Towards an aligned design approach for the engineering curriculum

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INTRODUCTION

'Designing' is a core competence for any engineer. Students at the Faculty of Engineering Science at KU Leuven develop their engineering design skills in several integrating team assignments of the course 'Problem Solving and Design' (P&D) throughout the curriculum. The P&D assignments start from the first semester. Working in small groups, the students integrate basic principles of all regular scientific courses to solve engineering problems that gradually increase in complexity and realistic content [1]. In an engineering context, designing is a complex issue that can be considered as a form of problem solving [2]. This inherent complexity, however, makes evaluation of this competence a very difficult activity. Since the implementation of P&D, the staff constantly seeks to improve the assessment of the students, e.g. peer-assessment has been introduced as well as tools for the assessment of written and oral communication [3]. However, although 'design' is defined a core competence in the P&D assignments and in the curriculum at large, this competence is not explicitly evaluated [1]. At the same time students experience a lack of feedback on their design competences, as expressed by students and indicated in quality review reports .

Hence, an educational project was initiated with the objective to develop feedback methods for design competences in the engineering curriculum. This paper reports on the first results of this project.

1 FEEDBACK IN DESIGN PROJECTS

In order to analyze the problem of insufficient feedback, an online survey was carried out to obtain the student's opinions on evaluation and feedback of design competencies in the curriculum. A total of 427 bachelor students in engineering science replied to the survey, of which 40% were first year students, 30% 2nd year students and 30% 3rd year students.

The students stated that 'designing' is sufficiently covered in the curriculum through the P&D-assignments. Yet, they were not satisfied with the quality and amount of feedback on their design competence (76%). With regard to assessment, 83% of the students would prefer more qualitative evaluation methods of their design competence. More specifically the students were asked whether they think that peer assessment would be an adequate means of providing feedback. 88% of the students feels confident to assess the 'design competence' of their peers.

Providing sufficient and adequate feedback seems a common problem in higher education. According to Boud [4] *higher education institutions are being criticized more for inadequacies in the feedback they provide to students than for almost any other aspect of their courses.*

A main challenge of providing feedback in the P&D projects lies in the nature of the assignments, where students work in teams on design projects. Tutors can provide general feedback on the team progress and performance, but it is very hard to discern the individual contribution of each student and to provide tailored feedback on design competence to each student. At the same time a system in which feedback is provided by tutors faces practical problems because of large student numbers and a limited amount of tutor capacity. Moreover we seek for a more student-centered approach in the assessment (both formative, i.e. feedback-oriented, and summative) of design, in which students are supported to actively take on responsibility for their own learning process. Hence, feedback and assessment transform from isolated one-direction activities to part of the learning process itself. This view is in line with a feedback model based on sustainable assessment [4] [5], which involves characteristics as (1) involving students in dialogues about learning and performance, (2, 3) stimulating and supporting student's capacities in monitoring and planning and evaluating their own learning and (4) facilitating student engagement over time by seeking feedback from varied sources on multiple stages of assignments.

2 SELF-ASSESSMENT OF DESIGN COMPETENCE USING ICE RUBRICS

In the start-up phase of the project, it became clear that staff is in need of both improved methods for feedback (or formative assessment) as well as of methods for summative assessment. As described in the previous section, in a sustainable and learner-centred assessment model, both summative and formative assessment are closely connected. It is very hard, if not impossible, to find a single assessment activity that is both summative and formative and that balances between individual and group assessment. Hence, the assessment of large project courses will preferably consist of several assessment activities that can be combined into one model [6]. Existing assessment activities in the P&D assignments are peer assessment, oral presentations for an external jury and written reports. In this section we describe the preliminary results of the educational project in developing a model of assessment and feedback activities.

Developing an adequate sense of your own knowledge and skills is an important aspect of self-regulated learning [7]. Therefore, the first step towards a more student-centered way of assessment of design competences in our educational project was to set up a method for self-assessment. Self-assessment involves comparing one's own learning and performance with certain criteria, in order to become aware of potential gaps in competence. [8]. It has been reported [9] that criteria-referenced self-assessment helps students to increase their effectiveness in identifying strengths and weaknesses and increases their awareness of learning objectives. Other relevant factors in the assessment process are to give students feedback on their self-assessment and to make sure that the self-assessment does not turn into an evaluation by using the results for grading the students.

2.1 Method

We started with developing a pilot test for a self-assessment for the 3rd year bachelor P&D assignment for students in the specialization electrical engineering. The idea was to extend a similar self-assessment to the other P&D assignments in the future, thus building up a set of self-assessments.

For individual students, the results of this self-assessment should be kept accessible in the Blackboard learning environment as part of an individual 'design competence portfolio'. Objectives of the self-assessment are (1) to stimulate students awareness of and reflection on design competences, (2) to explicitly stimulate students to ask for feedback on their performance in design when they feel the need for it and (3) to detect students or project groups who may need special attention, e.g. students who rate their own competence extremely low or groups with low scores on the 'teamwork' aspect of competence.

As a method to develop assessment-criteria we used the ICE (Ideas, Connections and Extensions) approach [10] that has been proven successful for project-based learning in engineering education [11]. In the ICE approach the levels Ideas, Connections, and Extensions represent three different levels of learning growth from novice through to competence and expertise. Ideas being the basic understanding of a concept, Connections describing the ability to relate knowledge and articulate relationships among elements and Extensions showing the ability to take knowledge and apply it to a novel situation. Based on the work of Planatitis [11], we developed criteria for self-assessment of design skills for 3rd year students in the bachelor of engineering.

The self-assessment was carried out online. The entire assessment included seven items: each item representing an essential aspect of 'design competence' for engineers and marked relevant for the assignment: problem definition, gathering information, brainstorming, sketching/modelling, prototype demonstration, keeping a log and teamwork.

For each item three possible performance levels are described, according to the ICE approach. However, after consultation with the responsible teachers, we decided not use a three-point scale for the self-evaluation, but a seven-point scale to give students the opportunity to rate themselves 'in between' two ICE-levels. Table 1 gives an example of the ICE criteria for the aspects 'problem definition', 'gathering information' and 'brainstorming'.

Table 1. ICE rubrics for self-assessment (pilot test) in 3rd year P&D project

Aspect of design	Ideas	Connections	Extensions
Problem definition	• Problem is divided into coherent sub-problems	• Customer requirements converted into measurable requirements • Inventory of criteria that determine success	• Awareness of limitations (Reality!) • Deliverables that are envisaged at the end of the project are clearly listed
Gathering information	• Different sources of information are used • Advantages and disadvantages of existing products and systems are considered	• Understanding, analyzing and application of new information in order to resolve questions • Able to select and combine the right information from various sources	• Appropriate knowledge is operationalized and, where needed, additional knowledge is created • Critical attitude towards information sources
Brainstorming	• Relates required functions to desired specifications • Shows creativity in the way the set conditions are met • Logical sequence in brainstorming process	• Merges various ideas to generate new concepts • Comes up with additional specifications to improve the final product	• Considers additional factors such as ease of use, durability, … • Takes into account the most optimal design for manufacturing

The students were informed that they were taking part in a pilot form of a self-assessment method. Participation was required and students were informed that the self-evaluation would have no effect on their grading. During the assessment and immediately after completing the assessment students were asked to note their opinions, questions and remarks on this new method in open questions. The

answers were categorized afterwards. Parallel to the self-assessment the tutors of the P&D groups were also asked to fill out the same assessment for each individual student. The goal of this parallel assessment was to compare the assessment by students themselves with the assessment by the tutors. The pilot was also used to evaluate whether an ICE rubrics model would be supportive for tutors in grading the students – compared to the grading system that they are currently using.

2.2 Results and discussion

86 students participated the self-assessment. Less than half of the students (41%) of the students appreciated the method of self-assessment as 'good'; the criteria were helpful and students reported spontaneously that it stimulates them in self-reflection on their design competence. About 45% of the students responded 'neutral': They perceived self-assessment as a meaningful method for reflection, but reported many of the criteria being unclear (25%), which made them unconfident in assessing themselves. Other students (14%) indicated that they would prefer peer assessment, as they believe that this would give a fairer view on their performance to the tutors. About 20% of the students reported negatively on the method of self-assessment, mainly because the criteria and the differences between the levels were perceived unclear or not relevant for their assignment. Students also reported that the highest levels ('Extensions') of the criteria were too difficult for them to reach within this assignment. This frustrated them as they want to score 'well' on the test, even when it is a self-assessment with no impact on their grading.

A comparison with the student's self-assessment results and the scores of the tutors who assess their students showed that there is little correspondence between the two. In general it appeared difficult for the tutors to assess the students on an individual basis. They merely rated the performance of the sub-teams consisting of four students.

Based on the individual outcomes of the self-assessment two teams were detected that were low-performing and that encountered difficulties in cooperation in the team. Tutors were aware of the problems, but the results of the self-assessment supported them in talking to the teams.

From this small-scale self-assessment pilot we conclude that a small majority of students value the method of self-assessment as a means of reflection on 'design competence'. However, the current description of the criteria following the ICE approach is not clear enough to use the tool as an effective means of reflection. In its function as a 'signaling tool' it may work to detect problems in team cooperation or to detect students with low self-confidence. With large students groups, the method does not support the tutors in giving individual feedback on student design competence.

3 DEVELOPMENT OF A LEARNING TRAJECTORY

In line with Boud and his views on sustainable feedback [4] our next step in this project was to rethink the fundamentals of feedback, formative and summative assessment in the P&D assignments. Within our long-term aim of building up an aligned design curriculum pathway for a gradual development of students' competence in engineering design, we introduce a *design approach model* that is tailored to our educational needs.

The design approach model (Fig. 1) is a schematic representation of relevant steps in the engineering design process and includes additional professional skills, such as teamwork, reporting and project management. For each aspect of the model we define competences that students are supposed to develop throughout the curriculum. Already in the first semester assignment the basic model is presented to the students, but only a few aspects are treated in detail. For the first assignment the main focus will be on how to work in teams and how to collect relevant information. Subsequent assignments focus on other aspects, e.g. using tools or methods for evaluating design alternatives, project planning and oral presentation of results. In this way the model is gradually refined and students will gradually build up their competence in designing. Working with the same model throughout the P&D curriculum will support students' awareness of the design competences and their reflection on their learning.

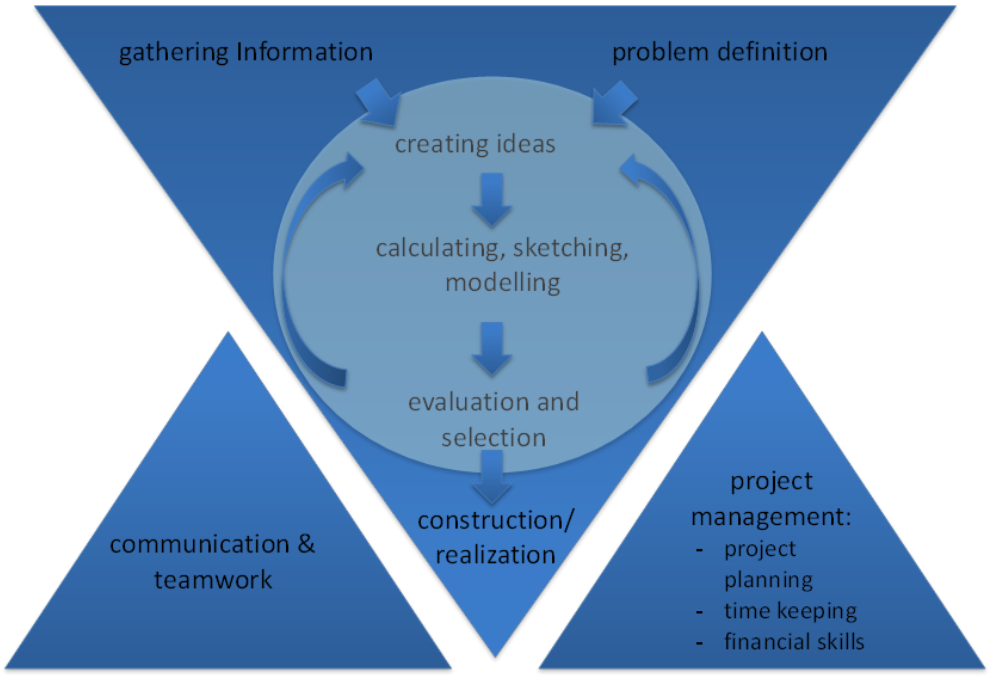

Figure 1. Design approach model

Assessment and feedback on the design competence in each assignment will be clearly linked to the aspects of design as presented in the model and its underlying competences. More specifically, feedback will be ensured by a system of peer feedback combined with self-assessment. The ICE approach is used to redefine the criteria for the peer assessment system. In addition to the peer feedback students will rate themselves and formulate individual learning objectives for the next P&D assignment.

Currently, students are already familiar with peer assessment in the P&D assignments where they rate the commitment and contribution of their team members. The aspect that will be added is that they will be asked to give their team members feedback on the design competences that are in focus in the particular assignment. This serves two goals:

1) Experience from peer assessment indicates it can lead to a deeper learning [12]. It is part of the learning process during which students develop skills like making informed judgments, self-evaluation, critical thinking, and formulating feedback. While assessing the performance of their peers, students are also reflecting on their own performance [13].
2) In a situation with large numbers of students and limited staff capacity a peer feedback system can enable a lot more individual feedback to students than can be provided by the tutors [13].

It is expected that this method of peer-feedback, based on a transparent learning trajectory that gradually builds up design competences throughout the curriculum, will ensure a better student engagement as well as deeper learning of design competences.

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