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Preparing engineering students for tomorrows challenges:

Investigating challenges to support interdisciplinarity

Project report.
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ABSTRACT

TU/e innovation Space offers an environment for students to work in interdisciplinary teams on societal challenges. These challenges ask for development of a shared language for interdisciplinary collaboration and to facilitate learning processes. Little is known about design characteristics for these challenges, and what is needed to support interdisciplinary learning in student teams. The educational concept Challenge-based learning (CBL) uses authentic societal challenges to urge student learning. The main research question for this case study is: What design characteristics of innovation Space challenges support interdisciplinary student collaboration? Data collection consisted of analysis of learning materials, interviews with teachers and students, student surveys about motivation and collaborative learning in four courses and two honour's tracks. The results show how teachers ask for competence development in supporting students, especially in assessing and integrating discipline knowledge. Students reported high motivation combined with anxiety for open and complex challenges. Over time this anxiety decreases, as students develop knowledge and skills for solving the challenge. Students also reported a need for a clear mapping of learning goals to activities and assessment. For students it appeared often unclear how and on what criteria they are assessed. Yet, students also reported support in developing ownership, self-directed learning, and collaborative learning. This study confirms existing literature that emphasises difficulties students encounter developing rigorous discipline knowledge in CBL while facing interdisciplinary assessment. This study increases our understanding of challenge design and how interdisciplinarity can be situated in this design. It offers starting points for research on motivation and collaborative learning in CBL.

INTRODUCTION

Challenge-based learning in higher engineering education

Today, many universities are embracing the concept of 'challenge-based learning' (CBL), to better prepare students to contribute to societal challenges (Tassone et al., 2017). CBL is an interdisciplinary experience where learning takes places through identification, analysis, and collaborative design of a sustainable and responsive solution to a real world – authentic - sociotechnical problem (Malmqvist, Rådberg-Kohn, & Lundqvist, 2015). These authentic problems, also known as 'challenges ', are seen as self-directed work scenarios in which students engage (Johnson, Smith, Smythe, & Varon, 2009). The goal of these challenges is to learn how to define and address the problem and to learn what it takes to work towards a solution, rather than to solve the problem itself. The final deliverable can be tangible or a proposal for a solution to the challenge (Membrillo-Hernandez & Garcia-Garcia, 2020).

At Eindhoven University of Technology in the Netherlands (TU/e) CBL has been introduced in a bottom-up approach by allowing teachers to experiment with a variety of implementations. The result is diversity in characteristics of CBL between courses and departments, adding a local colour to CBL. Many of these experiments are conducted in the context of the award-winning TU/e innovation Space. TU/e innovation Space offers an environment that encourages and facilitates students to work in interdisciplinary teams on challenges that directly impact our world (Reymen et al., 2020). These challenges are often open-ended and ill defined (Gomez Puente, Van Eijck, & Jochems, 2013) and are based on collaboration and interdisciplinarity.

The working definition for interdisciplinarity in education that studies of Interdisciplinary Engineering Education (IEE) seem to agree on is that interaction between fields of expertise requires some level of integration between those fields to count as "interdisciplinary" (Klein, 2010). Interdisciplinary interactions can be considered as attempts to address societal challenges by *integrating* heterogeneous knowledge bases and knowledge-making practices, whether these are gathered under the institutional cover of a discipline or not. Individuals in interdisciplinary teams learn from others' perspectives and produce work in an integrative process that would not have been possible in a mono-disciplinary setting (McNair, Newswander, Boden, & Borrego, 2011). The end result is that team members develop a shared language for collaboration and interdisciplinarity in order to facilitate learning processes (Van den Beemt et al., 2020). This language should be shared among stakeholders, including students, teachers, and industry or NGO's.

However, little is known about characteristics that make societal challenges work as assignments, and what should be done to support interdisciplinarity in CBL, more specifically in innovation Space courses. Furthermore, current courses and projects appear to support interdisciplinarity insufficiently as part of the student learning process, as intended in the TU/e innovation Space educational vision/philosophy. This project aimed to address this lack of knowledge by investigating support for interdisciplinarity in CBL-assignments in TU/e innovation Space courses and projects.

We did so by exploring innovation Space challenges with the purpose to find a shared language that supports interdisciplinarity in engineering education. The result is (1) a description of interdisciplinarity in innovation Space education, to be shared with stakeholders, and (2) characteristics of challenge-based learning in innovation Space that support this interdisciplinary engineering education (IEE).

Research questions

The core research question is:
W*hat characteristics of innovation Space challenges support interdisciplinary student collaboration?*

Given the purpose of this project, this research question can be divided into sub questions:

- How does interdisciplinarity appear in innovation Space projects and courses?
- How can challenges in innovation Space projects and courses be characterised?
- What motivates students to undertake CBL activities?

We operationalised interdisciplinarity by focusing on collaboration and integration (Van den Beemt et al., 2020). We characterise challenges by focusing on open-ended versus structured (Gallagher & Savage, 2020).

Method

Approach and included courses

To understand how challenge characteristics support interdisciplinarity in CBL, an evaluative case study method was chosen. Evaluative case studies can be defined as enquiries into an educational programme, system, project, or event to determine its worthwhileness, as judged by researchers, and to convey this to interested audiences (Bassey, 1999). The context for the current case study is an extensive educational innovation initiative focused on development, implementation, and evaluation of CBL at Eindhoven university of technology.

The included courses aimed toward CBL in interdisciplinary teams, working on assignments in close interaction with high-tech companies and societal organizations. They combined the design and engineering of a product, service, or system with new business development. Defining and refining of a problem and ideas for a solution simultaneously and iteratively through analysis, synthesis, and reflection processes were important elements of these courses.

1ZM150, Innovation space project, graduate school.
Industrial Engineering and Innovation Sciences
This course aims toward challenge-based learning in interdisciplinary student teams, working on open-ended assignments in close interaction with high-tech companies and societal organizations. It combines the design and engineering of a product/service/system and new business development. The course involves no lectures, but studio style group work, self-study, and personal and team development.

Several out-of-the box pressure-cooker style workshops are given, either online or offline. Students are in the lead of their own learning processes. The course is part of educational innovation in TU/e innovation Space.

1AUB0, USE - entrepreneurship in action, Bachelor college
Industrial Engineering and Innovation Sciences - Innovation, Technology Entrepreneurship & Marketing
In this last project course of the USE sequence “Technology Entrepreneurship” students apply the theoretical knowledge gained from the previous two USE courses. The ultimate goal of this project course is the development of a value proposition for a technological innovation. Each student team produces a unique solution and concept based on given technologies.

Food for Health and Safety Challenge (F4HS), Bachelor and Master's
EWUU interuniversity
In this challenge students from TU/e, UU, UMCU and WUR are part of a interdisciplinary team, designing an innovative and sustainable food concept for the Dutch Military. They solve a real-life problem while working on personal and professional skills.

TU/e honors program, Bachelor college
Energy transition track
Students are encouraged to start a new project on the energy innovation of their preference. Project opportunities are also offered by the Eindhoven Institute of Renewable Energy Systems (EIRES). Additionally, students can join existing Honors Teams of this track. Coaches assist students in defining their project. However, each student team is responsible for setting and reaching objectives, making a planning, managing budget, or organizing the team. Teams are multidisciplinary and consist of at least three students having at least two different backgrounds. As energy production, consumption, transport and storage offer a broad line of (technological) challenges that need to be solved and incorporated in our society, all innovations should be analysed from different perspectives. Organizing students in multidisciplinary teams is therefore a necessity.

Empowerment for Health and Wellbeing track
Leading an unhealthy lifestyle is currently one of the main problems in western society. As a result, the costs of healthcare are increasing exponentially. This combination currently presents a huge societal but also an economical and organizational challenge. To give focus to the challenge at hand we pose the following question: "How do we design intelligent systems that empower people to take care of their own health and wellbeing?" Students try to tackle this problem by learning how to develop and design systems together with these people, in a real context and with a real client. Through advanced design processes students learn about working with patients, medical professionals and businesses to develop physical or digital tools that empower people to take their problems into their own hands.

Data collection
Data collection consisted of learning materials, five interviews with individual teachers and coaches, four focus group interviews with three to four students each, surveys about student motivation and collaborative learning, and course-evaluations of five TU/e innovation Space courses, including two honor's tracks.

1ZM150, semester 1: course materials, interview coach, survey (2 measurements: 29+23 responses), 3 focus group interviews students
1ZAUB0: course materials, interview responsible teacher
Honors Track Health: course materials, interview coach, survey (13 responses)
Honors Track Energy transition: course materials, interview coach, survey (5 responses)
F4HS: interview coach; survey data (16+18+3 responses)

Instruments and analysis
In addition to analyses of course materials and student evaluations, semi-structured interviews with teachers and coaches were held. These interviews focused on how teachers and coaches approached interdisciplinarity in student teams in their course, and how they supported and assessed the learning process. Focus group interviews with students focused on how they perceived the design of the course and the support of their learning process.

Analysis of interview results was guided by sensitising concepts (interdisciplinarity, integration, collaboration, structured vs open-ended, group-learning, anxiety and motivation) that were derived from the theoretical background. These concepts were used to categorise answers from interviews, focus group and open-ended questions. The categorisation was validated by the authors, by continuous discussion and evaluation. To increase the reliability of this qualitative analysis, the authors collaborated closely in the process. Points of debate and uncertainty were discussed until consensus was reached.

Motivation and group learning were measured with the nine-item version of the intrinsic motivation inventory (Ryan & Deci, 2000), and the dimensions of social learning framework (Vrieling, Van den Beemt, & De Laat, 2016; Huijben, Van den Beemt, Wieczorek, & Van Marion, 2021).

Results
Interdisciplinarity in innovation Space Projects and Courses
Collaboration
Interdisciplinarity is analysed here as the ways in which collaboration and integration are required and scaffolded. In general, the five included courses show a high level of support for collaboration, for example because teams are composed on an "interdisciplinary basis" (course 1) at the start of each course. Furthermore, the learning goals and assessment show how students develop the ability to contribute and work in a team: "Develop skills in cross functional communication and cooperation" (course 2).

Most often these learning goals are assessed with individual reflection (e.g., the honors tracks) or peer-review tasks (course 2). Issues of team-performance, organization, and direction are most often addressed in weekly team meetings with the coach (honors tracks, course 1, course 2) or workshops (course 1).

Existing literature shows how engineering students are in need of clear signposting and scaffolding, especially for open-ended and complex assignments (Van den Beemt et al., 2020). Team development in the included courses is scaffolded through multiple (non-summative) instruments, such as mini-pitches, weekly team-member scores, and Agile project plans per week. The fact that students have ownership of the problem/challenge and have control over it, is also perceived as well supported and scaffolded, as the interviews with both the coaches and the students showed.

From the interviews appears a suggested role for broadening the scope of interdisciplinary instruction and supervision within courses, including for example:

a. Monitoring and supporting team interactions, beyond peer review, to ensure workload spread (“Team coaching”).
b. Foregrounding interdisciplinarity as a learning goal and aligning assessment better to reward quality of interdisciplinary outcomes (see also 'Integration' below)

Integration

The results show how teachers to a certain extent experience a challenge in implementing interdisciplinarity in their course, for example in aligning learning goals with student support and assessment. Teachers also reported a need for competence development in supporting students, especially in assessing and integrating disciplinary knowledge. For most of the courses this need is reflected in learning goals addressing problem-solving instruments and targets that are largely given by one disciplinary framework. Still, students were encouraged to be open and creative, and assess each other’s value. But in only one course were specific workshops addressed to interdisciplinary team building (course 1). In one of the honors tracks, the course coordinator required students not to work as 'islands'. Students should understand each other’s work but not in-depth, however, they needed to be able to explain to team members what they were doing – their intent and plans.

The criteria for learning goals on integration in the included courses lack clarity and specificity with respect to measuring the level of integration. For example, in course 1, assessment criteria for integration evaluated students in terms of how well they “Identified, envisioned and promoted explicitly the role and contributions of different engineering disciplines. Demonstrated and explained convincingly how knowledge and skills from all different fields were considered in the designed system.” This puts weight on the engineering disciplines, which might bias students towards putting most energy into the engineering side of the problem, but it is also unclear with what is meant with 'explicitly' and 'convincingly'. Still, it does demand that students with more than one engineering group think about the role of their different technical fields in the project.

Integration is sometimes defined in learning goals as "synthesis." For example: students will "Develop a problem-driven, creative and integrative design, resulting in an original and validated prototype that balances desirability, feasibility and viability." (course 1). It is thus expected that the prototype will at least score well on each of those three categories. However, none of these goals or criteria give any real solid meaning to what could be meant by integration here, except the ability to produce a design which scores jointly well on viability, feasibility and desirability.

That said, an interdisciplinary project outcome is expected to emerge by virtue of this set-up, even if it is not an interdisciplinarity necessarily governed by the bachelor's degrees of the students. Further, although interdisciplinarity is not a learning goal in most of the included courses, students were required to make sense of concepts relevant to the challenge, from their own disciplinary perspectives. This is overall a kind of integrative task.

Considerations for assessing interdisciplinary content (in TU/e innovationSpace)

If interdisciplinarity is to be a learning approach, then there needs to be more incentives for the students to think about integration. Assessment is a relevant tool here for creating such incentives.

Observations:

1. At present students are perhaps able to treat usability, feasibility and viability relatively independently.
2. At present students tend to think the entrepreneurial goals (perhaps viability) dominate at the expense of demonstrating other competencies and interdisciplinarity.
3. Entrepreneurial goals are perhaps the easiest to satisfy given the majority of students are from business areas (in course 1 and course 2).
4. The courses have the right learning objectives and basic concepts for interdisciplinarity ("synthesis, integration, etc"). But these concepts can be abstract, and it might not be clear to students how to satisfy them.

Type of challenges

Open-ended vs structured

Project-structure usually has a substantial effect on interdisciplinary learning. And instructors do not always realize that a project-design or structure can push students in different directions, sometimes away from interdisciplinarity. In three of the courses the challenges appeared open-ended. However, the targets students were meant to hit were mostly described with disciplinary frameworks, and thus structured rather than strictly open-ended. For example, in course 1 a framework of technical feasibility, business viability and customer desirability meant that students did not have complete freedom with respect to how they could frame their approach. Technical feasibility weights towards an engineering-based assessment, and business viability towards a business-science based assessment. Customer desirability leaves options for students to bring in different perspectives from fields like psychology. Each three were separately built into the learning goal "Analysis" as distinct requirements, without the prerequisite of an integrated result of analysing them. "Analysis" requires students to be able to analyse their problem from each of these different points-of-view and make a distinct case for each, rather than integrating them.

It should be noted that in innovation Space education technical feasibility, business viability, and customer desirability are considered prerequisites for innovations, and indeed for solutions to challenges. This paradigm allows for challenges to be labelled open-ended, despite a framework defining the how of solving a challenge.

For three courses the "challenge", in the sense of CBL, seem to be interpreted in practice mostly as the c*hallenge of commercialization of technologies*. There is at least an ambiguity there, which may lead to a bias in how students identify challenges and their potential solutions towards business-based solutions, when for instance other social sciences (or natural scientific) approaches may be important or even necessary to effective solutions.

The two honors tracks allow students freedom in taking an approach to the challenge. After students decided upon an approach, they had to familiarize themselves with it if necessary. This is supported by workshops (e.g., research design methods; qualitative/quant research; prototyping; graphic design courses; professional skills courses) on relevant topics related to the subject of the challenge, and through meetings and students' personal-development plans (including plans for knowledge acquisition).

Table 1 (p.14) shows an overview of included challenges and their characteristics. This overview can be summarized as:

- There is quite a variety in problem/challenge structure in Innovation Space. Some challenges are open some are more closed. Some are biased towards one discipline over another, some are not. This indicates a great degree of freedom in how problems can be structured and challenges are not necessarily consistently formulated along these dimensions. This can be a good thing to the extent that students can choose what best fits their profile but can lead to problems down the line of course if the problem structure constrains students from other disciplines from contributing to the extent they would like.
- There are few strict correlations between the categories in Table 1 (again indicating multiple degrees of freedom and the many things to think about). Questions can be open in many respects but still biased towards one field in the way they are framed. They be closed structured but nonetheless prescribe a strategy for integration that is closer to interdisciplinarity than multidisciplinarity. In general, though, open structured problems tend to be broader in the potential knowledge and skills they suggest as relevant. More close-structured problems use that structure to pin down relevant questions and methods, which closes down the problem to just certain fields.

- The entrepreneurship in action (course 2) challenges are just suggestions. They are framed in a very open-ended way. But it is worth noting that other aspects of the course focus on entrepreneurship as the principal goal for students and students will know that how they interpret those questions is not completely open. So, aspects of educational context can shape how challenges/problems are perceived by students, not just the problems themselves, and these too might be biasing.

Student motivation

Students reported high motivation combined with anxiety for open and complex challenges. Over time this anxiety decreased, as students developed knowledge to solve the challenge. Students also reported a need for a clear mapping of learning goals to activities and assessment. For students it appeared often unclear how and on what criteria they would be assessed. Yet, they also reported support in developing ownership, self-directed learning, and collaborative learning.

Regarding social learning, the students showed a hands-on attitude rather than a learning attitude (courses 1 and 2). They appeared focused more on solving day-to-day hassles than developing and working on a team learning agenda including personal learning goals (see also Vrieling et al., 2016, and Huijben et al., 2021).

The honor's tracks address a specific type of students: the ones looking for the extra learning challenge, and for in-depth personal development. The consequence is that honor's coaches search for individual needs in students and adapt their coaching to these needs. TU/e innovation Space project does this to a certain level as well, although the focus appears more on group-level needs. Both approaches, however, require specific coaching skills. During the interviews some coaches expressed the need for competence development on this topic.

Discussion and conclusion

This study explored how interdisciplinarity can be supported in courses that are based on the educational concept of CBL. We focused on collaboration and integration as aspects of interdisciplinarity, and open-ended versus structured to characterise challenges.

Regarding collaboration, the results suggest attention for equal division of disciplines in team selection. This can be solved by attracting students from departments such as mechanical engineering, chemical engineering, or electrical engineering. Furthermore, students are in need of support in bringing disciplines together and learning to speak each other's language. This can be done by weekly team meetings with a coach, and designated workshops. Finally, it is advised to make interdisciplinary collaboration part of the learning goals and assessment, for example with individual reflection or peer-review assignments.

Teachers appear in need of competence development especially on assessing integration and integrating discipline knowledge, and on supporting students in integration and synthesis. Integration can be scaffolded by activities that emphasize the relevant contribution of single disciplines to the challenge, for instance by discipline pitches given by individual team members.

With respect to interdisciplinarity overall it is not suggested that students need to produce a novel or unique methodological approach which goes beyond their existing disciplinary frameworks. However, it appears better to ask students to explain how each part might have contributed to improvement in other parts, or how each discipline was able to accomplish more based on information from other disciplines than could have been accomplished otherwise.

Whatever approach is chosen, it is important to make clear to students how integration will be assessed. The challenge for teachers is to clarify basic concepts for interdisciplinarity (“synthesis, integration etc”), define them in practical rather than abstracts terms, and make clear to students how to satisfy them.

If integration of both engineering fields and non-engineering fields, such as entrepreneurship, are in the learning goals, they should be mentioned explicitly in assessment criteria, to avoid biases with respect to what kinds of integration students think of as important or necessary. If interdisciplinarity is to be a learning approach then there needs to be incentives for students to think about integration. Assessment is a relevant tool here for creating such incentives.

Deeper assessment of interdisciplinary skills can be made by asking students individually at some point in the course to represent their understanding of the other fields in their groups. This would encourage them to seek out this knowledge from others, and explain its relevance. Further to this -more in the line of formative assessment- students could be asked to perform perspective-taking tasks on problems – by being asked to explain themselves how other fields might address or perceive the task.

However, generating constructive alignment between learning goals and assessment procedures raises significant challenges, especially when students from different disciplines collaborate. Because CBL evenly values the process of working towards a solution, it should stimulate forms of assessment balanced between product focused assessment and process focused assessment. In product focused assessment the deliverable represents what is learnt in terms of content knowledge and understanding, and the mastery of real-world skills. Process focused assessment evaluates whether the knowledge and skills have been obtained, also known as assessment for learning, which includes feedback loops and meta-cognition. The balance between these two stands for the extent to which intended learning behaviour becomes visible in both product and process, known as 'assessment as learning'.

From our results can be concluded that challenges need not necessarily be fully open-ended. It appears more important that students have ownership of the problem/challenge and have control over it, and that this ownership is well supported and scaffolded, and that structured problems are balanced, or at least not too unbalanced. Scaffolding can be done by encouraging students to cross boundaries themselves and take on different roles and developing different expertise. This potentially allows students a much deeper insight into interdisciplinary work, by gaining the perspective of how others using other methods might think.

Motivation for working on challenges appeared high in this study. However, this was combined with anxiety for the challenge and stakeholders. The result was that students develop a hands-on attitude, rather than a learning attitude, by focusing on daily hassles of the project. It is suggested to support students in developing a learning attitude by helping them develop and reach individual and team learning goals.

The results contribute to our understanding of challenge design and how interdisciplinarity can be situated in this design. It offers starting points for research on motivation and collaborative learning in CBL.

7. Suggestions for educational practice

Characterising interdisciplinarity in innovation Space education

1. Challenges appeared open-ended. However, the targets students were meant to hit were mostly described with disciplinary frameworks
2. Courses show a high level of support for collaboration
3. Learning goals and assessment show how students develop the ability to contribute and work in a team
4. Although interdisciplinarity is not a learning goal in the courses, students are required to make sense of concepts relevant to the challenge, from their own disciplinary perspectives; the alignment between learning goals, course design, and assessment not always support interdisciplinarity
5. Learning goals and assessment show difficulty in measuring/evaluating the level of integration in student work
6. Although integration of engineering fields is mentioned in the learning goals and assessment criteria, non-engineering fields such as social scientific aspects, are not mentioned explicitly which may create biases with respect to what kinds of integration students think of as important or necessary
7. The learning goals demand student groups to think about the role of their different technical fields in the project
8. These learning goals are assessed with individual reflection, or peer-review tasks
9. Team development is scaffolded through multiple (non-summative) instruments
10. Teachers to a certain extent experience challenges in implementing interdisciplinarity

Advice for improving interdisciplinarity in innovation Space challenges

1. Develop a learning attitude among students, rather than a hands-on attitude. This can be supported by a clear mapping of learning goals to activities and assessment. Furthermore, requiring team learning goals, and how to obtain those goals supports this learning attitude.

2. Students should be able to demonstrate in the final report (in the synthesis section) how technical understanding and knowledge was integrated into their projects, and how it informed their entrepreneurial choices in a dynamic way and also perhaps how it improved the scientific robustness of their case. This can be an explicit requirement in the final report. This helps elaborate for students what is meant by integration in this course. Demonstrations can be visual showing for instance feedback loops in decision making (in which case students should keep track of them and report during interim tasks). Give an example of such a demonstration to students.
3. Students can be informed on the potential correlation between deeper use of technical knowledge (and social scientific knowledge) and entrepreneurial outcomes.
4. “Integration” should be clearly defined in the course materials and learning goals, to make clear to students how it will be assessed at the end of the course.
5. The mini-discipline pitches and workshops could be deepened to convey more information.
6. There is a risk with the current set-up that the perceived emphasis on business goals means that students might not be aware of the value or nature of the required technical contribution, which could be more explicitly represented.
7. Deeper assessment of interdisciplinary skills can be made by asking students individually at some point in the course to represent their understanding of the other fields in their groups. This would encourage them to seek out this knowledge from others, and explain its relevance. More in the line of formative assessment- students could be asked to perform perspective-taking tasks on problems – by being asked to explain themselves how other fields might address or perceive the task.
8. Instructors should reflect on project-design and reflect on whether designs facilitate interdisciplinarity well, taking in mind other learning goals and other aspects of the educational context which guide students.

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Table 1. Problem/Challenges formulations and their Interdisciplinary Content

Categories:
Structured: the problem/challenge instructions outline specific targets and criteria to be met in order to constitute a good solution, defines the fields, methods or approaches, or technologies, that should be involved (each of those can be more or less structured/detailed/precise). Highly structured problems also set out necessary steps or intermediate goals for solving the problem. Open problems/challenges set few constraints on the method or allowed solution.
Modularity or ID vs MD: does the problem description suggest a problem which can be pre-divided along disciplinary lines or pre-structure it along those lines through setting specific disciplinary targets or applying disciplinary constraints.
Knowledge and skills foregrounded: what kinds of disciplines are relevant given the problem description. Does the problem invite many perspectives to contribute or perspectives with are quite distant. These are labelled broad. NB: if not labelled it is because the challenge is in between.
Imbalances: does the problem/challenge description put more weight (implicitly or explicitly) on one disciplinary contribution over another.

Challenge	Open vs Structured	Modularity (or ID vs MD)	Knowledge and skills foregrounded: broad or narrow scope	Imbalances? (business v engineering)
Course - *Innovation Space project*				
A gentle eye	Relatively close structured – using existing technology with constraints on solutions (unobtrusive and ethical)	Business tasks and design tasks are mostly separable – the business case be run with little input from the technology and vice-versa – (**MD**)	Business analytics; design; ethical insight	none
Airport mobility	Relatively open structured – type of transport is open, few constraints	Business and engineering tasks are relatively integrated (close to true ID)– transport solutions require business feasibility at the outset. (**ID**)	Business analytics; sustainability; smart systems; transport engineering	Weight is put on the engineering side: “new smart way of transportation for passengers which is attractive, sustainable, feasible and scalable, and which can be

				tested in a live operation”
Biorhythm tracker	Relatively open structured – the goal is to track biorhythm but without a set technology and strict of set of functional goals for that technology	Depends on the strategy since this is so open	• Signal processing and machine learning • computer science- algorithm • Define product specifications and design user interfaces * Biology of biorhythms. - **broad**	Weight is put on the engineering and computer science tasks compared to the business tasks.
Digitally transforming the transportation industry	Relatively close structured – task domain is limited to reconfigurations of existing technologies and to making a business case: but few constraints are put on how to solve the problem otherwise so completely closed	Closer to a monodisciplinary challenge hard to see how such a problem could be decomposed amongst different disciplines	Business analytics including stakeholder analysis and business model development - **narrow**	Weight is put on business: “Instead of taking the traditional technology- push approach, we expect you to clearly focus on these current and future needs of the different actors in the transportation industry, using existing or new technologies as enablers instead.”
Future of human computer interaction	Relatively close structured- design an application for existing technology for engineers and designers. Application otherwise open	Limited **MD**: mostly a computer-based problem with some role for business	Computer science; business science - **narrow**	Weight towards application development; business limited potentially to obtaining customer feedback.
Human- technology interaction on an emotional level	Close structured: existing technology and somewhat well-defined set of measurement goals.	Closer to **ID**, students will have to integrate information from biology plus information from an artist.	Biology (of emotion); computer science; biomechanical engineering; aesthetics - **broad**	(no business here) Otherwise none.

Solving the drought challenge in Brabant: watermill landscapes	Relatively open-structured: an existing basic technology framework (the water-mill) but the goals of what to do with that (how to modify it; which targets to aim for) left up to students	Closer to **ID:** potential problem solving goals range across a variety of technology, environmental and social aspects. These are not easily separable.	Civil engineering; hydrology/soil systems; drought science; water management; economics; energy science -**broad**	None
Entrepreneurship In Action (suggested challenges)				
Dirty Public Toilets	Open-structured – no real constraints – just the challenge.	Depends on how the problem is further refined by students	Open to an entrepreneurial/economics/business based, engineering, or social science based solution - **broad**	None
Preventative healthcare	Open-structured – no real constraints	Depends on how the problem is further refined	Open to any social science, plus technological approach - **broad**	None
Falling riders in tour de France	Bit more structured but largely open – a clear goal to protect the skin of riders which narrows in on engineering	Depends on how the problem is further refined -> students have a basic choice over whether to refine the question to necessitate integration or not.	Materials engineering and perhaps biomechanical engineering. - **narrow**	Bias towards engineering
F4HS				
Health and Safety Challenge	Relatively open-structured but several constraints on a food solution (e.g. sustainable; food experience etc)	Suitability, sustainability and satisfaction somewhat decomposable and could be dealt with separately but only once a basic approach is agreed upon i.e.	logistics, sustainability, design, experience, and health - **broad**	None

		the problem/challenge formuation is open to both ID and MD approaches with a lean towards MD.		