Learning Content in Engineering Design Education: An Analysis for Developing Learning Materials Used at Multiple Universities

Frederike Kossack[1], Marc Neumann[1], Beate Bender[1], Fabian Dillenhöfer[2], Bernd Künne[2], Alina Sersch[3], Peter Gust[3]

[1]Ruhr-University Bochum
[2]TU Dortmund University
[3]University of Wuppertal

Abstract: The creation of e-learning materials often involves high initial effort for its first development and tool-implementation but can then be used by a large number of students with very little additional effort for a lecturer. It therefore makes sense to develop common e-learning materials for use across universities. Particularly in the field of engineering design education, due to the standards used as the basis for technical representation and calculations learning content the potential is high. To be able to quantify this potential, this paper analyzes course descriptions from 21 universities of applied sciences and universities as a basis for the development of e-learning materials for cross-university use. Frequently taught topics in the field of technical drawing and machine elements are identified, the proportion of the total course workload for students and the differences between universities and universities of applied sciences are shown.

Keywords: Design Education, Engineering Design, Design Learning, Standardized Learning Content, E-Learning

1 Introduction

Well-educated design engineers are crucial for successful product development in order to address current challenges (Albers et al., 2012), e.g., the development of sustainable products (Kattwinkel et al., 2018). Engineering design education in higher education is an important part of this, for example in mechanical engineering degree programs. The development and implementation of e-learning materials requires a high level of development effort by lecturers (Schönwald, 2007). This development effort in engineering design education is even higher for complex learning concepts with AI (artificial intelligence) like Garland et al. (2023) or intelligent systems for evaluating students results like Hoppe et al. (2021) or adaptive systems like Kossack and Bender (2023). However, especially e-learning materials can be used by a large number of students with little supervision and without almost no extra effort by the lecturer (Schönwald, 2007). Existing guidelines for standardization exist mostly for the field of mechanical engineering and electrical engineering (Handelsblatt, 2017). The design guidelines, calculations, specifications, and procedures contained in these standards are therefore also represented in the content of courses in the field of engineering design education. As a result, there is enormous potential to develop and, above all, use digital learning materials across universities. To be able to assess the scale to which engineering design contents across universities overlap, this paper examines the content of engineering design courses at universities and universities of applied science in North Rhine-Westphalia in Germany.

2 State of the art

In this chapter, the higher education system in Germany is described with focus on the integration of engineering design education in degree programs like mechanical engineering. Additionally, the basic didactic principles and terms relevant to this paper are introduced (section 2.1). Building on this, a detailed description of engineering design education and existing knowledge of its content is given (section 2.2).

2.1 Higher education in Germany

In Germany, there are different types of educational institutions in higher education that offer degree programs with engineering design education such as mechanical engineering, namely universities and universities of applied sciences. Universities, on one hand, often look back on centuries of history and emphasize the unity of research and teaching in a broad range of subjects (Riphahn et al., 2010). As such, they are aimed at high school graduates and graduates of technical colleges and are responsible for the next generation of academics. Universities of applied sciences, on the other hand, were mostly founded in the last century and focus more on practical applications with an industrial background (Riphahn et al., 2010). The degree programs at universities of applied sciences are often shorter and have a larger proportion of practical phases compared to universities (Reimer, 2009). In addition to the general matriculation standard and technical matriculation standard, access to the universities of applied science is possible with a range of other school certificates and a higher percentage of students already have professional experience (Schindler, 2014). The Bologna Process in 2010 resulted in the standardization of degrees. Since then, a bachelor's degree program in mechanical engineering at universities and universities of applied sciences is considered equivalent and a change to a master's degree program from a university of applied science to a university, for example, is easier (European Education Area, 2024). The bachelor's degree program in mechanical engineering starts with basic courses such as technical drawing, mathematics, material science, mechanics, and engineering design of machine elements. The basic courses in the first two study years are usually the same for all students. In the following years, students can choose as well individual courses as fields of specialization in the degree program, examples for specializations are material science, design engineering or production engineering (Kossack et al., 2022). The contents as described above need to be presented appropriately for the students in line with a chosen didactic concept. In this paper, we focus on the didactic concept of *Constructive Alignment*. It comprises three components (Biggs and Tang, 2020) and is generally suitable for the development of individual learning units up to the development of entire degree programs (Jungmann et al., 2016). The *Intended Learning Outcomes* are essential for the system. These describe the students' required skills and competencies at the end of a particular course, often semester wise. The Intended Learning Outcomes detail the competence level to be achieved and the related context or application in which it should be achieved by the students. The Intended Learning Outcomes are named in course descriptions at the level of Indicative Learning Outcomes and can be refined for individual lectures into General Learning Outcomes and even further into Refined Learning Outcomes, whose achievement can be tested with individual exam questions. (Mayer and Hertnagel, 2009; Pfäffli, 2015). Usually only one or two verbs are used in the formulation (Biggs and Tang, 2011). Depending on the verb used, Krathwohl classifies based on Blooms taxonomy learning outcomes into six main categories of cognitive dimensions: remember, understand, apply, analyze, evaluate, and create (Krathwohl, 2002). The *Assessment Task* evaluates the extent to which students have achieved the Intended Learning Outcomes (Biggs and Tang, 2011). This assessment of learning outcomes can be formative, i.e., during the learning process, for example in the form of several submissions of exercises during the lecture period as a portfolio, or summative, i.e., after the course, for example in the form of a final exam (Baumann and Benzing, 2013; Arnold et al., 2018). The *Teaching and Learning Activities* describe the work required of students to achieve the Intended Learning Outcome (Biggs and Tang, 2020). This includes both presence study-time, such as attending lectures or participating in exercises, and self-study time, i.e., phases in which students work independently on exercises or repeat the lecture content (Baumann and Benzing, 2013; Arnold et al., 2018). Working with e-learning materials is a frequent component of the self-study time as it is characterized by time and location-independent use (Mayer and Hertnagel, 2009; Arnold et al. 2018). E-learning is a multifaceted objective and organizational arrangement of electronic resources, spaces and links and can be used individually or collectively for learning or for the development of skills and education of learners in self-determined times (Arnold et al. 2018).

2.2 Engineering design education

Engineering design is defined as the totality of all activities which are performed to provide the information necessary for the manufacture and use of a product (VDI 2221, 2019). Main phases in the product development process are to plan and clarify the task, develop the principal solution and the construction structure, develop and define the construction structure and to finally prepare production and operating documents (Pahl et al., 2007). To be able to put this process into practice, students learn the necessary skills in various courses of the mechanical engineering degree program. In Albers et al. (2012) a distinction is made between *design-relevant* and *design-related* courses. Design-relevant courses include the basic training that every mechanical engineering student must complete, such as mechanics or material science. Design-related courses, on the other hand, are those that train engineering designers for the core of their work - synthesis. Basic knowledge in university education includes, for example, dimensioning of machine elements, CAD, CAE or design methodology. Building on this, selected specialist knowledge in higher education includes, for example lightweight construction, drive machines or railroad technology. The difference in terms of learning content between universities and universities of applied science in Germany can be attributed to the practice orientation. A degree course in design and development at a university tends to be more scientific, while a degree course at a university of applied sciences tends to be more practice oriented (Reimer, 2009). There is no consensus among the respondents as to in what way the professional qualifications of graduates of the two types of universities differ from one another (Albers et al., 2012). An important element of engineering design education is the representation of the technical system, i.e. drawings, and designs of machine elements up to their integration into complex technical systems such as an entire drive train. Metraglia et al. (2011) suggested a standardized assessment framework for the technical drawing education. It is based on the assignment of existing standards for technical drawings to levels of the European Qualifications Framework. However, this does not reflect the actual content of the courses. With regard to teaching of machine elements, the *Scientific Society for Product Development* (Wissenschaftliche Gesellschaft für Produktentwicklung e.V.) formulates that the courses on engineering design education should provide an overview of machine elements, describe important stresses, convey methodological knowledge on dimensioning and design and deepen the knowledge imparted using selected examples. However, the paper states also, that it is not possible to fully cover the diversity of all machine elements. (WiGeP e.V., 2018)

3 Research questions and method

The cross-university development and use of learning materials for engineering design education has already been successfully implemented in an exemplary research project (https://www.orca.nrw/content/492cef23-c2a4-455a-a4b3-761d94f95cdc). As part of the *TZ digital* (technical drawing - digital) project, e-learning materials to support students in creating technical drawings was elaborated and made available as open educational resources (OER). These learning materials are designed as a modular system so that lecturers can integrate the elements relevant to their course into their individual learning management system (Dillenhöfer at al., 2023). To expand this approach to develop further learning materials, needs across universities must be identified. For the usage of learning materials for learning activities at different educational institutions, each learning context with the Intended Learning Outcomes of the courses must be identified (Niegemann et al., 2008). Existing studies on engineering design education like the regularly revised CDIO syllabus (https://www.cdio.org/content) focus on overarching competencies and don't specify typically used examples e.g. of machine elements to gain these overarching competencies in core engineering fundamentals. This article therefore examines the need and possibility for the development and application of learning materials, across educational institutions by analyzing learning contents on the level of concrete examples. We focus specifically on e-learning materials. To this end, the following specific research questions (RQ) are investigated:

- RQ1: What are common contents in engineering design education?
- RQ2: What need is there for e-learning materials based on the existing teaching and learning activities?
- RQ3: What are deviations in the content of engineering design education, especially between universities of applied sciences and universities?

To answer the research questions, design-related courses were identified across universities and universities of applied sciences. A title analysis was carried out for the identification of relevant courses, as in Albers (2012). The following keywords were used: Construction, technical drawing, representation, machine element, engineering design, CAD. The course descriptions for these identified courses were analyzed regarding learning content addressed in the different courses and the effort for the students in self-study times. To reduce the number of higher educational institutions, only campuses in the federal state of North Rhine-Westphalia in Germany were investigated. In North Rhine-Westphalia, design-related courses in engineering degree programs such as mechanical engineering and logistics were identified in the curricula of 21 universities and universities of applied sciences. In the degree programs examined, students specialize in a subject area such as material science or automotive engineering from the third year of the standard period of study or can at least choose individual courses. To be able to develop e-learning materials for a group of students as large as possible, the focus of this paper is on design-related courses in the first two years of study. The course descriptions contain information on the Intended Learning Outcomes, the Teaching and Learning Activities and the assessment task. For research question one (RQ1) the Intended Learning Outcomes are relevant. However, there are major differences in the form of the course description and often no concretely formulated Intended Learning Outcomes, e.g. according to *Bloom's taxonomy*, are mentioned but only the topics of the course. Therefore, in this paper only the content areas addressed by the analyzed courses are identified. For research question two (RQ2) the Teaching and Learning Activities mentioned in the course description are analyzed. Since e-learning materials have a high benefit for the self-study time, the percentage of self-study time in the total effort is analyzed and it is not examined in more detail how the presence-study times are conducted. For research question three (RQ3) the differences in the total expense for the students and the proportion of self-study times at universities and universities of applied sciences are compared statistically. For the comparison between the two groups of educational institutions, a Mann-Whitney-U test is performed using *SPSS* software (IBM Corp., 2021) and a significance level of 5 % is assumed (Döring and Bortz, 2016). The study also examines whether there is a difference between universities and universities of applied sciences in the number and type of content covered in the courses. The presentation of the results is basically split into two parts, because the analysis of the course catalogue shows a difference of the courses for the first semester and the second to fourth semester. The first part presents the analysis of basic engineering design education courses, which are typically taught in the first semester. These courses focus on technical representation and are attended mandatory by students from 19 different degree programs. These include not only engineering degree programs such as mechanical engineering and logistics, but also other degree programs such as economics and management. The second part deals with follow-up engineering design education courses, which are typically taught in the second to fourth semester of the degree program. These all 44 courses are mostly mandatory for all students in a degree program too, although these are only included in four different degree programs, which are all engineering degree programs. For these follow-up courses, it does not make sense to evaluate the courses separately, as many courses last more than one semester, or they start in different semesters of the degree program. In addition, the content is often covered in several of these courses at the same educational institution. The follow-up engineering design education courses specialize more on application-based topics for the degree program and include more specific topics based on the engineering design education, e. g. gears and calculations for life cycle time, which are described in detail in chapter four.

4 Results

This chapter shows the findings from the course description analysis. In the first section the results for the basic courses in engineering design education addressing the technical drawing are presented (section 4.1). In the second section the results for the follow-up course in engineering design education addressing mostly the calculation of machine elements are presented (section 4.2).

4.1 Basic courses in engineering design education about technical drawing

The course descriptions contain topics from engineering design education. For identifying the intersection across the different universities and universities of applied sciences, the described topics are clustered into 13 main contents. Figure 1 shows these different contents regarding the teaching of technical drawings (mostly first semester) as well as the percentage of universities, universities of applied science and both types of educational institutions together, where the course description comprises the named content. The course descriptions in the field of technical drawing mention all the contents about *using standards* with *basic knowledge* e.g., typical paper formats or line thickness and the introduction of standards like *ISO* norms. For reading and creating technical drawings the *third angle projection* and *axonometric representation* are learning contents at all educational institutions. For the components illustrated, *cuts* for detailed views are also thematized, the components are *dimensioned* and provided with *tolerances*. In this context, the topic of *fits* is integrated into the courses. Drawings of individual parts that are assembled into complete courses are explicitly mentioned in the course descriptions of five of the six universities (83 %) and 11 of the 15 universities of applied sciences (73 %).

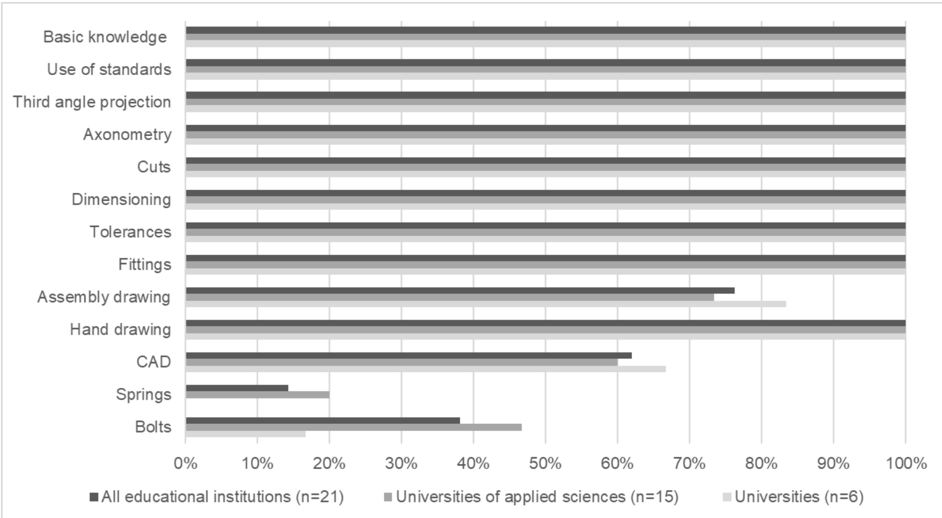

Figure 1. Content analysis from German universities and universities of applied sciences teaching technical drawings in engineering (mostly 1st semester)

Technical drawings are created by hand in all educational institutions, and in 13 courses (61 %) drawings are also created in the courses using a CAD system. CAD systems are used more frequently in these courses at universities (approx. 67 %) than at universities of applied sciences (approx. 60 %). At universities of applied sciences in particular, these courses sometimes start with the design calculation of machine elements. Three universities of applied sciences (20 %) already address the functionality and design of springs, which is not included in any of the analyzed courses at universities. The functionality and design of bolts is discussed at seven universities of applied sciences (46 %) and one university (16 %). In addition to the contents shown in Figure 1, further topics on the fundamentals of the methodical development of products, such as the Failure Mode and Effects Analysis method, are mentioned in the course descriptions. Next to the content details the information about the Teaching and Learning Activities with the focus on the self-study time are analyzed and presented in Table 1. For each of the 21 educational institutions in North Rhine-Westphalia, the total time spent by students for completing the courses and the hours worked in the self-study time are shown.

Table 1. Workload for the students in courses about technical drawing at each university of applied science (UAS) and university (U)

Educational institution	**UAS 1**	**UAS 2**	**UAS 3**	**UAS 4**	**UAS 5**	**UAS 6**	**UAS 7**
Total expense (hours)	150	150	150	150	60	150	120
Self-study time (hours)	94	90	90	70	30	90	75
Educational institution	**UAS 8**	**UAS 9**	**UAS 10**	**UAS 11**	**UAS 12**	**UAS 13**	**UAS 14**
Total expense (hours)	150	75	150	150	120	150	270
Self-study time (hours)	60	43	90	90	60	90	180
Educational institution	**UAS 15**	**U 1**	**U 2**	**U 3**	**U 4**	**U 5**	**U 6**
Total expense (hours)	150	105	90	270	120	150	150
Self-study time (hours)	78	60	56	180	60	75	105

The data for each educational institution is presented in coded form: UAS for universities of applied sciences and U for universities. The total time required for the courses at the educational institutions varies between 60 and 270 hours (mean 140 and median 150). There is a small difference between university of applied science with a mean of 143 hours and universities with a mean of 132.5 hours. There is no statistically significant difference between universities (n= 6, median= 135) and universities of applied sciences (n=15, median=150) with a significance of p= 0.604. For most educational institutions, the self-study time accounts for at least 50 % of the total workload and varies between 30 and 180 hours (mean 79.66 and median 78). It is with a mean of 82 hours higher at universities of applied sciences then at universities with a mean of 73.8 hours. There is no statistically significant difference between universities (n= 6, median= 67.5) and universities of applied sciences (n=15, median=90) with a significance of p= 0.551 either.

4.2 Follow-up courses in engineering design education addressing machine elements

The learning content mentioned in the course descriptions of engineering design education of overall 44 identified courses after the first semester in degree programs is clustered in 14 main contents all about machine elements. Figure 2 shows the percentage of educational institutions as a whole and of universities of applied sciences and universities separately that explicitly mention the particular content in the course descriptions. The contents *axis and shafts*, *shaft and hub connections*, *rolling-element bearings*, *bolts*, and *gear wheels* are mentioned in the course descriptions of over 80 % of the educational institutions. Four of these five contents are taught at all universities. Some universities of applied sciences, however, focus on *bolts* in the first semester (see section 4.1), which means that the percentage in this part of the analysis is lower. This also applies to the learning content of *springs*, which is mentioned by all universities in the course descriptions analyzed here and only by 46 % of the universities of applied sciences. At three universities of applied sciences (i.e. 14 %) *springs* are already addressed in the first semester (compare Figure 1). *Clutches* are taught at all universities, whereas they are only taught at 60 % of universities of applied sciences. The different types of *joints* are addressed at 33 % (*soldered joints*) to 61 % (*welded joints*) of all educational institutions. These are mentioned considerably more at universities.

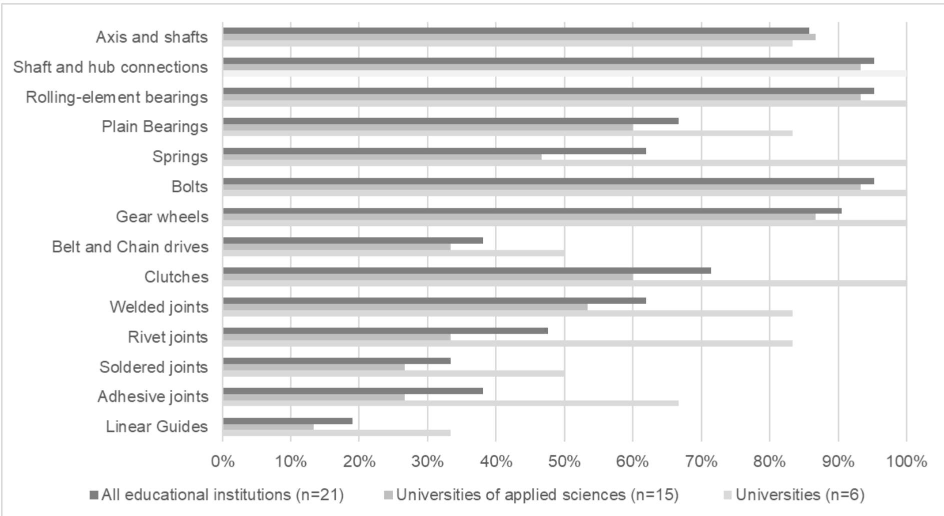

Figure 2. Content analysis from German universities and universities of applied sciences teaching mechanical engineering basics (mostly 2nd to 4th semester)

Four educational institutions thematize the topic of *linear guides*, two universities and two universities of applied sciences. In addition to these frequently mentioned contents in the field of machine elements, the complete dimensioning, design and technical visualization of assemblies and complex products with integration of the named machine elements is also listed as an overarching learning objective. Furthermore, the basics of mechanics and mathematics are sometimes mentioned in the course descriptions, although separate courses are often listed for this in the course catalogue. The information about the number of courses in engineering design education from the second to the fourth semester of the degree program, the total expense of all these courses for the students and the total number of hours for self-study time at each analyzed educational institution are presented in Table 2. The presentation and coding are as shown in Table 1. The number of courses varies between one and three courses. Only two universities of applied sciences provide one course, otherwise two courses are planned at most universities of applied sciences (except UAS9). At the universities, apart from two exceptions with only two courses, three courses are planned in each case.

Table 2: Workload for the students in courses about machine elements at each university of applied science (UAS) and university (U)

Educational institution	**UAS 1**	**UAS 2**	**UAS 3**	**UAS 4**	**UAS 5**	**UAS 6**	**UAS 7**
Courses (semester)	2	2	2	2	2	1	1
Total expense (hours)	330	300	300	300	300	90	120
Self-study time (hours)	190	188	188	188	174	34	64
Educational institution	**UAS 8**	**UAS 9**	**UAS 10**	**UAS 11**	**UAS 12**	**UAS 13**	**UAS 14**
Courses (semester)	2	3	2	2	3	2	1
Total expense (hours)	300	450	300	360	450	300	150
Self-study time (hours)	188	282	188	220	282	188	94
Educational institution	**UAS 15**	**U 1**	**U 2**	**U 3**	**U 4**	**U 5**	**U 6**
Courses (semester)	2	2	3	3	2	3	2
Total expense (hours)	300	330	450	360	240	540	180
Self-study time (hours)	160	218	282	192	142	372	96

The total time required for the courses at the various educational institutions varies between 90 and 540 hours (mean 307 and median 300). There is a difference between university of applied science with a mean of 290 hours and universities with a mean of 350 hours. There is no statistically significant difference between universities (n= 6, median= 345) and universities of applied sciences (n=15, median=300) with a significance of p= 0.261. For most educational institutions, the self-study time accounts for at least 50 % of the total workload and varies between 34 and 372 hours (mean 187.14 and median 188). It is with a mean of 217 hours higher at universities than at universities of applied science with a mean of 175.2 hours. There is no statistically significant difference between universities (n=6, median=205) and universities of applied sciences (n=15, median=188) with a significance of p= 0.270 either.

5 Discussion

Based on the results presented in chapter four, research question one (What are common in engineering design education?) can be answered for both technical drawing and machine elements. In the field of technical drawing, basic guidelines and the use of standards are relevant at all educational institutions. Drawing by hand is also subject everywhere, with a particular focus on the *third angle projection*, *axonometric representations*, *cuts*, *dimensioning* including *tolerances* and the calculation of *fits*. *CAD* drawings are not addressed at all educational institutions in the courses analyzed, but these are sometimes addressed in separate courses (in higher semesters), so that there may be greater potential for shared learning materials than has been shown here. The machine elements *bolts* and *springs* are sometimes already covered in these courses but sometimes also in the follow-up courses. In total, *bolts* are the most frequently identified machine elements, followed by *shaft-hub connections*, *rolling-element bearings*, *gear wheels* and *springs*. Overall, the analysis of the course descriptions shows a large proportion of self-study phases in the total workload and in absolute numbers of up to 447 hours (Table 1 and 2 U5), students spend a lot of time in the first two years of study working independently on the learning content. The huge difference in overall workload is caused by topics or activities that may be not included in some courses such as CAD or practical activities like laboratory training sessions, because they may be implemented in other courses not identified by the title analysis. Furthermore, the study program is structured differently among the different educational institutions, which results in six or seven semesters for the bachelor’s degree. As e-learning materials are particularly suitable for these self-study times, it can be assumed that there is a need for e-learning materials for use in the self-study time as an answer to the second research question (What need is there for e-learning materials based on the existing Teaching and Learning Activities?). However, neither the presence-study times nor the self-study times were analyzed. There is therefore no knowledge about what learning activities the students carry out during the self-study time and what exactly is required of e-learning materials so that they can be ideally integrated into the existing courses as additional Teaching and Learning Activities in accordance with constructive alignment. General information on the two different types of educational institutions of universities and universities of applied sciences indicates a difference in teaching hours. Regarding the third research question (What are deviations in the content of engineering design education, especially between universities of applied sciences and universities?), this article shows that the courses in the first semester are on average more extensive at universities of applied sciences and the follow-up courses in higher semesters of the first two years of study at universities. However, these differences are not statistically significant. Due to the greater scope in the first semester, some universities of applied sciences start earlier in the curriculum with content that is planned later at universities (see content about *bolts* and *springs*). In the field of *technical drawing*, there are hardly any differences overall between universities and universities of applied sciences. In the field of teaching machine elements, however, significantly more different machine elements were identified in the courses at the universities (see different types of joints in Figure 2).

The results of this analysis are subject to some limitations. Firstly, only 21 educational institutions offering engineering design education courses were analyzed in a first approach. Although the same textbooks are often used within Germany and the *Scientific Society for Product Development* (Wissenschaftliche Gesellschaft für Produktentwicklung e.V.) also attempts to ensure uniform teaching, further analyses are required, particularly at European or global level, to be able to assess the extent to which the results can be generalized. Secondly, the results are based on the information in the course descriptions that were accessible online. No lecture materials were analyzed. Therefore, no conclusions can be made about the extent to which students are only introduced to the topics mentioned in passing or work on these topics in detail. For example, no information can be provided as whether students are able to draw complex components in axonometric views or whether they can only name the two existing types of axonometric representations. However, an analysis of the learning outcomes is not only necessary to create learning materials for cross-university use but would also provide further insights about potential greater differences in engineering design education between universities and universities of applied sciences. Thirdly, the test groups used for the comparison between universities of applied sciences (n=15) and universities (n=6) differ in size, as all available course descriptions were used by educational institutions in North Rhine-Westphalia. Therefore, the total number of analyzed courses at universities of applied sciences (n=44) is clearly higher than at universities (n=21). Thirdly, the analysis only presents today's learning content. When developing learning materials based on this work, it should be considered that learning content changes and therefore these learning materials can be updated easily and adapted to current topics. Despite the limitations mentioned, the analysis makes an important contribution to the development of learning materials for use across universities. If these materials are made available as open education resources, a large number of students can use them and benefit when acquiring skills. In addition, the knowledge gained can help with coordination in engineering design education. Firstly, for lecturers in engineering design education as a basis for developing or updating the learning content in their courses. And secondly, because engineering design education is an integrative course (WiGeP e.V., 2018). Engineering design education builds on the fundamentals of mechanics, for example, and is itself the basis for other courses such as drive technology. A standardized framework with the content, as presented in Metraglia (2011) for the content of technical drawing, would be helpful for the coordination between these different courses.

6 Conclusion and Outlook

This paper examines engineering design education in Germany to identify the extent to which there is a need and possibility for the development and use of learning materials, in particular e-learning materials, across universities. The analysis of course descriptions from 15 universities of applied sciences and six universities shows a large proportion of self-study time for which e-learning is particularly suitable. In addition, many overlapping topics were identified that are addressed in both technical drawing and machine element teaching across universities. The development of e-learning materials for these topics therefore makes sense, as the number of potential users could be very high. However, no concrete Intended Learning Outcomes were examined for the individual topics, which would be necessary for the development of such learning materials. This should be determined in a next step. To ensure that future e-learning materials complement teaching in the best possible way, a detailed determination of the requirements for the learning materials is necessary. To this end, Teaching and Learning Activities should be analyzed in detail. For example, how the self-study times currently work and what specific support is needed. Further studies on how students and lecturer can be included to this research can be find in Dillenhöfer et. al (2023). The project TZ Digital.nrw evaluated the opinions of students and teachers regarding the content, i.e. how the workload is distributed and how the content is structured and conveyed. The identification of typical topics of engineering design education in undergraduate courses not only provides an important contribution to the development of e-learning materials but can also be used as a basis for the development of a standardized qualification framework for engineering design education. Lecturers could use this for the development of courses in the fundamentals of engineering design education or for coordination with courses based on it in the degree program e.g. drive technology, lightweight construction, or development for sustainable products.

Acknowledgements

The data presented and analyzed in this article were collected during the project TZ digital. We gratefully acknowledge financial support through the DH.NRW with funds provided by the Ministry for Culture and Science of the state of North Rhine-Westphalia (MKW) under Grant No. 214-5.01.03.02 - 145504.

References

Albers, A., Denkena, B. and Matthiesen, S. (2012), Faszination Konstruktion: Berufsbild und Tätigkeitsfeld im Wandel.

Arnold, P., Kilian, L., Thillosen, A.M. and Zimmer, G.M. (2018), Handbuch E-Learning: Lehren und Lernen mit digitalen Medien, utb Pädagogik, Vol. 4965, 5. Auflage, W. Bertelsmann Verlag, Bielefeld.

Baumann, C. and Benzing, T. (2013), “Output-Orientierung und Kompetenzformulierung im Bologna-Prozess”, available at: https://www.uni-wuerzburg.de/fileadmin/39030000/ZiLS/Material/Kompetenzorientierung/Kompetenzformulierung_15.10.2013.pdf (accessed 13.11.21).

Biggs, J. and Tang, C. (2020), "Constructive Alignment: An Outcomes-Based Approach to Teaching Anatomy", in Chan, L.K. and Pawlina, W. (Eds.), Teaching Anatomy, Springer International Publishing, Cham.

Biggs, J.B. and Tang, C.S.-k. (2011), Teaching for quality learning at university: What the student does, UK Higher Education OUP Humanities and Social Sciences Higher Education OUP Ser, 4th edition, McGraw-Hill/Open University Press, Maidenhead.

Dillenhöfer, F., Künne, B., Frye, S., Haertel, T., Altland, L., Kossack, F., Bender, B., Sersch, A., Gust, P., Lattner, Y., Müller, M., Hinse, D., Pantke, K., Bechthold, J., Frank, J., Richard, T., (2023). Development of Modular E-Learning Materials as OER for a MOOC, in: 17th International Conference on E-Learning and Digital Learning. Presented at the International Conference on e-Learning and Digital Learning, Springer International Publishing, Cham.

Döring, N.; Bortz, J. (2016): Forschungsmethoden und Evaluation in den Sozial- und Humanwissenschaften. Berlin, Heidelberg: Springer Berlin Heidelberg.

European Education Area (2024): The Bologna Process and the European Higher Education Area. Online verfügbar unter https://education.ec.europa.eu/education-levels/higher-education/inclusive-and-connected-higher-education/bologna-process, zuletzt aktualisiert am 08.01.2024.000Z, zuletzt geprüft am 08.01.2024.438Z.

Handelsblatt (2017). Wie Normen den (Handels-)Alltag prägen. Online https://www.wiwo.de/unternehmen/industrie/100-jahre-din-wie-normen-den-handels-alltag-praegen/20571938.html . Stand vom 11.12.2023

IBM Corp. (2021): IBM SPSS Statictics. Version 28.0. Armonk, NY.

Jungmann, T., Ossenberg, P. and Wissemann, S. (2016), "Begriffsklärung zur Kompetenzorientierung", in Frerich, S., Meisen, T., Richert, A., Petermann, M., Jeschke, S., Wilkesmann, U. and Tekkaya, A.E. (Eds.), Engineering Education 4.0, Springer International Publishing, Cham, pp. 863–868 https://doi.org/ 10.1007/978-3-319-46916-4_70.

Garland, Nigel Patrick; Wade, Russell; Palmer, Sarah (2023): NON-EXPERT PRACTICAL APPLICATION OF AI VISION SYSTEMS IN DESIGN ENGINEERING PROJECTS. In: Proceedings of the International Conference on Engineering and Product Design Education, EPDE 2023. 25th International Conference on Engineering and Product Design Education, 7th and 8th September 2023: The Design Society.

Hoppe, L.V., Gembarski, P.C. and Lachmayer, R. (2021), "INTELLIGENT TUTORING SYSTEM AS A TOOL OF FORMATIVE ASSESSMENT IN DESIGN EDUCATION", in DS 110: Proceedings of the 23rd International Conference on Engineering and Product Design Education (EPDE 2021), 9th and 10th September 2021, The Design Society https://doi.org/ 10.35199/EPDE.2021.40.

Kattwinkel, D., Song, Y.-W. and Bender, B. (2018), "ANALYSIS OF ECODESIGN AND SUSTAINABLE DESIGN IN HIGHER EDUCATION", in Proceedings of the DESIGN 2018 15th International Design Conference, May, 21-24, 2018, Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, Croatia; The Design Society, Glasgow, UK, pp. 2451–2460 https://doi.org/ 10.21278/idc.2018.0305.

Kossack, Frederike; Bender, Beate (2023): INDIVIDUALIZATION IN ENGINEERING DESIGN EDUCATION: IMPLEMENTATION OF AN ADAPTIVE E-LEARNING ENVIRONMENT (ADE-LE). In: Proc. Des. Soc. 3, S. 2295–2304. DOI: 10.1017/pds.2023.230.

Kossack, F., Kattwinkel, D. and Bender, B. (2022), "Adaptive E-Learning for the Engineering Design Education at Ruhr-University Bochum", Proceedings of the Design Society, Vol. 2, pp. 2313–2322 https://doi.org/ 10.1017/pds.2022.234.

Krathwohl, D.R. (2002), "A Revision of Bloom's Taxonomy: An Overview", Theory into practice, Vol. 41 No. 4, pp. 212–218.

Mayer, H.O. and Hertnagel, J. (2009), Lernzielüberprüfung im eLearning, Oldenbourg, München https://doi.org/ 10.1524/9783486848984.

Metraglia, R., Baronio, G. and Villa, V. (2011), "LEARNING LEVELS IN TECHNICAL DRAWING EDUCATION: PROPOSAL FOR AN ASSESSMENT GRID BASED ON THE EUROPEAN QUALIFICATIONS FRAMEWORK (EQF)", paper presented at ICED11, 15.8-18.08, Köbenhavn.

Niegemann, Helmut M.; Domagk, Steffi; Hessel, Silvia; Hein, Alexandra; Hupfer, Matthias; Zobel, Annett (2008): Kompendium multimediales Lernen. Berlin, Heidelberg: Springer Berlin Heidelberg (X.media.press). Online verfügbar unter http://nbn-resolving.org/urn:nbn:de:bsz:31-epflicht-1542105.

Pahl, G., Beitz, W., Feldhusen, J., & Grote, K. (2007). Engineering design: A systematic approach third edition. Berlin, Springer Science+ Business Media Deutschland GmbH, 2007.

Pfäffli, B.K. (2015), *Lehren an Hochschulen: Eine Hochschuldidaktik für den Aufbau von Wissen und Kompetenzen, UTB Schlüsselkompetenzen Hochschuldidaktik*, Vol. 4325, 2., überarb. und erw. Aufl., Haupt, Bern.

Reimer, M. (2009), "Studienbewertung und Kompetenzniveau von Hochschulabsolventen – Bayern und andere Bundesländer im Vergleich", in Bayerisches Staatsinstitut für Hochschulforschung und Hochschulplanung (Ed.), *Beiträge zur Hochschulforschung: Thema: Hochschulen und ABsolventen im Wettbewerb: Studienqualität - Berufseinstieg - Profilbildung*, pp. 32–51.

Riphahn, R.T., Eschelbach, M., Heineck, G. and Müller, S. (2010), "Kosten und Nutzen der Ausbildung an Tertiärbildungsinstituten im Vergleich", *Perspektiven der Wirtschaftspolitik*, Vol. 11 No. 2, pp. 103–131.

Schindler, S. (2014), *Wege zur Studienberechtigung – Wege ins Studium?*, Springer Fachmedien Wiesbaden, Wiesbaden https://doi.org/ 10.1007/978-3-658-03841-0.

Schönwald, I. (2007), *Change Management in Hochschulen: Die Gestaltung soziokultureller Veränderungsprozesse zur Integration von E-Learning in die Hochschullehre*, Zugl.: St. Gallen, Univ., Diss., 2007, *E-Learning*, Vol. 12, 1. Aufl., Eul, Lohmar.

Verband deutscher Ingenieure (2019), *Entwicklung technischer Produkte und Systeme 0 Modell der Produktentwicklung* No. 2221 Blatt 1.

WiGeP e.V. (2018), *Universitäre Lehre in der Produktentwicklung: Leitfaden der Wissenschaftlichen Gesellschaft für Produktentwicklung (WiGeP)*.

Contact: Frederike Kossack, Ruhr-University Bochum, Department of Product development, Universitätsstr. 150, 44780 Bochum, Germany, +49 234 3225588, kossack@lpe.rub.de