

# TEACHING ENGINEERING DRAWING IN A TECHNOLOGY CHANGING ENVIRONMENT

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## **ABSTRACT**

Engineering drawing is one of the oldest technologies used in mechanical engineering and therefore also one of the oldest subjects of engineering study courses. Since the last century, engineering drawing has moved on from a subjective way of drawing to a very formalized common language among engineers. In addition, the drawing technology has changed from paper based 2D drawing to 3D volume modelling with help of computer aided drawing (CAD) systems. The 2D drawing is now only one point of view onto the product describing information. Parallel to the drawing technologies, also the teaching technologies have developed over the last decades. Especially during the last decade, the Institute of Mechanical Engineering introduced different teaching methods into its engineering drawing course. This paper analyses the consequences of those changes for the learning success of the students over the last 8 years.

*Keywords: Engineering drawing, e-learning, CAD, videos, multimedia.*

## 1 INTRODUCTION

Engineering drawing is one of the oldest technologies used in mechanical engineering and therefore also one of the oldest taught subjects at universities in mechanical engineering. During the last 30 years the drawing education has rapidly evolved. Trends started with 2D CAD over 3D CAD to manufacturing without drawings must be integrated into the lectures. Additionally, also the learning environment is changing from first e-learning modules on to smartphone and video based learning.

## 2 EVOLUTION OF ENGINEERING DRAWING AND THE USED TECHNOLOGY

### **2.1 Changes in engineering drawing and used technology**

The basic methods of engineering drawing were discovered at the ancient world and evolved slowly until the end of the mid ages. Then, the reintroduction of the central projection in 1420 as well as A. Dürer's textbook, describing the usage of the plan and elevation method in 1525, pushed the engineering drawing forwards. At the beginning of the 19<sup>th</sup> century, patent drawings continuously gained in importance. Starting with the standardization activities in the early 20<sup>th</sup> century, engineering drawing developed further and became a formalised engineer's language, understandable worldwide (compare [1] and [2]). Beginning in the 1960s computer programs were introduced to support the engineer creating 2D drawings and started the era of computer aided design (CAD). At first they only support 2D drawings and therefore replaced the drawing on paper, without introducing a new basic drawing technology. In contrast the new 3D CAD Systems, introduced in the 1980s, changed the complete engineering drawing process completely. From then on, not the 2D representation of the product was focused, but a complete 3D volume model. The 2D engineering drawing is only one view on that model. All needed information should be stored within the 3D model. Nevertheless, the engineering drawing remains important as a legal document and part of the contract between the supplier and the customer. Also the fast creation of 2D sketches during discussions, in order to communicate ideas or as part of the thinking process is common usage of basic engineering drawing skills.

## 2.2 Changing educational technologies

Following [3] the history of machine supported learning started at the end of the 19<sup>th</sup> century with the spelling machine from H. Skinner in 1866. The machine displays a picture and the user should enter the correct word, shown on the picture. Later on, at the first decade of the 20<sup>th</sup> century, educational films extended the media supported learning methods [4]. At that time, H. Aiken patented an improved spelling machine, very similar to the one from H. Skinner. Aikens machine was based on the law of effect theory by Thorndike. Thorndike found out that an association is strengthened if it is followed by a reward. In the following year many learning machines, utilizing this theory, were invented. This included the mechanical teaching machine from S. Pressey in the 1920s. Also the first test, containing only multiple choice questions was introduced during the world war I to test US military recruits. In 1938 a first machine supporting a linear learning program, based on operant conditioning, was invented by B. F. Skinner and J. G. Holland in the US. Those programs presented the content in small pieces followed by questions in order to test the understanding. In 1959 N. Crowder introduced the branching program which allowed individual sequence of the content presentation. One year later the University of Illinois started a classroom system with linked computer terminals where the students could access additional learning resources while listening to the recorded lectures. In 1971 the National Science Foundation (NSF) started the research projects TICCIT (time-shared, interactive, computer-controlled information television) and PLATO (programmed logic for automatic teaching operation) to prove the efficiency and cost effectiveness of computer based learning methods. From the NSF point of view, both projects were successful and proved the advantages of e-learning methods. Since the 1990s e-learning has become more important as well as widely used, caused by the rise of the internet. Today the new smartphones and tablets are changing the e-learning environment again, moving the learning activities from the pc to mobile applications.

## 3 THE ENGINEERING DRAWING COURSE

In 2005 the students learned the theoretical basis in a lecture, supported by the lecture notes. Those lectures were recorded and the students could use the recordings to prepare for the practical exercises (s. [5]). As **Table 1** shows, the students must pass 7 exercises in 2005. They started drawing a free hand sketch of a simple part using parallel projection and anometric view. The drawn part was provided as a physical model. Within the exercise A2 the source was an axonometric view of another machine part. The students created an engineering drawing in parallel projection from the axonometric view and also added dimensions according to the German drawing standards. The third exercise treated the correct drawing of machine elements like nuts and bolts. Based on provided assembly drawings the students had to add the nuts and bolts to the drawing. The task A4 dealt with welds and the related symbols on technical drawings, A5 covered calculations of tolerances and fits. In frame of the task A6 the students changed a given assembly drawing and added 5 different machine elements to it. During the last exercise the students created an engineering drawing of a given physical part. They had to determine the dimensions and all needed information to create a part drawing suitable for production. In addition to the drawing tasks the students had to pass two multiple choice tests, asking questions about drawing rules. Since winter semester 2005 the students attended 15 training hours in parallel in which they were introduced in the usage of the CAD system Pro/ENGINEER (now called Creo Parametric). Before the 2D CAD system Medusa was used. The CAD part ended a small practical test in which the students had to model a simple part. The course has been passed if every exercise and the three tests (Test 1, Test 2 and CAD Test) has been passed.

Based on the e-learning module pronorm, introduced in 2007/08, the lecture notes has been renewed. Nowadays they contain a compressed version of the e-learning content. Thereby the students could lookup content while practicing engineering drawing. The deeper theoretical studies should be done with help of the e-learning system.

In 2010 the complete structure of the engineering drawing part has been redesigned. The lecture has been shortened up to the introduction and the organisational part. Also the drawing exercises have been changed. The tasks A3 and A4 are combined and shortened up to A3. A6 has been removed and A7 replaced A4. Additionally, A5 was replaced by a CAD task, where the students should build and draw a small assembly with help of the 3D CAD system. The drawing should also contain fits and tolerances as a precondition to achieve the desired functionalities. As a result, the CAD part and the drawing part have the equal time slice.

Until 2013 some more changes have been made. The CAD lecture notes are now available as a website and in a printed version. The website is the homepage of the internal browser within the CAD system. So students in higher semesters can access the lecture notes without leaving the software. This is very welcomed by the students because they are using the CAD system in a productive way in the higher semesters to complete their thesis or other work. On the drawing side the e-learning environment has neither been used very often nor intense by the students within the course or afterwards. Therefore the institute decided to stop offering the e-learning module for the students and use it as a content source for the lecture notes only. As a replacement a small video for every drawing task (s. [6]) has been created. The videos introduce the topic in a practical way, discussing some very common problems related to the task and showing a best practice approach.

Table 1. Exercises in engineering drawing in 2005 and 2010

Exercise	2005 Content	Attendance time	2010 Content	Attendance time
Lecture	-	2,0h	-	0,5h
A1	- Free hand sketch of a simple part (physical model) - Parallel projection - Axonometric view	2,5h	- Free hand sketch of a simple part (physical model) - Parallel projection - Axonometric view	2,5h
A2	- Sketch of a part (axonometric projection) - Parallel projection - Dimensions	5,0h	- Sketch of a part (axonometric projection) - Parallel projection Dimensions	5,0h
A3	- Draw Nuts and Bolts in assemblies	5,0h	- Draw Nuts and Bolts in assemblies - Draw welds and weld symbols	7,5h
A4	- Draw welds and weld symbols	2,5h	- Drawing of a physical part - Suitable for production - Fits and tolerances	5,0h
A5	- Calculate Fits and tolerances	2,5h	- Creating and draw assemblies with CAD	7,5h
A6	- Changing a given assembly drawing - Add 5 machine elements	7,5h	-	-
A7	- Drawing of a physical part - Suitable for production - Fits and tolerances	5,0h	-	-
Test 1	Multiple choice		- Multiple choice	-
Test 2	Multiple choice		- Multiple choice	-
CAD		5 x 3h = 15,0h		5 x 3h = 15,0h
Σ Drawing		30,0h		20,0h
Σ CAD		15,0h		22,5h
Σ Total		47,0h		43,0h
Percentage Drawing		64%		47%
Percentage CAD		32%		52%

#### 4 EVALUATION OF THE LEARNING METHODS

One evaluation source is the result database of the students in engineering drawing hosted at the institute. **Figure 1** shows the student's results per exercise over a time range of several semesters. The reached points of Test 1 (T1) and Test 2 (T2) are much lower than the ones for A1 – A5 because the tests have 15 points at maximum und A1 – A5 100. It can be seen, that the results are very constant over the years. The results of nearly all exercises and tests are located inside 2/3 to 3/4 of the maximum points. At first view this result is a bit unfruitful, but closer inspecting it reveals possible root causes for this behaviour. One reason is the data basis of the statistics. The values represent all currently last tries of the students, whether successful or not. Since the course could be repeated as often as wanted by the students, some students participated one time and other 2 times or even more often. Some students paused between the attendances for several semesters. Therefore an assumption is, that the repeating ratio will lower in future. Nonetheless, this is not yet measurable due to the above described facts.

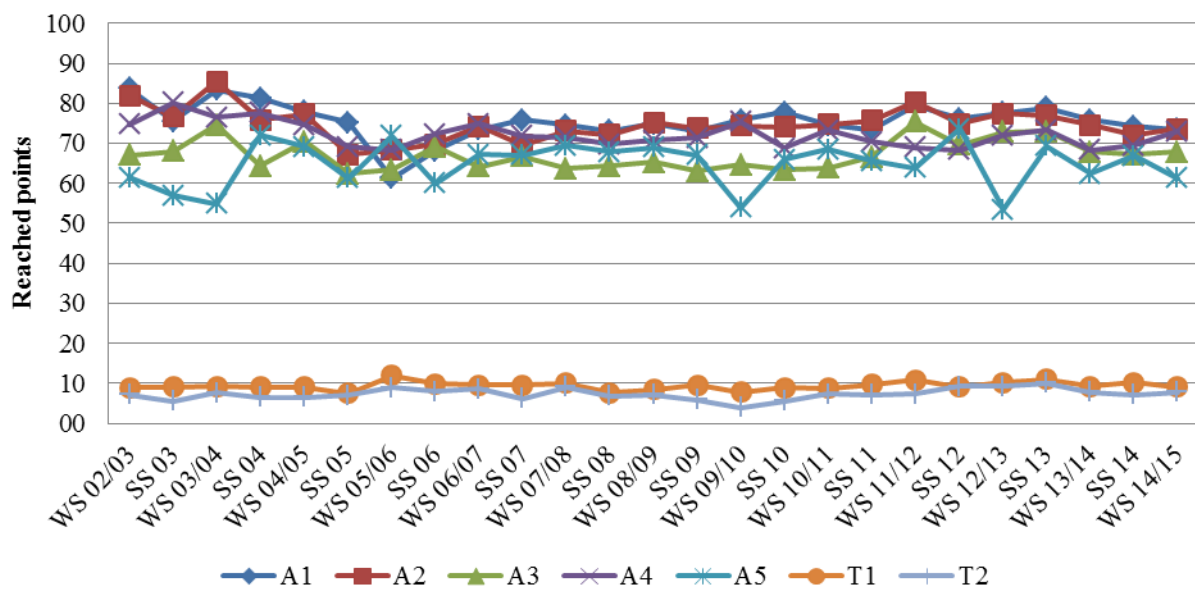
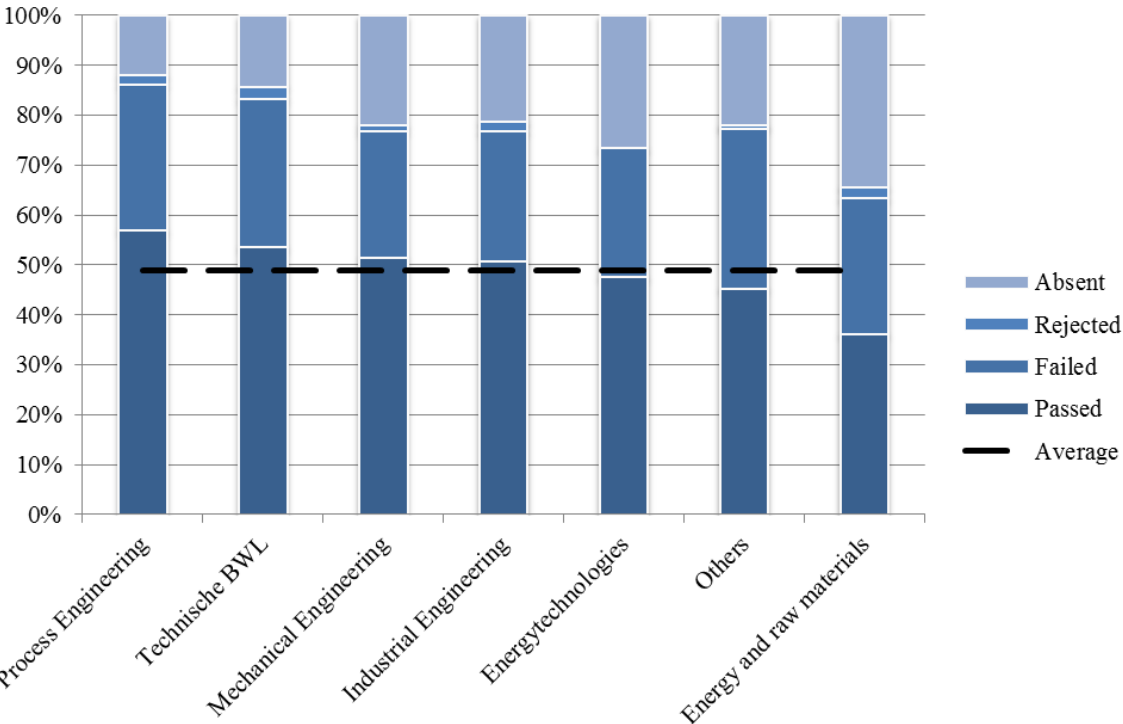


Figure 1. Average result per returned exercise and semester. On exercise A1 - A5 the maximum is 100 points, whereas T1 and T2 has 15 points as maximum

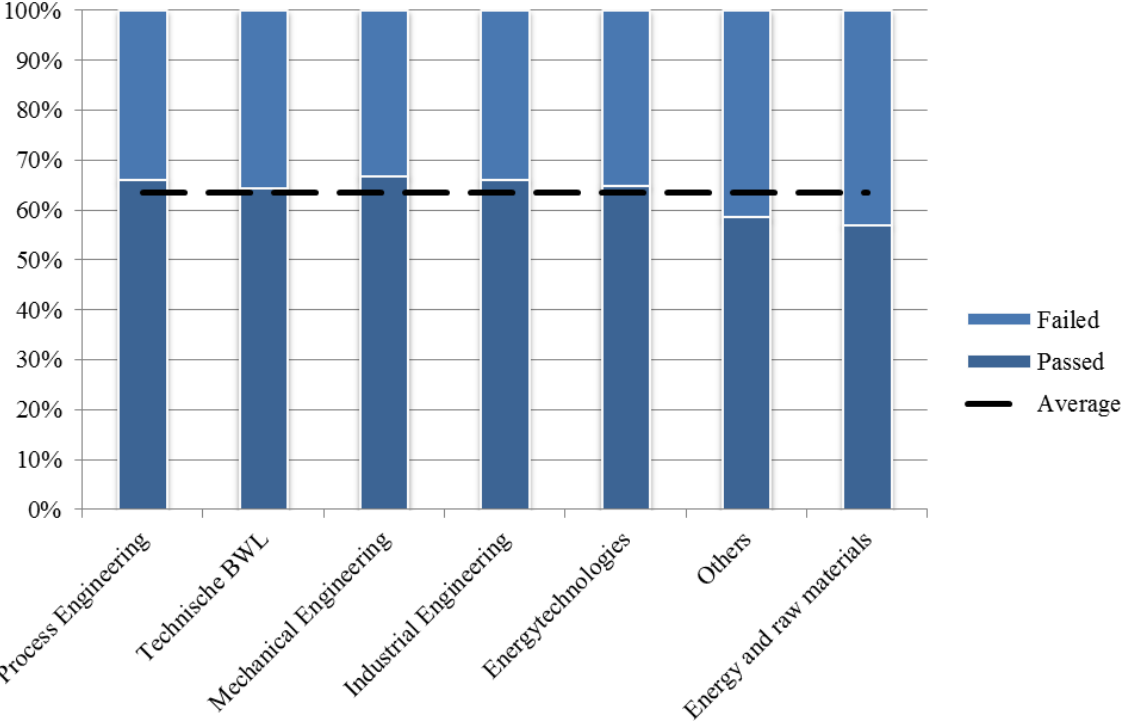
Another reason for the shown constant results might be caused by the fact that engineering drawing belongs to the basic study courses. The students must learn some rules about the drawing language's rules. Furthermore they have to train their geometrical imagination. There is no complex mathematical or physical background. Therefore the motivation and not the abilities of the student is the most important factor. **Figure 2** encourages this relation. In **Figure 2a** there is a difference of about 20% (standard deviation 7%) between the study course with highest percentage of passed students and the lowest one. Excluding the students which were absent within the test or did not attend the exercises for at least 3 times (rejected), the difference between maximum and minimum passed ratio is only about 10% (standard deviation 4%). This indicates that not the study background of the student is important, but only the motivation to attend and finish the course.

Based on the described statistical findings, other criteria must be used to evaluate the realized activities. A first source for an additional evaluation of the used methods, are the standard evaluation sheets and the direct feedbacks of the students. With the help of those sources, the online lecture notes for the CAD part and the videos for the drawing part are highlighted by the students. Another source are visitor statistics of the offerings. For example **Figure 3** shows the rising usage of the teaching videos of the drawing course. In the first semester of this offering, only every 4<sup>th</sup> student has watched the video before starting to work on the exercise. In the last semester, each student watched the video 1.25 times in advance. So, these videos are one of the main preparation sources. On the other hand the visitor statistic of the e-learning module clearly shows that almost no student used it. This might be caused by two reasons. The first reason could be related to the lecture notes themselves. They provide enough information to prepare for the exercise and successful finish them. On the other hand, using

smartphones and tablets for browsing the internet, is very common. But the e-learning module was designed for larger displays and is not usable comfortably on smartphones or tablets. The integrated monitors in the drawing tables were also not competitive enough with smartphones. So the students used the internet on the smartphones to lookup something more often than the e-learning offering.



a) Including absent and rejected students



b) Excluding absent and rejected students

Figure 2. Percentages of results for the students including absent and rejected (a) and excluding absent and rejected (b) students

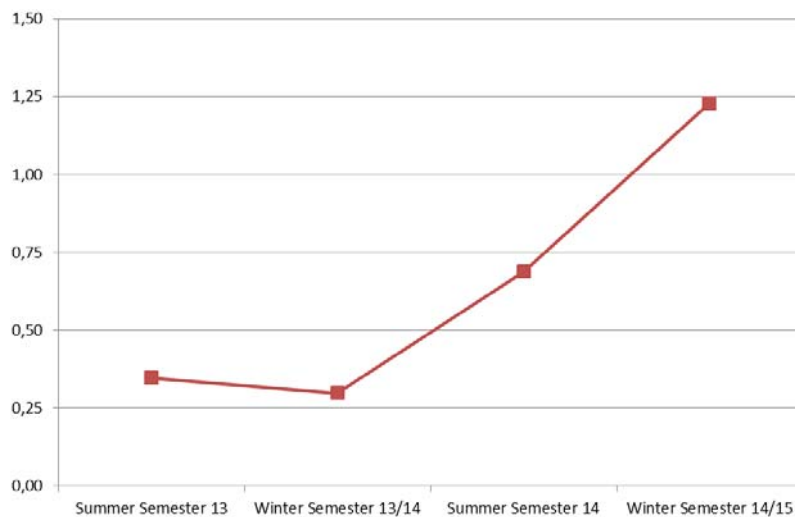


Figure 3. Average count of video views per student

## 5 SUMMARY AND CONCLUSIONS

The engineering drawing course at the Institute of Mechanical Engineering has been in constant flux until today and will also be in the times to come. Since 2005 the share of the CAD part raised from 32% to 50% of the attendance time. In parallel the used learning methods have changed. Starting with recorded lecture notes in 2005 and e-learning offers in 2007, the recorded lecture notes have been used by the students to prepare for the exercise, whereas the e-learning module has not been accepted by the students as expected. As one reason for this the upcoming smartphone and tablet era has been identified. The e-learning module has not been ready for that. Therefore, the e-learning offer has ended in 2013 and been replaced by small introduction videos for each exercise in the drawing part.

Evaluating the acceptance and success of the changed learning environment, it has come out that the new methods have not yet raised the reached points in average. Nonetheless other statistical results have shown that there might be a stronger correlation between the student's motivation and finishing the course successfully than between the knowledge background of the students, due to different study courses. Since the students find the videos very useful and the hit rates are rising, as shown in **Figure 3**, the videos may stimulate the student's motivation. A rising motivation should be followed by sinking repeating rates per student, which could not be analyzed yet. To analyze repeating rates, a longer history after the introduced changes is needed. Therefore it will be a possible metering in the future.

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