

COLLABORATIVE COURSE DESIGN IN ENGINEERING EDUCATION – A CASE STUDY OF TEACHERS’ DESIGN PROCESS

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ABSTRACT

Due to changes of the labor market and increased competition on an (inter)national scale, institutions of higher education are forced to innovate, creating an additional need for teacher professional development. In engineering education, interdisciplinary education has become increasingly important, bringing many advantages for both students and teachers. Instead of being individually responsible for a course, teachers collectively design and teach courses that integrate their areas of expertise and make interdisciplinary education a reality. However, to better support teacher teams and their professional development, higher education institutions require more information on their course design processes. This case study compares the course design processes of two teacher teams in the context of a university-wide educational innovation. One team chose to create an interdisciplinary course, whereas the other chose to design a multidisciplinary course. Design conversations of these teams were analyzed to study the similarities and differences between both teams concerning the design topics and design acts shown during team meetings. Our findings show that both teams primarily focus on the same three design topics: the teaching practices, course organization, and their own teamwork. Other important topics such as the specific characteristics of the student population were mostly neglected. When comparing the specific design acts of the two teams, the interdisciplinary team more often engaged in collaborative planning and adaption of the course and also engaged in more collective reflection compared to the multidisciplinary team. In doing so, the interdisciplinary team created more opportunities for professional development of its team members.

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1 INTRODUCTION

1.1 Collaborative course design to further educational innovation

There is an ongoing demand for higher education to change its focus from monodisciplinary education focusing on one discipline at a time to educational approaches that integrate different disciplines such as in interdisciplinary or thematic education. This demand is placed on both graduate and undergraduate education, for example in engineering, health care, or business.^[1-2] Changes of job market requirements and increased (inter)national competition between universities makes educational changes necessary.^[2] For engineering education, interdisciplinary education has for example become increasingly important to meet the changing job-market needs.^[3] The challenges for higher education not only call for pedagogical changes, but also changes in the way education is designed. Teachers in Higher Education, being used to a high degree of autonomy, are more and more required to work together in multidisciplinary teams, and collaboratively design courses that allow for the integration of various disciplines.^[4] Collaborative curriculum design has been shown to be an effective strategy for ongoing educational renewal and corresponding professional development of the teachers involved.^[5-6]

However, it is one thing to promote collaboration among highly qualified academics, it is quite another to succeed in practice. Collaborative course design practices confront teachers with major challenges.^[5] A planned innovation may result in completely different outcomes as originally intended. The design process of any new course requires making many decisions about the content and teaching methods of the unit, as well as practical decisions regarding organization and scheduling. This holds for both individual teachers as for teacher teams. Practical decisions may feel as more pressing matters and may put off the importance of taking pedagogical decisions. Consequently, intended changes or innovations are not implemented as planned, resulting in conservative courses: the innovation failed because of urgent other matters.

The present study unwraps essential conditions of the course design process conducted by teacher teams engaged in innovative course design in undergraduate engineering education. We focus on collaboration within teams by assessing design conversations topics, the cognitive demand of specific design tasks, and the evolution of these topics and design tasks over time. This study aims to provide a clearer understanding of how multidisciplinary teacher teams can prepare and provide education that better prepares students for the complexity of their future profession and also supports the necessary professional development of the teachers involved.

1.2 Conceptual framework

As is the case with any design process, the design cycle of a new course requires teacher teams to go through the stages of preparation (phase 1: planning), teaching (phase 2: enactment) and evaluation (phase 3: reflection). During each stage,

teachers discuss various *design topics* that involve the content and teaching methods of the course on the one hand, and the organization of the unit on the other hand.^[7] Finally, when discussing important design topics, teams engage in various task-related actions, which we refer to as *design acts*. These design acts can be divided into five categories of increasing cognitive demand (see Figure 1). Design discussions of teacher teams should involve higher level design acts to ensure that important topics are discussed with sufficient depth.

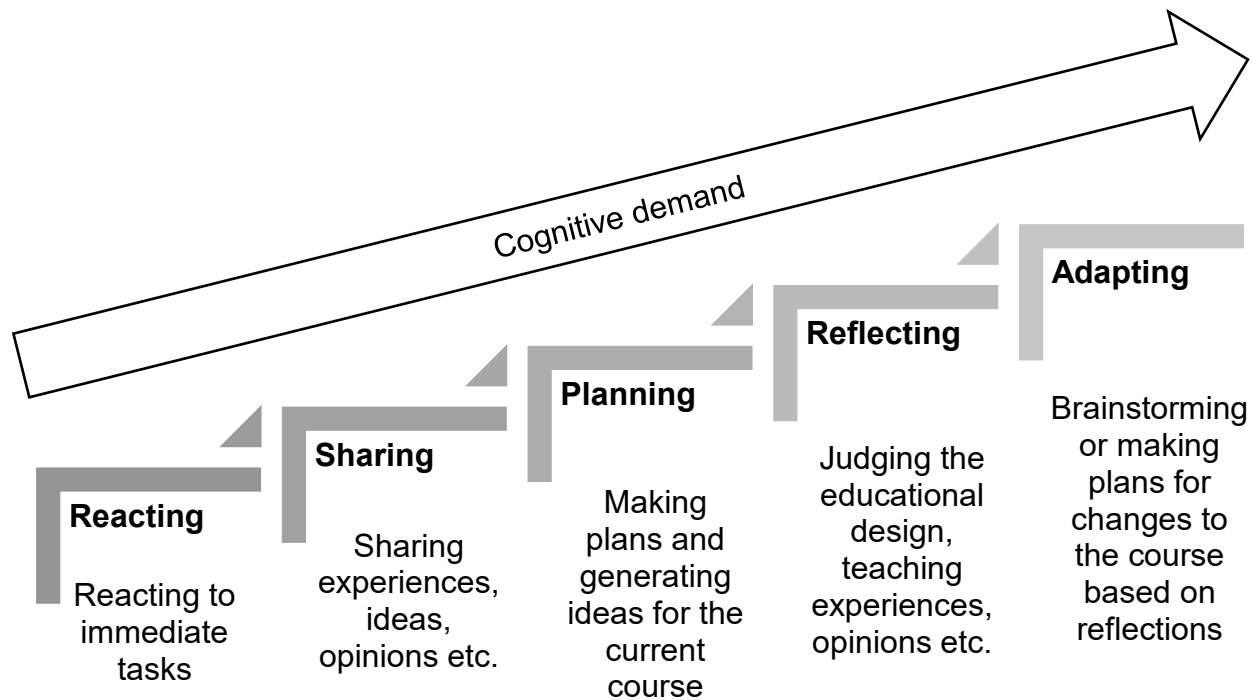


Fig 1. Higher and lower levels of design acts in teacher teams^[7-8]

A collaborative design process can be challenging as failing to keep to the steps of the design cycle, to focus on all important design topics and to engage in higher level design acts, will ultimately threaten educational change as well as the professional development opportunities of the team members.

The design cycle: During each stage of the design cycle, teams have to overcome various challenges that are related to the design topics and the design acts they perform. For example, teams need to make sure not to prioritize practical decisions over pedagogical needs (1st phase), to monitor their design and allow themselves to adapt it to the needs of the students (2nd phase), and to employ a meta perspective and critically reflect on their own design and implementation (3rd phase). However, keeping to this design cycle can be a problem for teachers who lack the knowledge and/or skills to do so. Research has shown that design conversations are often shallow, and limited by a lack of design skills.^[9]

Design topics: During collaborative curriculum design, multidisciplinary teacher teams need to discuss a variety of design topics. They not only need to decide on the content of their course, but also on the teaching or assessment methods they want to use. In doing so, they have to make sure that they meet the needs of the student population. However, previous research in secondary education has shown that teachers have a tendency to focus more on urgent and pragmatic components of a curriculum, neglecting the pedagogical basis for their design decisions.^[10] For innovative teams this could mean missing the point of the innovation (adapting the content and methods of the course to the changed needs of students and the job market) completely.

The design acts: Instructional design involves a high level of precision and expertise, is cognitive demanding and requires higher order thinking skills (see Figure 1). Research has shown that cognitively demanding conversations are not only crucial for the design of a new course (as important issues are discussed with sufficient depth), they also create valuable learning opportunities for teachers.^[7] When teams do not engage in higher level design acts such as collective planning by building on each other's knowledge, interdisciplinary education will fail as teachers are not able to truly combine their disciplines and further develop their educational design.

A shift from traditional monodisciplinary education to interdisciplinary education is difficult to make. It requires that teacher teams are supported in this endeavour.^[1] However, research on educational design issues in the domain of education seems to be missing. It is therefore crucial to zoom in on teams' design conversations to determine how teams can best be supported. The present study examines the following three questions:

- 1) *What topics are discussed during teacher teams' design conversations?*
- 2) *How do types of design acts vary among the different topics of the design conversations?*
- 3) *How do types of design acts vary in relation to the topics of teacher teams' design conversations during the phases of the teams' design cycle?*

2 METHODOLOGY

2.1 Setting

The present study was conducted at a Western European university that had recently introduced a curriculum innovation for all bachelor programs in the university, making the step from traditional lecture-based education to project-based education. This innovation required teachers for the first time in their careers to work together in teams to design new courses. These courses put a student project at the core of the course, supported by lectures, tutorials etc. Twelve teacher teams were formed for each bachelor programme. ^[11] Teacher teams had a high degree of autonomy in designing the new course with respect to course contents and choice of teaching methods. The teams were required to create courses that included a central project

and integrated various disciplines. However, the specific design of the course was left up to the teacher teams.

2.2 Sample

Two teacher teams, one from the civil engineering and one from the applied mathematics study programs, both consisting of six teachers, participated in this study. The teams also included teachers from other disciplines such as governance studies and educational sciences, respectively. The members already had several years of teaching experience. Each team was assigned a designated team leader. Both teams were among the first to design integrated courses at this university. The teams were selected for the study based on the comparable amount of team meetings during the course design cycle.

2.3 Analysis

Team meetings of both teams were audiotaped and transcribed. The transcripts were divided into meaningful utterances (i.e. one speaking turn) and coded regarding the topics and design acts involved. A total of 10 different design topics were deductively and inductively coded: Pedagogical knowledge, content knowledge, pedagogical content knowledge, scheduling, teamwork process, student population, student feedback, student learning and off topic (see Table 1). All five design acts (Reacting, Sharing, Planning, Reflecting, Adapting) were coded. The inter-rater reliability of .87 (Cohen's Kappa) shows the validity of the findings. To answer the research questions, the percentage of utterances of each design topic was calculated, followed by the percentage of design acts per topic. Finally, the percentage of topics per design act was calculated for each phase of the design cycle. Based on these calculations, the design processes of both teacher teams were compared.

3 RESULTS

Providing the teacher teams with a high amount of freedom concerning the design of the new courses led to two different educational approaches. Whereas team A chose to create an interdisciplinary educational module, team B chose to create a multidisciplinary module.^[3] In the interdisciplinary module, various disciplines and a project were closely integrated. In the multidisciplinary module different disciplines were added to one another instead of being integrated. When looking more closely at the design conversations of both teams, some similarities but also important differences can be seen concerning the design process.

In both teams, the vast majority of utterances involved *pedagogical content knowledge* (e.g. talking about aligning the content of the course with suitable assessment methods) followed by *scheduling* of teaching activities and talks about the *teamwork process* of the teacher team itself (see Table 1). Other important design topics such as the student population or discussions about how student learning can best be supported were (mostly) neglected.

Table 1. *Percentage of utterances spend on various design topics*

	Pedagogical knowledge	Content knowledge	Pedagogical content knowledge	Teaching values	Scheduling	Teamwork proces	Student population	Student feedback	Student learning	Off topic
Team A: Interdisciplinary	8%		56%		14%	12%				
Team B: Multidisciplinary			35%		23%	19%		9%		

Note. Only results above 5% of utterances are reported; percentages were rounded.

Furthermore, when comparing the two teams, the results show that design acts varied greatly between both teams as well as among design topics. Team A engaged in more higher level design acts (reflecting and adapting) than team B. For both teams, and especially for team A, higher level design acts were mostly connected to the topic of pedagogical content knowledge (see Table 2 & 3).

Team A also engaged in reflecting and planning for the topics of scheduling and the teamwork process itself. Other topics were not discussed with this level of cognitive demand, limiting the learning opportunities for team members of both teams. Crucial topics such as the student population were almost never discussed and if they were discussed, the conversation involved low cognitive demand. The fact that team A engaged in more higher level design acts compared to team B could be explained by the different educational approaches of both teams. Whereas the goal of a high level of integration of different parts of the course asks for a more collective planning (Team A), the multidisciplinary design of the course of team B involving more separate unit components made it easier to divide tasks and not engage in collective design acts of a higher cognitive level. As shown in the case of team B, this practice can be problematic as it withholds teachers from in-depth conversations and is therefore a missed learning opportunity for them. Furthermore, combining disciplines to reach interdisciplinary education becomes difficult and the educational innovation is not implemented as intended.

Finally, for team A the level of design acts involving pedagogical content knowledge also increased during the design cycle (see Table 2). The design acts of other design topics however stayed on a low level during the whole design cycle. Team B showed no actual increase in level of design acts during the design cycle (see Table 3) apart from some reflection in the second phase. Especially the lack of the higher level design acts of reflecting and adapting in the third phase of the design cycle is apparent.

Table 2. *Percentage of topics per design acts per phase of the design cycle: Team A (interdisciplinary)*

Phase of design cycle	Design act	Pedagogical knowledge	Pedagogical content knowledge	Scheduling	Teamwork process
1 st Phase	Reacting	8%		9%	14%
	Sharing	18%	9%		7%
	Planning		22%		
	Reflecting				
	Adapting				
2 nd Phase	Reacting			7%	
	Sharing		11%	5%	
	Planning		51%		
	Reflecting		6%		
	Adapting				
3 rd Phase	Reacting				
	Sharing		18%	7%	
	Planning				
	Reflecting		16%		
	Adapting		21%		

Note. Only results over 5% of utterances are depicted; percentages were rounded.

Table 3. *Percentage of topics per design act per phase of the design cycle: Team B (multidisciplinary)*

Phase of design cycle	Design act	Pedagogical knowledge	Pedagogical content knowledge	Scheduling	Teamwork process	Student Feedback
1 st Phase	Reacting			16%	15%	
	Sharing	6%	23%	16%	6%	6%
	Planning					
	Reflecting					
	Adapting					
2 nd Phase	Reacting				8%	
	Sharing		36%			12%
	Planning					
	Reflecting		10%			
	Adapting					
3 rd Phase	Reacting				7%	
	Sharing		30%	27%	17%	6%
	Planning					
	Reflecting					
	Adapting					

Note. Only results over 5% of utterances are depicted; percentages were rounded.

4 SUMMARY

The results show that independent of the educational approach chosen, it is difficult for teams to engage in higher level design acts. However, for some topics such as pedagogical content knowledge a cognitively demanding discussion might come more natural than for other topics. Furthermore, a more interdisciplinary teaching approach makes the engagement in discussions involving higher level design acts (such as collective planning, reflecting and adapting) necessary, whereas this is not necessarily the case for a multidisciplinary teaching approach. This study shows that teacher teams have the potential to support the shift from monodisciplinary education to interdisciplinary education as it is demanded from both undergraduate education as well as from professional education. When teacher teams meet the right conditions, teachers can learn from each other and truly combine their disciplines in new courses that better prepare students for the new demands of the job market. However, although literature on professional education is pleading that collaboration of teachers (and other stakeholders) can make interdisciplinary education a reality, this study shows that this is not easily done. Teachers often lack design experience and tend to prioritize specific design topics while neglecting others and miss their chance to engage in collective reflecting and adapting. However, compared to a multidisciplinary teaching approach, interdisciplinary teaching opens opportunities for teachers to share and build new courses together. In doing so, teachers can create valuable learning opportunities for themselves. A multidisciplinary teaching approach on the other hand seems to hold the danger of teacher teams missing out on valuable collective design opportunities as well as opportunities for their own professional development.

Previous research has shown that teacher teams benefit from the support of a facilitator, which might also be the case here.^[12] Team leaders can also play a crucial role in creating cognitively demanding design conversations that benefit the design of the course as well as the professional development of the team members.^[1] This however requires a preparation of the team leader for the leadership role that focusses on both the design topics that need to be discussed and the skills that are needed to foster cognitively demanding discussions. Furthermore, teams need to be exposed to robust design processes as a good example for their own teamwork. It has become clear that universities cannot expect teams to engage in innovative design processes without supporting them in this endeavor.

REFERENCES

- [1] Koeslag-Kreunen, M.G.M., Van der Klink, M.R., Van den Bossche, P. and Gijssels, W.H. (2018). Leadership for team learning: the case of university teacher teams. *Higher Education*, Vol. 75, No.2, pp. 191-207.
- [2] Graham, R. (2012). *Achieving excellence in engineering education: the ingredients of successful change*. The Royal Academy of Engineering: London.

- [3] Richter, D.M. and Paretto, M.C. (2009). Identifying barriers to and outcomes of interdisciplinarity in the engineering classroom. *European Journal of Engineering Education*, Vol. 34, No. 1, pp. 29-45.
- [4] Borrego, M. and Newswander, L.K. (2008). *Journal of Engineering Education*. Vol. 97, No. 2, pp. 123-134.
- [5] Kezar, A. (2006). Redesigning for collaboration in learning initiatives: An examination of four highly collaborative campuses. *The Journal of Higher Education*, Vol. 77, No. 5, pp. 804-838.
- [6] Vesikivi, P., Lakkala, M., Holvikivi, J. and Muukkonen, H. (2019). Team teaching implementation in engineering education: teacher perceptions and experiences. *European Journal of Engineering Education*, Vol. 44, No. 4, pp. 519-534.
- [7] Author, 2015
- [8] Bloom, B.S., Engelhart, M.D., Furst, E.J., Hill, W.H., and Krathwohl, D.R. (1956). Taxonomy of educational objectives – The classification of educational goals. New York, NY: David McKay Company, Inc.
- [9] Huizinga, T., Handelzalts, A., Nieveen, N., and Voogt, J. M. (2013). Teacher involvement in curriculum design: Need for support to enhance teachers' design expertise. *Journal of Curriculum Studies*, Vol. 46, No. 1, pp. 33-57.
- [10] de Kock, A., Slegers, P, and Voeten, M. J. M. (2005). New learning and choices of secondary school teachers when arranging learning environments. *Teaching and Teacher Education*, Vol. 21, No. 7, pp. 799-816.
- [11] Visscher-Voerman, J.I.A. and Muller, A. (2017). Curriculum development in engineering education: Evaluation and results of the Twente Education Model (TOM), Proceedings of the 45th SEFI Conference 18th-21st of September, Azores, Portugal, pp. 1167-1175.
- [12] Wergin, J. F., Mason, E. J., and Munson, P. J. (1976). The practice of faculty development: An experience-derived model. *The Journal of Higher Education*, Vol. 47, No. 3, pp. 289-308