INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
6 & 7 SEPTEMBER 2012, ARTESIS UNIVERSITY COLLEGE, ANTWERP, BELGIUM

ASSESSMENT OF ENGINEERING DESIGN THESES

Robert WATTY[1] **and Matthias KREIMEYER**[2]
[1]Hochschule Ulm, University of Applied Sciences
[2]MAN Truck & Bus AG

ABSTRACT
To evaluate a student's work best possible, the assessment of theses written as part of the curriculum has to meet certain standards from both an academic and an industrial perspective to fully embrace the goals of engineering education.
Most universities usually use standard forms for the evaluation of theses. For the purpose of this research, available assessment forms within the *WiGeP*, a German-speaking network of university institutions active in design education and research, were collected, compared and analyzed to find common evaluation criteria and to judge the current state of how theses in design education are evaluated. From this analysis, a proposal of a comprehensive evaluation form for theses was deduced that could be adapted to special needs of evaluating institutions.
This paper shortly describes the theoretical background of evaluation of engineering theses and the results of the study on evaluation procedures and criteria. It presents criteria and a proposal for an assessment form for the evaluation of theses in universities.

Keywords: Design education, assessment, thesis, evaluation criteria

1 INTRODUCTION

The main goals of engineering education in universities are to provide technical knowledge and to enable students to apply it successfully to concrete design problems in the "real world". Thus, both requirements of industry as customer and upcoming demands of accreditors for study courses in the Bologna process challenge the education of design engineers at university to "prepare graduates for the practice of engineering at a professional level" [1] [2].
The required skills can be acquired by solving realistic design problems to foster the skills of coping with technical tasks as well as of working and organizing work as a team. Project-based learning is a fundamental model to implement practice-oriented education in undergraduate courses. Within common curricula in engineering sciences, such projects usually take shape as written term papers and master or diploma theses. They are mostly implemented in the advanced phase or at the end of study courses and therefore demonstrate academic skills and recheck the employability of students. The main objective of this paper is to compare and discuss current approaches to the evaluation of such theses in German universities and to provide subsumed criteria as a result of this survey. The paper concludes a series of papers on this topic [3] [4].

2 OCCUPATIONAL PROFILE OF ENGINEERS

The occupational profile of engineers in practice has changed over the last decades. Employers' ratings of the importance of EC2000 accreditation criteria [5] take a firm stand concerning requirements to new staff. Therefore, the industrial demand for engineers includes technical experts or engineers with a broad technical knowledge as well as diverse soft skills, personal attributes, intercultural competence and interdisciplinary knowledge, being summed up and categorized in figure 1: Technical knowledge, its application, and the use of modern engineering tools are still highly relevant. They have to be complemented by soft skills ands personal attributes enabling the engineer to communicate, to cooperate and to perform in a professional environment. Moreover, young engineers need not only competence in their own discipline, but also in related sciences as products and development processes become more and more interdisciplinary. Global cooperation furthermore requires intercultural competencies as well.

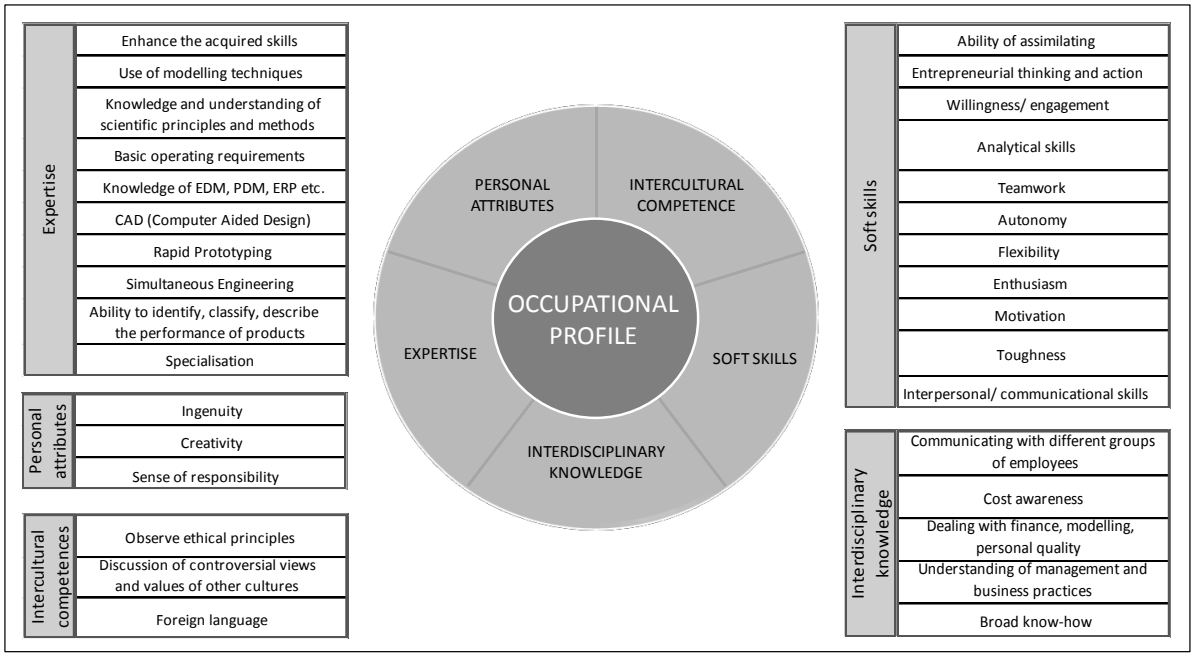

Figure 1. Occupational profile of engineers [6]

3 IMPACT ON STUDY PROGRAMMES

Consequently, study programs have to place greater emphasis on personal skills, increase the use of active learning methods and strengthen the students' occupational competence. Design projects are the preferred method to enhance the above-mentioned competencies commonly employed in many universities [7] [8]. Students have to demonstrate their abilities in this field especially in their theses. Figure 2 shows the actual characteristics of theses in German universities.

Duration (in months)

	min.	max.	Ø
SA	3	6	5
DA	3	6	5
BSc	2	6	4
MSc	4	6	5

Effort (in hours)

	min.	max.	Ø
SA	200	600	360
DA	800	900	850
BSc	250	500	350
MSc	600	900	830

ECTS-Credits

	min.	max.	Ø
SA	10	14	15
DA	30	30	30
BSc	6	15	13
MSc	15	30	30

Figure 2. Characteristics of projects in German universities

Most universities differentiate the following forms of written assignments: Term Paper (SA), Diploma- (DA), Bachelor- (BSc), and Master-Thesis (MSc). In German universities, the Bologna system necessitates three larger projects for the MSc level: the BSc thesis, an additional graduate term project of 350 to 500 hours, and a MSc thesis of six months. Typically, students receive a task description and some initial material when starting their projects, and they are closely supervised throughout their work; in many cases, the thesis is part of a larger project in research or in cooperation with industry and/or other disciplines. For each project, students have to hand in a written report. Varying among the universities as well as within the universities, projects take different forms but are always of scientific character. They can range from classic design tasks, e.g. the development of a certain device ("design"), to e.g. researching the means of managing communication in the design process ("theoretical"), to e.g. running a series of tests or trials ("experimental"), although often this differentiation is not further regarded. Often, such projects are part of larger research projects and vary in both nature and degree of complexity, something that, of course, the respective assessment procedure has to take into account.

4 ACTUAL ASSESSMENT PROCEDURES

This study was based on the evaluation forms from institutes of the *WiGeP*-network, a German speaking society regrouping 24 institutions that focus their educational and research work on engineering design. Most universities use standard forms for the assessment of theses.

4.1 Academic regulations

Examination regulations in universities in Germany specify the elements of study programs and their sequence. From the perspective of these academic regulations, projects in higher education primarily aim at the students' ability to use scientific methods and to demonstrate that they are able to solve engineering problems autonomously, accurately and timely. Figure 3 lists the criteria given in all regarded universities and the occurrence of each criterion (column) for the four different types of theses (rows). The data was generated based on a detailed analysis of all exam regulations.

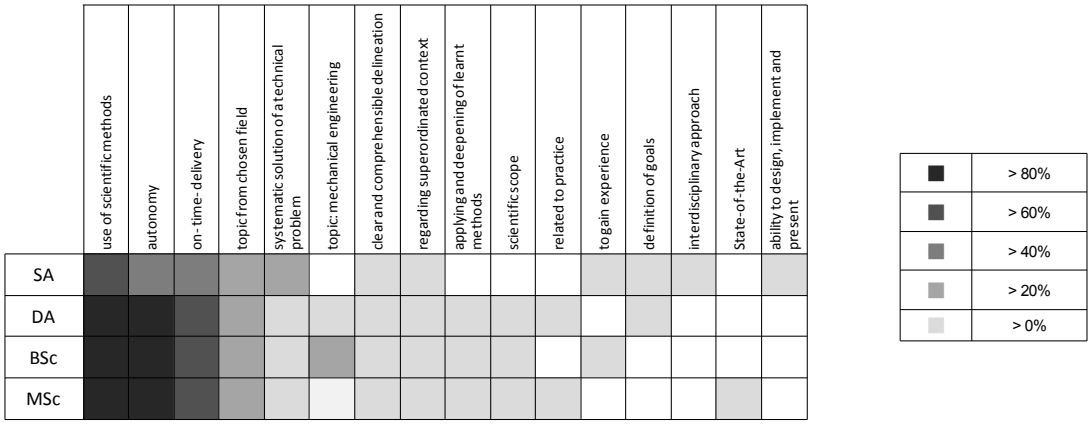

Figure 3. Academic regulations

4.2 Evaluation criteria

With regard to the above criteria, the assessment criteria for theses were analyzed by collecting the assessment forms of all participating universities. Only those criteria that appeared for five or more universities were listed; figure 4 lists by what criteria theses are most commonly graded.

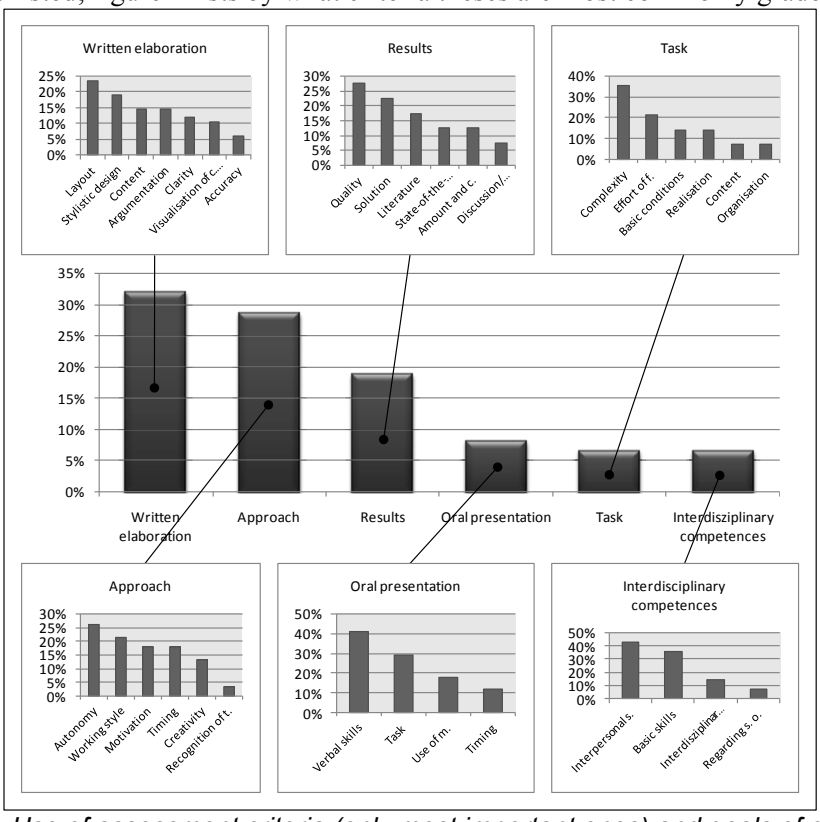

Figure 4. Use of assessment criteria (only most important ones) and goals of education

All criteria (small bar charts) were classified by the goals they support (large bar chart). Although no direct mapping between goals and criteria is possible, it can be seen that some aspects are more stressed than others, above all the written elaboration and the oral presentation. A strong focus is furthermore put onto the scientific approach. There, the stress is mostly put on the effort taken, the active project management, the extent of dedication to and familiarization with the task, and the level

of innovation achieved, which is among the hardest to judge. The section "results" focuses mostly on the scientific aspects of a thesis, i.e. what skills and effort a student has shown in his work. The task design is actually quite under-represented; however, many forms take into account that, according to the complexity of the task, one or more criteria can be weighted differently. Both the interaction in a team (if applicable) and the greater context of the work draw no attention at all, although they are stressed to be just as important.

5 FINDINGS AND SUGGESTED EVALUATION CRITERIA

An improved assessment process for theses has to meet several requirements: It has to fulfill the current practice, which implies that all already commonly considered assessment criteria should be enclosed. Secondly, the goals of education as well as the demand of industry on graduates have to be considered in an extensive way. Last, the learning outcomes, outlined in the context of Bologna have to be involved and evaluated.

5.1 General Requirements to an evaluation form

In general, grading is the primary and probably the most important outcome of an assessment by indicating whether and to what extent a particular student has attained requirements of the project task [9]. Therefore, fair and equal evaluation and grading has to meet several requirements, as it has to be towards the students, recognize their work, evaluate success, or has to motivate for future learning. In using a standardized template and communicating the assessment criteria to the students before they start their projects this fact is taken into account.

Criteria included in the assessment forms have to meet several requirements. They have to enable the consistency of marking as well as to provide a basis for useful feedback to the students, but also have to match the assessment task and help students in achieving the determined learning outcomes [10].

All points mentioned above concern to assessment in general. Furthermore the requirements outlined by the several mappings, figure 5, have now to be considered in creating a new evaluation form.

Academic regulations	•Interdisciplinary approach •Relation to practice •Scientific Scope •Regarding superordinated context •State-of-the-art •Gaining experience
Goals of education	•Problem sensitivity •Creative techniques, practice •Development methods •Courage for new solution •Branch or subject-related knowledge
Occupational profile	•Sense of responsibility •Creativity, ingenuity •Observe ethical principles •Communication in interdisciplinary/intercultural context •Understanding of management and business practices
Learning outcomes	•Ability to fulfil engineering practices •Interdisciplinary knowledge •Ability to use a variety of methods •Ability to use adequate tools

Figure 5. Criteria to be considered

5.2 A proposal for a coherent set of assessment criteria

As suggested, there are different groups of assessment criteria, which have to appear in the evaluation form. Primarily, these groups of criteria are written elaboration, approach, results, task, interdisciplinary competences, and oral presentation (c.f. figure 6). All types of criteria have in common that they either are a statement of what the learner will do, or a reference to the quality of the work. Therefore, the criterion has to refer to something that must be present or absent (e.g. presence of stylistic design or absence of grammatical mistakes), or some requirement that must be fulfilled, for example verbal skills [11].

Written elaboration	35%								
Content	***	The coverage of the project is appropriate, the content is made clear							0,00
Layout and graphics	**	Layout is attractive and clear, content is presented in a useful way, praphics are useful and comprehensible							0,00
Structure and rationale	***	The chapters are designed in a consistent way, articulacy of project is apprpriate, typographical and							0,00
Literature	**	Literature research, citation, bibliography							0,00
Written comment								Grade:	0,00

Figure 6. Exemplary evaluation form (Documentation)

The proposed form has three main categories: project management, documentation, and presentation (a section of the resulting evaluation form is shown in figure 6):
'Project management' implies the accomplishment of project, as well as the working style of student in general, and is divided into four groups (scope and challenge, approach taken, results during project, and cooperation and communication). While scope and challenge covers the complexity of the task (e.g. different types of theses), the approach taken requires deep understanding of the task. The results during project and the quality of solution have to incorporate a certain volume regarding content and must be based on the current state-of-the-art. Within project management, an assessment is done of how the project is carried out, i.e. if the student has recognized the task, delivered in the provided time, worked independently, and achieved planned results (including a discussion and conclusions from the findings). Cooperation and communication assesses interpersonal competences, as the ability for teamwork and leadership, and considers the interdisciplinary share of project as it is required. These criteria attach great importance in the proposed form as they are required of industry and academia.
'Documentation' deals with the content and layout of thesis, the stylist and design, the comprehensibility of the written elaboration, clarity, accuracy, and the visualization of charts and graphs. The documentation of project implies the demand made on students to structure the thesis in a comprehensive way and to use a well understandable verbalization.
If applicable in the type of thesis, final 'presentation' implies the oral presentation at the end of project time and assesses criteria as the content, verbal skills, the use of media and the timing of the student.
For every particular assessment criterion the evaluation scheme provides a compact description of how the formal criterion has to be met in the project. Additionally, these descriptions oblige the supervisor to reflect upon every criterion and to consider to what extent the student has achieved the requirements. Moreover, the evaluation scheme implies a grading system, which specifies whether the criterion is met in an "inadequate", "sufficient", "satisfactory", "good" or "excellent" way. Moreover, the form provides space for an additional text or a few written statements of the supervisor to complete the numerical assessment and to communicate he results to students in a complete manner. Besides that, the written comments aim at documenting assessment in a comprehensive way in the form of an expert report as suggested by the Bologna process [12].
Another important aspect with regard to evaluation forms is the weighting of every particular criterion. A system of weighting may be superimposed in many assessment forms. On the one hand, this is important and necessary to stress criteria, which are more significant than others in later career. An independent working style, for example, may play a more important role from the employer's view than the visualization of charts and graphs or the use of media. At the same time, weights for the criteria can be used to adjust the assessment to the different types of theses. A thesis with a constructive or experimental character, for example, therefore has to emphasize the results of elaboration, whereas in a theoretical thesis the written elaboration plays a more significant role. In general, there are some aspects of the work, which can be identified as contributing to a greater extent to the achievement than other (e.g. scientific approach by contrast to literature research).
The approximate weighing of project management and documentation of project, which combines the documentation itself and the final presentation, is based on current practice. Primarily this aims at ensuring that e.g. bad projects that are well written up, well presented are graded accordingly. However, it is here suggested that project management is weighted more importantly (55%) than documentation of the project (45%) in order to meet the requirements of industry and academia and to provide students with the necessary skills.

6 CONCLUSION AND OUTLOOK

The analysis of the approaches of engineering design institutes used to assess theses in engineering design shows clear similarities and little variance in the criteria that are used. The suggested set of evaluation criteria is, therefore, based upon the intersection of the criteria used in the actual evaluation forms in German universities and completed by requirements of the Bologna process. This process suggests the idea of using similar criteria for the evaluation of engineering courses and their outcome and the evaluation forms clearly show a common perspective.

There is a broad consensus about core competencies that must be demonstrated especially in projects at the end of engineering courses, which, however, is slightly different from the goals that engineering design education is supposed to comply with. Commonly, an autonomous and systematic approach is an obvious goal of engineering education that requires deep understanding of the task and a creative and efficient solution process. Results must be based on the actual state of the art and incorporate a certain volume regarding content. The written elaboration and the oral presentation, if required, demand a comprehensive structured and an understandable verbalization. Reasonable additional criteria used by some universities cover the complexity of the task to distinguish between different types of projects, the treatment of the results and the accuracy of the student. Teamwork and interdisciplinary play an increasingly important role in engineering sciences, but they are not yet sufficiently regarded in projects and their evaluation. They require a continuing revolution of tasks and evaluation.

REFERENCES

[1] Accreditation Board for Engineering and Technology (ed.): Criteria for accrediting engineering programs. Effective for Evaluations During the 2006-2007 Accreditation Cycle, Baltimore, 2006.

[2] Akkreditierungsagentur für Studiengänge der Ingenieurwissenschaften, der Informatik, der Naturwissenschaften und der Mathematik e.V. (ed.): Fachspezifisch ergänzende Hinweise zur Akkreditierung von Bachelor- und Master-Studiengängen des Maschinenbaus, der Verfahrenstechnik und des Chemieingenieurwesens, 2005 (ASIIN e.V., Düsseldorf 2005).

[3] Watty, R.; Kreimeyer, M.: Assessment of theses – A comparison of current approaches practiced in engineering education. 10th Engineering and Product Design Education International Conference, Brighton, September 10 – 11, 2009.

[4] Watty, R.; Kreimeyer, M.: A proposal for an assessment form for engineering design theses. 18th International Conference on Engineering Design ICED11, Copenhagen, August 15-18, 2011.

[5] Lattuca, L., Terenzini, P., Volkwein, J.: Engineering Change: A study of the Impact of EC2000, Executive summary, 2006 (ABET, Baltimore).

[6] www.vdma.org

[7] Volkwein, J., Lattuca, L., Terenzini, P.: Engineering Change: A study of the Impact of EC2000, Int. J. Engng Ed. Vol. 20, No. 2, 2004.

[8] Eris O., Holliger C., Elspass W. and Leifer L., Towards a Theory of Distributed Interdisciplinary Project-Based Design Education. International Conference on Engineering Design - ICED '05.

[9] Kreimeyer, M., Ponn, J., Lindemann, U.: Methodical evaluation of single and group projects – International Conference on Engineering and Product Design Education, Northumbria University, Newcastle Upon Tyne, United Kingdom, 13-14 Sept. 2007.

[10] Brown, G.: Assessment: Guide for lectures. LTSN Generic Centre Assessment Series, York, UK.

[11] Gosling, D., Moon, J.: How to use Learning Outcomes and Assessment Criteria. London: SEEC Office, 2001.

[12] Froment, E., et. al.: EUA Bologna Handbook, 2008 (Raabe, Stuttgart).