to take into consideration the limitations of this study that have come to light during the execution. Firstly, the survey used in this study had a sample size of 39 which proved to be insufficient for a factor analysis to be performed to ascertain the internal validity of the survey. However, the survey had a response rate of 83% of all the students enrolled in the course which can be said to represent the student population well. The survey was designed to measure the student perspectives about the *perceived value* of this module, *collaboration within their group,* and the *competencies developed* through this module. For the latter, all the possible components concerning the myriad of skills that can be developed through participation in such a module were not included. This was done to keep the survey short and improve the response rate from the participants. However, an open-ended question about the learning from this module was included to included and this was also discussed in the focus group studies. Besides, it is imperative to note that the self-reported competencies developed cannot be isolated from existing competencies students already possessed and used in this module.

Next, the answering options for the survey item about the different types of support were not explained clearly. Although it was expected that students who did not gain from or utilize a type of support would opt for the 'NA' option, this cannot be ascertained. Students could have possibly chosen this option also when they did not know about a specific type of support. Hence, this question lacks nuance in unearthing the preferred and underutilized types of support. Regarding the collaboration in the groups, the items aimed at measuring the students' perspectives about the nature and type of collaboration. In hindsight upon analysis of the results it can be said that although this is aligned to research question 3, information about the rationale for the groups' choice of collaboration is needed to understand the support required to guide this process. Limited data about the same was collected from the students, through the smaller sample in the focus groups.

Moreover, the COVID-19 pandemic and ensuing regulation had an impact on the study. The observations were limited due to the pandemic regulations at the university. This led to reduced attendance in the physical meetings which were intended to be observed and the adherence to social distancing norms had the students sitting quite apart and the researcher was not able to participate effectively due to spatial constraints. In addition, the second wave of the pandemic in the Netherlands restricted the educational activities on the UT campus and the module opted for a blended learning approach instead. This in turn affected the interaction

and facilities available for the project groups. Moreover, reduced interaction and constraints on working together effectively were attributed to the online learning model by several students and staff members interviewed across the different roles. Lastly, the representation of the study programmes in the focus group studies included five students from Social Science disciplines and two students from Applied Science programmes. Although it was intended to have at least ten participants with equal representation from Applied and Social science disciplines, scheduling difficulties posed by the pandemic regulations was a constraint. This skewed representation could have influenced the conclusions drawn about student perspectives and missed hearing about the perspectives of the students from the other disciplines. However, other methods of data collection were used to draw triangulated conclusions to address this problem.

10. Recommendations

This study intended to describe the implementation of the Science2Society: Idea to Prototype module which adopted a challenge-based learning pedagogy for ID education with students from diverse studies. Specifically, the value of the module, support for ID education, collaboration in the student groups, and the competencies developed through participation in the module were examined through data from multiple sources and instruments. The analysis sheds light on these research focus areas and reveals several strengths and struggles in the module. These give rise to the following recommendations for the module to consider towards further developing the strengths and solving for some of the shortcomings:

1. Scaffolding support for students

Despite having multiple options for support, the module had minimal structure in terms of checkpoints, planned feedback moments, and guidance. It can be said that many of the difficulties that were found regarding group collaboration and lack of integration, can be attributed to a lack of scaffolded support for ID education. Although the module intends to adopt student-driven learning, research shows that students need scaffolds to take ownership of and regulate their learning especially in active learning contexts (English & Kitsantas, 2013). Moreover, the students and staff members need to be supported in the transition to the instructional conceptions of student-driven learning (Lowyck et al., 2004) which is the crux of CBL. Hence, it is suggested to incorporate scaffolds and tools that can bridge the competency gap and enable student groups to be self-directed within the CBL environment. There are numerous examples from prior studies (see section 8.2) that have outlined different scaffolding strategies to guide students while fostering student-driven learning in open problem contexts. These strategies can be in the form of methodological tools such as for defining group processes (Sortland, 2019), discourse frameworks (Oberg, 2009), reflective dialogue for assessments (Manathunga et al., 2007), and process management methods such as Scrum (Magnell & Högfeldt, 2015). Moreover, more progress checkpoints with planned feedback moments aligned to all the learning objectives can be included. These checkpoints can serve as a guide for the student groups to show mastery of the learning outcomes and especially self-evaluate and reflect on their work. The balance between freedom and structure may be achieved through equipping students with the skills required to self-direct and regulate their learning, as an ID team. Therefore, guidance for ID groups can be in the form of targeted scaffolds to support them through the process of CBL and thereby cater to the relevant learning objectives can be incorporated.

2. Teaching team

Currently, there are more than 20 academic staff members involved in this module in various roles. Staff involvement has been restricted to their specific task and although this can be said to minimize the time investment, it causes a disconnect between their individual aims and a lack of clarity of expectations. The module coordinator donned multiple roles and mediated between all the other roles and the students. Literature has emphasized the importance of role modelling of key ID competencies such as perspective-taking and collaboration (McNair et al., 2011; Schaddelee & McConnell, 2018). Moreover, training staff for guiding ID education and open-ended problem solving is important, which can improve their skill set, confidence, and role clarity. Hence, it is suggested to involve and train the staff in supporting the student groups to collaborate and effectively integrate their disciplines to produce a prototype in response to the challenge. Teacher team development has been suggested to be a substantial factor in the ID learning environment (Spelt et al., 2009). Therefore, the staff members across roles may be included in the module from the design phase and regular meetings for staff with supervisory roles would help with formative improvements and peer support.

3. Constructive Alignment and assessments

In terms of the assessments of learning, this module takes a unique approach by devising assessments for ID projects at the individual and group level intending to measure the learning objectives that are rooted in interdisciplinarity. However, through the module and with the formative assessments, there is a dominant focus on the objectives concerning problem definition and prototype development as opposed to interdisciplinary collaboration and evaluation of work. It is suggested that the assessments for learning effectively cater to and support the realization of learning objectives one and four as well. It is imperative to reflect on the learning activities (lectures/workshops) in terms of alignment to the learning objectives, the topic of the groups' challenges, and internal coherence so they are not disconnected silos of disciplinary knowledge. At the learning objectives level, the assessment rubric for the report clearly defined the objectives and provided the success criteria which is a good practice. It is recommended to make this definition and success criteria more visible to the students towards developing a culture of reflection and growth. The rubric can be used in tutor meetings and other spaces towards improving the clarity of expectations and fostering self-evaluation in students.

3. Peer assessment

In the current design, peer assessment was used during the final presentation for individual students to grade the presentation of other groups. Besides that, the out of comfort zone week

provided groups with the opportunity to work on a task for another group. These are good examples of peer learning and fostering interaction. This can further be maximised by using peer assessments for formative evaluation through the course of the module in the form of peer feedback instead of only peer grading. Hersam et al. (2004) found the use of peer assessments in ID group processes successful. This can have the dual benefits of getting groups to leverage their peers for support and sharing innovative practices (ex: group processes or involving stakeholders). Moreover, peer feedback could work well for this module due to its alignment with active learning, encouraging engagement with assessment criteria, improving reflection and self-assessment skills and reducing the workload for the staff (Nicol, 2011). Peer feedback within the groups could also foster group collaboration, improve accountability, and reduce social loafing.

4. Recruiting challenges and defining the problem

Since real-world challenges are sought in this module from external and internal challenge providers, care should be taken to define and convey expectations. Specifically, the requirements about the initial challenge information, expected involvement, deliverables from students, and the CBL model in the module need to be clarified. Ultimately, this can help guide the module coordinators in recruiting the right challenges, provide adequate information to students during and after the pitch, and ensure the best-suited group composition for the challenge.

Next, since the groups get the opportunity to define the problem from the open-ended challenge, the onus is on them to define it taking into consideration the disciplinary perspectives and integrating them. Students need guidance in this process to support them in the problem definition to ensure disciplinary perspectives are compared and balanced disciplinary contribution is envisioned. Moreover, supervisors can monitor so that the problem is not too well defined into disciplinary components and a multidisciplinary approach is adopted. This connects to the first recommendation of guiding students to drive their learning.

11. Practice and future research

The findings from this study are directly applicable for the Science2Society: From Idea to Prototype module and relevant to inform practice and guide further research in the field of interdisciplinary higher education and challenge-based learning. This section outlines suggestions for practice and future research.

Firstly, towards developing thick descriptions of interdisciplinary collaborations and teamwork, it is suggested to conduct ethnographic studies of ID groupwork and allied support structures. This could prove to be crucial to understand the ways of working of ID groups, the path to integration, and the support required to facilitate the same.

Secondly, CBL is a relatively novel pedagogy and it is recommended to further study the effectiveness of CBL for interdisciplinary education and compare it with other pedagogies like PBL and PjBL. Previous studies have compared the latter two with the ID competence outcomes (Brassler & Dettmers, 2017), it might be beneficial to include CBL in such a study. This can provide much needed empirical evidence to drive policy decisions and support practitioners in designing ID education.

Thirdly, regarding student-driven learning (SDL), it is recommended to study the scaffolding required for students to effectively transition from guided spaces and for teachers to foster the same (Lowyck et al., 2004). To support future practice, it would be substantial to study the strengths, weaknesses, and boundary conditions for SDL in interdisciplinary education. This can help practitioners evaluate existing programmes' support structures and effectively design future programmes. In addition, research is needed to develop a theoretical model of the relationship between SDL and challenge-based learning similar to English & Kitsantas's (2013) study about self-regulated learning and PBL.

Fourth, a primary selling point of ID education is the relevance to the future work of students primarily due to the competencies developed. It is recommended to undertake longitudinal studies to gather evidence for this hypothesis. This would be of interest for deepening the belief in the need for ID education and be an impetus for the growing research into the future of work and universities. Lastly, offshoot research can be focused on implementing active learning pedagogies in online and remote learning contexts. Considering the uncertainty of in-person learning posed by the COVID19 and increased global connectivity, it is now more than ever relevant to further develop online education.

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Appendices

Appendix A: Student Survey items and sources

Theme	Question	Source
Demographic	**1. Consent** **2. Age** **3. Gender** 4. **Faculty**	
Value	**5. Based on your experience, select the most appropriate option for the following statements**	
	5.1 The learning from this module will help me in my future study/career.	Adapted from IPAS (Norris et al., 2015)
	5.2 I found the interdisciplinary aspect of this module interesting	Adapted from Gero, 2017
	5.3 I believe I have a better understanding of the challenge and solution due to the interdisciplinarity of my group	Adapted from Gero, 2017
	5.3 In this module, working on a real-world challenge motivated me	Self-created based on CBL literature
	5.4 I would welcome the opportunity to work on group projects with students from other disciplines in my future	IPAS (Norris et al., 2015)
Group collaboration	**6. In my group, the nature of teamwork was... (Select all that apply)** ☐ We divided tasks based on our expertise ☐ We worked on tasks individually and coordinated our work in the meetings ☐ We engaged in group work most of the time and shared our expertise ☐ We formed sub-groups to tackle the challenge ☐ We sought support for working together effectively ☐ We all had an equal role in the project ☐ Students of certain disciplines had more or less work in our project ☐ Other	Self-created
	7. Based on your group experience, select the most relevant option	
	7.1 The way the groups were formed worked well for me and my group.	Self-created based on literature Jensen, Ravn, & Stentoft, 2019
	7.2 I recognize the role that the team members from the other study programmes played in the project.	Adapted from Richter & Paretti, 2009

	7.3 I feel that students from other disciplines have prejudices or make assumptions about me because of my discipline.	Johnson-Veldhuis (2020) based on IPAS (Norris et al., 2015)
	7.4 I have prejudices or make assumptions about students from other disciplines.	Johnson-Veldhuis (2020) based on IPAS (Norris et al., 2015)
	7.5 My perspectives about other disciplines were broadened, through participation in this module	Adapted from IPAS (Norris et al., 2015)
	7.6 I am aware that people from other study disciplines use the same words differently than how my discipline uses them.	Adapted from Petrova (2020) based on IPMQ
	8. What is an example of a positive situation that happened because of the different disciplines in your group?	Johnson-Veldhuis (2020)
	9. What is an example of a negative situation that happened because of the different disciplines in your group?	Johnson-Veldhuis (2020)
Support	**10. Who or what were your biggest sources of support?** ☐ Process Tutor ☐ Challenge Facilitator ☐ Module Coordinator ☐ Lectures and workshops ☐ Challenge Provider ☐ Other groups	Self-created
	11. Overall, how would you rate the support you and your group received in this module o Very good o Adequate o Neutral o Needs improvement in certain areas o Inadequate	Self-created
	12. In your opinion, what can be improved regarding 'support for students/groups' in this module?	Self-created
Competency outcomes	**13. Through participating in this module and project..**	
	13.1 I have improved the way in which I explain my ideas so that students from other programmes can understand.	Adapted from Petrova (2020) based on IPMQ
	13.2 I was able to make connections between the challenge and my prior learning from my study programme	Adapted from Richter & Paretti, 2009
	13.3 I see connections between ideas/theories in my discipline and other disciplines.	Lattuca, 2012
	13.4 I was able to stop and think where I might be going wrong or if I am missing something	Lattuca, 2012

	13.5 I have improved my capacity to analyse, critique and assess a problem.	Lattuca, 2012
	14. What have been your biggest learning (knowledge, soft skills, reflections) from this module?	Self-created
	15. How was your experience with remote learning and working situation in this module?	
Additional comments	**16. Please add any further comments or suggestions about the module or the survey here.**	
Voluntary participation in a lottery	**17. If you would like to be placed in a lottery to win one of four Bol.com vouchers, please fill in your email addresses below** (Note: Winners will be notified on 20th November 2020)	

Appendix B: Online survey - SurveyMonkey

Student experience in interdisciplinary challenge based learning

Hi! I am Niveditha, an Education Science master student examining the module, 'From Idea to Prototype' for my master thesis and I would like to request your help.

This questionnaire is for students enrolled in the module, "From Idea to Prototype", it intends to explore students' perspectives of this interdisciplinary challenge-based module. Your opinions will contribute to improving this module and the STRIPES2021 research project. As a reward for your participation, you will be placed in a lucky draw to win one of four Bol.com vouchers, 25euro each.

The results of this study will only be presented in summary form and individual responses will be strictly confidential. The survey takes approximately 7 minutes to complete. Your time and support are highly appreciated!

Thank you.

If you have any questions, please contact me at n.uthrapathishakila@student.utwente.nl

Kind regards,
Niveditha Uthrapathi Shakila

1. Do you agree to participate in this study aimed at improving interdisciplinary education?

- ◯ Yes
- ◯ No

2. What is your age?

- ◯ 18 or below
- ◯ 19 - 21
- ◯ 22 - 24
- ◯ 25 or above
- ◯ I would rather not specify

3. What is your gender?

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

4. Which faculty does your study programme belong to?

- ◯ EEMCS (Electrical Engineering, Computer Science)
- ◯ ET (Mechanical Engineering, Industrial Design)
- ◯ TNW (Health Science, Chemical Science and Engineering, Technical Medicine)
- ◯ BMS (Psychology, International Business Administration)
- ◯ Other

Other (please specify)

5. Based on your experience, select the most appropriate option for the following statements

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
The learning from this module will help me in my future study/career.	○	○	○	○	○
I found the interdisciplinary aspect of this module interesting	○	○	○	○	○
I believe I have a better understanding of the challenge and solution due to the interdisciplinarity of my group	○	○	○	○	○
In this module, working on a real-world challenge motivated me	○	○	○	○	○
I would welcome the opportunity to work on group projects with students from other disciplines in my future	○	○	○	○	○

6. In my group, the nature of teamwork was.. (Select all that apply)

- ☐ We divided tasks based on our expertise
- ☐ We worked on tasks individually and coordinated our work in the meetings
- ☐ We engaged in groupwork most of the time and shared our expertise
- ☐ We formed sub-groups to tackle the challenge
- ☐ We sought support for working together effectively
- ☐ We all had an equal role in the project
- ☐ Students of certain disciplines had more or less work in our project

Other (please specify)

7. Based on your group experience, select the most relevant option

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
The way the groups were formed worked well for me and my group	○	○	○	○	○
I recognize the role that the team members from the other study programmes played in the project	○	○	○	○	○
I feel that students from other disciplines have prejudices or make assumptions about me because of my discipline.	○	○	○	○	○
I have prejudices or make assumptions about students from other disciplines	○	○	○	○	○
My perspectives about other disciplines were broadened, through participation in this module	○	○	○	○	○
I am aware that people from other study disciplines use the same words differently than how my discipline uses them.	○	○	○	○	○

8. What is an example of a positive situation that happened because of the different disciplines in your group?

9. What is an example of a negative situation that happened because of the different disciplines in your group?

10. Who or what were your biggest sources of support?

	Not applicable	Very little support	Neutral	Moderate support	Major support
Process Tutor	○	○	○	○	○
Challenge Facilitator	○	○	○	○	○
Module Coordinator	○	○	○	○	○
Lectures and workshops	○	○	○	○	○
Challenge Provider	○	○	○	○	○
Other groups	○	○	○	○	○

11. Overall, how would you rate the support you and your group received in this module?

- ○ Very good
- ○ Adequate
- ○ Neutral
- ○ Needs improvement in certain areas
- ○ Inadequate

12. In your opinion, what can be improved regarding 'support for students/groups' in this module?

13. Through participating in this module and project..

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I have improved the manner in which I explain my ideas so that students of other studies can understand.	○	○	○	○	○
I was able to make connections between the challenge and my prior learning from my study programme	○	○	○	○	○
I see connections between ideas/theories in my discipline and other disciplines.	○	○	○	○	○
I was able to stop and think where I might be going wrong or if I am missing something	○	○	○	○	○
I have improved my capacity to analyse, critique and assess a problem.	○	○	○	○	○

14. What has been your biggest learning achievement (knowledge, professional skills, reflections) from this module?

15. How was your experience with remote learning and working situation in this module?

- ◯ Highly positive
- ◯ Positive
- ◯ Neutral
- ◯ Negative
- ◯ Highly negative

16. Please add any further comments or suggestions about the module here.

17. If you would like to be placed in a lottery to win one of four Bol.com vouchers, please fill in your email addresses below (these will be processed separately from the other data).
(Note: Winners will be notified on 20th November 2020)

Appendix C: Focus group study script

Thank you for agreeing to participate in a discussion about your experiences in this module. This is immensely useful for my master thesis focused on student experiences in this interdisciplinary module and the STRIPES202 research project which aims to support interdisciplinary courses. Today, I am interested in understanding about how the project group experience was for you all. I am going to ask you some questions about your experiences and project group work. I hope these questions will stimulate a discussion amongst you. I will not be joining the discussion, I am here to moderate and keep track of time.

You can of course ask me to repeat or elaborate a question.

I would like to record this discussion with your permission, this will be purely for transcription and analysis purposes. I will delete this recording after I have analysed it. No identifying information will be used, and this will be anonymized. Do you have any questions?

Let us continue.

1. What has been your overall experience of the project groups in this module?
2. What was new or different about the group work in this module as opposed to the other modules?
3. What is your opinion about support for you and your group?
4. What kind of support helps you and your group?
5. What did you like about group work?
6. What did you find challenging in your group?
7. When you first started working in this group, how did you collaborate?
8. How is it now group collaboration now?
9. What have you learnt through this group work?
10. How do you think the disciplines shared the work in your group?
11. How would you feel about working in such a group again?
12. Finally, is there anything about the group work in this module that has not been discussed and you want to bring up?

I would like to thank you for your time and support. If you would like to know more about my research, please drop your email ID in the personal chat.

Appendix D: Semi-structured interview scheme

Based on the role(s) of the staff (lecturer, facilitator, coordinator, tutor), the questions were modified or reordered.

1. Basic information
2. How many years of educational experience do you have?
3. What is your role in this module? How long have you been involved?
4. Do you have any prior experience with interdisciplinary education or research? How has it been?
5. *What, in your own words, is the purpose of this module? What makes this module unique?
6. How would you describe the planning and changes to this module?
7. What is your opinion about the support given to the academic staff?
8. How has your experience been in this module?
9. What value does CBL add to this module, in comparison to the previous versions?
10. *What, according to your opinion, are the main highlights in this module? (regarding interdisciplinary education)?
11. What, according to your opinion, are the main challenges in this module? (regarding interdisciplinary education)?
12. What are the competencies being developed in students through this module? (Communication, Teamwork/Collaboration, Self-regulation, Problem-solving, Critical Thinking, Entrepreneurial, etc.)
13. In your experience, what skills have you seen students develop through this module?
14. Which aspects of the challenge did the students most need your support with?
15. What do you think needs to be improved in this module for the next year?
16. What is your personal opinion about interdisciplinary education? Do you find it meaningful?

*Adapted from Lyall et al, (2015).