Challenge based tasks for fundamental knowledge

Innovation fund proposal

1. Details of applicants[1]

Who	Affiliation	Role	
Dr. Ruurd Taconis	ESoE	Project leader	
Prof. dr. Ton van Leeuwen	ESoE / Applied Physics	Team member	
Prof. dr. Henk Swagten	Applied Physics	Supporting	
See project: Signals & Systems AP-EE-ME: implementing inter-disciplinary challenge-based learning)	Mech. Engineering	Supporting	
	Electrical Engineering	Supporting/ Teacher	
Ir. Peter Janssens	Chemical Technology	Supporting	
Dr. Martijn Wienk	Chemical Technology	Supporting / Teacher	

2. Background and justification of the project

Challenge based learning is a cornerstone of the TU/e innovation strategy 'onderwijs 2030' strategy (TU/e, 2018). Challenge based learning in multidisciplinarity groups can be a tremendous step ahead, fostering students motivation, engagement, collaboration skills, multidisciplinary skills and problems solving skills. It also contributes acquiring and integrating knowledge, from a practical perspective in particular.

From a theoretical point of view, challenge based learning may also call forth questions concerning the learning outcomes, specifically concerning systematic and coherent theoretical knowledge and deep (theoretical) understanding. These questions arise particularly in the classical disciplinary studies/departments that emphasize theoretical in-depth knowledge and understanding. A worry may be that the transition to challenge based learning leads to a reduction of the level of fundamental understanding that the students achieve. Key theorists consider 'theoretical learning' and 'project based learning' alternative but somewhat overlapping metaphors/methods of learning (Paavola & Hakkarainen, 2005; Sfard, 1998), each with their own strength and weaknesses but also supplementing each other.

Complexities concerning the learning of theoretical knowledge and understanding in 'open' educational models related to 'challenge based learning' are found throughout literature. Gijbels, Dochy, Van den Bossche, and Segers (2005) - for example - conclude on the subject of Project Based Learning (PBL) that 'PBL had the most positive effects […] on […] principles that link concepts' and also find a positive learning effect concerning the 'linking of concepts and principles to conditions and procedures for application'. However, learning outcomes concerning the 'understanding of concepts' were found to be negative more often than positive. This is in line with findings by Hmelo-Silver (2004) who emphasizes that PBL 'offers the potential to help students develop flexible understanding and lifelong learning skills', but cannot claim that it would lead to more/deeper theoretical understanding. This seems in line with results are reported on Design Based Learning (DBL). Fortus, Dershimer, Krajcik, Marx, and Mamlok-Naaman (2004) who emphasize that the (potential) outcomes of DBL concern practical understanding of science problems, and skills. Literature on secondary STEM education also indicates that the students' cognitive efforts may tend to focused on completing the challenge, not primarily on to the learning (knowledge acquisition, theoretical understanding) itself (Bennett, Lubben, & Hogarth, 2007; R Taconis & den Brok, 2016).

Hence, challenge based learning may be expected to be 'less efficient' for acquiring 'theoretical knowledge' (Biggs & Tang, 1999), though it can/will have advantages in the field of practical knowledge and knowledge use,

[1] The project application must clearly state that the project is submitted with the support of the department(s) or capacity group(s). If the project has dependencies with other faculties, departments or teachers, they also have to be named as applicants.

skills and probably motivation, and collaboration skills. So, learning in Challenge Based projects will not automatically lead to 'complete and theoretical coherent knowledge'. However, it will lead to flexibly applicable knowledge, though possibly organized otherwise. More precisely: if the main focus is on completing the challenge, the learning process leads to (mainly) the knowledge and skills required to complete this (and related) challenges. Hence it may be expected to bear particular characteristics, that can be influenced by the precise architecture of the tasks. This is the central issue to be addressed in this project: to help make challenge based learning optimal in terms of the knowledge/understanding produced. Some key issues are:

- From a structural point of view, it may be relatively disjointed **(Issue 1** to be considered concerning theoretical knowledge learned through challenges). It is mentally organized in practically oriented 'schemata' (Mandler, 2014) with relatively few 'fundamental' interconnections (R. Taconis & Janssen, in preparation);
- These contain elements specific for the particular task(-type) or challenge they were learned in (e.g., problem solving, design, ...) that may help to perform this and akin challenges, but may be less helpful or even misleading in challenges that differ in some critical aspects (Ruurd Taconis, Ferguson-Hessler, & Broekkamp, 2001) **(Issue 2);**
- Paradoxically, it may result in 'chunks of application-tied knowledge/skill', that will be 'limited in versatile usability', although (actually: because) these chunks were acquired/constructed in only one (very specific) situation **(Issue 3);**
- Open challenges allow for solutions within a certain bandwidth. Hence, students may choose a route that is less knowledge-intensive. Such unwanted superficial solutions should not be rewarded if the acquisition of knowledge is an (additional) aim of the challenge-based learning, but it may lead to some knowledge theoretically considered relevant to be missing in the knowledge base of students **(Issue 4);**
- Student work may also vary in the knowledge they actually use and 'learn'. Students may choose a route that leans on another body of knowledge then intended to be applied. Such alternative routes and solutions should not be rewarded if unwanted, but it cannot be totally avoided that various students use and learn different bodies of knowledge when completing a particular challenge. From a curricular perspective, this may create a problem, since it becomes less clear what knowledge students exactly know/master at a particular stage in their university career **(Issue 5).** Though attractive from the perspective of 'individualized learning routes', there will probably be practical limits and probably strategical/managerial limits to this. In particular in relation to examinations (examination boards), regulations, and laws.

Theoretically well-structured knowledge may sometimes be more versatile in applicability than knowledge that is tied to one specific situation. Acquiring a 'theoretical meta-structure' could make the subject-knowledge acquired a more efficient 'cognitive tool' to address new challenges and solve new problems.

One way to prevent students from acquiring knowledge that is tied too close to the particular challenge it was acquired in, is to let the students perform various challenges within one knowledge domain. But this does not create 'theoretical completeness and coherence' and is limited in practice due to the large amount oftime that must be invested to make it effective. Having the students to study 'worked examples' {R. Taconis, 2013) is more time-efficient. Another approach combines challenge-based tasks in the curriculum, with theoretically oriented task, continuously moving back and forth from one to the other. Here, the theoretical tasks may precede de challenges but may also 'follow' the challenges. Finally, encouraging reflection on the 'solution chosen' and the 'choices made' and commenting on the solution of peers may help to restructure the knowledge acquired to fit into a more theoretical meta-structure.

Apart from the above, literature shows some more fundamental directions to help students to create a theoretical meta-structure, preferably within a challenge-based task. It is the aim of this project to make these available for TU/e in a practical form that supports various initiatives undertaken to innovate and create challenge-based education. Some of which have been tested in higher education and/or secondary education in particular. One possible solution involves a so called 'boundary object': the task should provide the student with an objective (object) that is part of both the 'theoretic system of physics' and the 'practical (engineering) system of physics' (Akkerman & Bakker, 2011). Challenges considered examples of this are: Write a chapter of a book on this physics/chemistry/.... - subject; create an exam-question for this physics/chemistry/.. - subject, or playing a serious game that requires the quantitative modelling/predicting in a competitive setting.

3. Objectives and expected outcomes of the project[2]

This project will address the issue of knowledge acquisition in challenge based learning in a practical way. The aim is to inspire and support teachers/projects creating challenge based learning that also want their students to acquire theoretical integrated knowledge and understanding. This can be subjects/courses already taught in a more-or-less challenge based form, but also projects that re-design a subjects/courses currently classically taught into a 'challenge based courses'.

As indicated above, this is partly done by making available the results and ideas found in literature in a practical form for teachers throughout TU/e. Secondly, it is done by the in-depth analysis (structure, completeness etc.) of the knowledgebase and understanding students acquire as a result of challenge based education and its particular characteristics.

Currently, two projects/subjects are included in this project. At AP, EE and ME a project has started on implementing interdisciplinary challenge based learning for the subject of Signals & Systems. At the department of Chemical Technology, the subject of 'DBL nanotechnology' is challenge based and emphasizes mainly the acquisition of appropriate skills and attitudes. Yet, knowledge will be acquired, and this provides an important opportunity to compare the structure and completeness of the knowledge acquired.

Outcomes of the project are:

- Improved challenge based education for the subjects involved. That is: challenge based education optimized for acquiring better theoretical knowledge/understanding (this involves both the tasks and the teaching behavior; the latter being included but not emphasized in this project).
- Best practices: both tested and theoretically underpinned from experiences at AP/CT/EE/ME.
- Formats for challenge based learning to be used at other departments also. Understanding of the merits and affordances derived from the projects/subject included. This leads to a) a 'model' of deepened challenge based education, and b) practical guidelines for creating deepened challenge based education, that can be used for other courses in other departments.
- Insight in the production of 'theoretical knowledge' in challenge based learning (PhD level-to be discussed). Thus contributing to building"up a body of knowledge/expertise in creating/implementing challenge based learning at TU/e.

4. Project design and management[3]

Ultimately, the project contributes to answering: What are the outlines (composition in terms of task-types, organization, etc.) of a challenge based curriculum that harvests on the promises of challenge based education on one hand, and leads to theoretically complete and coherent theoretical knowledge on the other?

Key questions in the project are:

1) How can we typify the desired type of 'theoretical knowledge' in terms of measurable characteristics (e.g. coherence, completeness, level of generalizability of 'rules of applicability', etc.)? This provides us with an underpinned way of mapping the learning results in terms of knowledge and deep understanding,
2) What are known best practices and formats for challenge based learning tasks that (also) lead to the desired knowledge and understanding? In particular: what characteristics of challenge based learning tasks influence this type of outcome. This leads to an overview of best practices and underpinned formats for 'deepened challenge based learning'.

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[2] The project should be and educational innovation, so the objectives should be about the educational added value. Moreover, the expected results and dissemination activities must be clearly outlined.
[3] What activities will be undertaken, and in which order? What is the timeframe of the project? How will success (or failure) be assessed, or established? Which are the risks for the project?

3) How can challenge based learning tasks be designed which maximize such learning outcomes? In this, the project seeks a perspective overarching various engineering subject and this may concern various forms of challenge based learning (e.g. design, problem, ...). But the projects primarily focusses on the courses involved, for which it contribute trough advise and co-creation.

Methods

The method comprises: harvesting on the vast international literature shedding light on these issues (review) in order: a) to identity models that proved effective, b) to identity relevant knowledge characteristics and set-up a way to map the acquired knowledge as to evaluate its (wanted) characteristics, and c) to identify best practices in challenge based teaching. And in practice by using case studies: d} analyzing (multi method approach) current challenge based learning practices at TU/e and their outcomes. Currently there is an agreement for subjects at the departments AP, ME, EE and CT.

In addition, the project will contribute to the (re) design of the courses involved (question 3). This will be done in co-creation with the teacher(s) and the ESoE researcher(s). A design research methodology (Van den Akker, Gravemeijer, McKenney, & Nieveen, 2006) will be applied. In this, the revision of the educational tasks and teaching approach alternates with the thorough evaluation of teaching and results (in terms of knowledge and understanding). The instruments to be used are: a checklist and an observation schema on the basis of the literature review, and concept mapping interview. Both approaches are based on instruments found in literature (Donnelly, 2017).

5. Dissemination and sustainability of the project' [5]

Communication with teachers and projects creating 'challenge based learning' goes both ways: data are collected and support and advice is being provided during the run of the project. Apart from this support, outcomes will be a practical guideline for developing challenge based learning that includes systematic knowledge and understanding, on the basis of models and best practices of proven value.

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[4] The application should have a clear sustainability strategy for the project. Who will use the products/outcomes, and who are the potential users once the project has been successful? How are these potential users going to be informed about the project, its progress and outcomes?

[5] Because these funds are part of the 4TU (supported by the government) and are assigned to the 4TU.CEE, a presentation at TU/e session organized by 4TU.CEE is a compulsory part of the dissemination activities. Moreover, all projects, and their products and outcomes, are disseminated via the 4TU.CEE website, and all project products will become freely available to all TU/e lecturers. Hence, reporting has to be in English.

[6] The Bachelor College and Graduate School assume that the applicants will themselves bear the costs over and above the contribution from the Education Innovation Fund, in accordance with the proposed budget.

8. Literature

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Taconis, R., & Janssen, F. (in preparation). Perspectives and tasks and the structure of physics knowledge.

TU/e. (2018). TU/e strategy 2030: drivers of change. Lanaken

Van den Akker, J., Gravemeijer, K., McKenney, S., & Nieveen, N. (2006). Educational design research: Routledge.

[7] The proposal has to be signed by the main applicant and his/her director of department (managing director), in addition to the teacher(s).