# Using Eye Tracking Technology in Design – Possibilities and Limitations

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## Abstract

*As part of the design education at Offenburg University, the teaching in technical documentation is continuously optimised. In this study, numerous mechanical engineering students, ages 19 to 29, are observed using the eye tracking technology and a video camera while performing various design exercises. The aim of the study is to enhance the students' ability to read, understand and analyse complex engineering drawings. In one experiment, the students are asked to perform the "cube perspective test" after Stumpf and Fay to assess their ability for mental rotation as part of spatial visualization ability. Furthermore, the students are asked to prepare and give micro presentations on a topic related to their studies. Students have a maximum of 100 s time for these presentations. Thus, they can practise presenting important information in a short amount of time, show their rhetorical skills and demonstrate their acquisition of basic knowledge. During the presentation, the eye movement of a few selected students is recorded to analyse their information acquisition. In a further test, the students' eye movements are analysed while reading an engineering drawing that consists of multiple views. All the spatial connections have to be included based on the different component views. Including these and their acquired knowledge, the students are asked to identify the correct representation of a component view. Furthermore the subjects are describing the function of an assembly, a parallel gripper and then they are to mentally disassemble the assembly to replace a damaged cylindrical pin. Simultaneously, they are filmed using a video camera to see which terms the students use for the individual technical terms. The evaluation of the eye movements shows that the increasing digitalisation of society and the use of electronic devices in everyday life lead to fast and only selective perceptual behaviour and that students feel insecure when dealing with technical drawings. The analysis of the videos shows a mostly non-technical and inaccurate manner of expression and a poor use of technical terms. The transferability of the achieved results to other technical tasks is part of further investigations.*

**Keywords:** *Engineering education in the age of digitalization, design education, technical drawings, spatial imagination, presentation skills, eye tracking*

## 1. Introduction and motivation

The results of the mechanical engineering students at the Offenburg University in presenting, reading and understanding technical presentations are decreasing all the time.

Today's products are becoming increasingly complex. At the same time, as a result of globalization, interfaces within the overall development process are increasing more and more. Complex presentations of product data are produced in the form of freehand sketches, technical drawings, CAD and FEM models. In addition the holding of presentations, in which complicated circumstances must be summarized in short time, belongs nowadays to the everyday life of engineers.

As part of the design training at the Offenburg University, teaching in the subjects Technical Documentation and CAx Techniques is continuously optimized. In order to make this process efficient and targeted, empirical laboratory tests are carried out on the key skills of presentation, spatial perception, reading and comprehension of technical drawings [1].

## 2. Goal setting

The aim of this work is to use various empirical methods to find out why students in technical courses increasingly show weaknesses in the practical key competences mentioned above and to derive from this how these deficits can be reduced and how existing abilities and skills in teaching can be supported.

## 3. Investigation of the spatial visualization ability

148 mechanical engineering students from the first, second and sixth semesters were tested. The students were subjected to Stumpf's and Fay's [2] tube figure tests to assess their mental rotation competence as a component of the ability to visualize three-dimensional figures. For each task there are

two illustrations showing a transparent cube with a twisted tube in it from two different perspectives, see Fig. 1. The students had to decide from which perspective the second illustration was taken. Almost half of all test persons were classified as average in the easier part A and far below average in the more difficult part B [3]. The interviews with the probands showed that those who used a combination of visualisation and logical reasoning to find a solution achieved better results. The students showed impatience and lack of concentration in finding solutions for the much heavier figures in part B. Consequently, only about two thirds of all tasks were handled at all and about 50% of them were faulty [3].

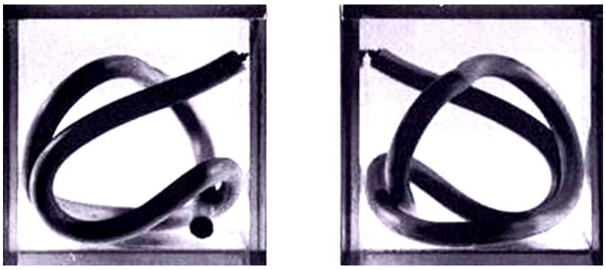

Figure 1: Example of a tube figure pair according to [2], left: the front view of the transparent cube with twisted tubes inside, right: the same tube figure shown from another perspective

## 4. Eye-tracking during micro presentations

A micro presentation is a session with a maximum duration of 100 s, in which the results of the investigation of a technically oriented task are presented and held in a clear manner in front of an audience [4]. The students from the main study course should divide their micro presentations consisting of a single slide into four quadrants Q1 (task area), Q2 (FEM result), Q3 (technical diagram), and Q4 (text summary). These quadrants are provided with so-called Areas of Interest (AOIs) for detailed recording of the results.

At 24%, the average length of stay of all test persons in Q1 is significantly shorter than it would have been necessary for the complete interpretation of the task. The total time in Q4 of 27% is significantly longer than desired. This is an indication that the ability to recognize the essential results of an investigation has not yet been developed. The students use less than half of the available time to deal with the actual result (Q2 = 21%, Q3 = 28%, Q2+Q3 = 49%). This tendency towards "fast, fast", which prevents a careful and precise investigation of a task, is not only observed among students today. Fig. 2 shows examples of the heat maps of an expert (left) and an above-average student (right). The picture shows that the subject dealt with all four quadrants and the time division was exemplary. This brought him very close to the expert's target.

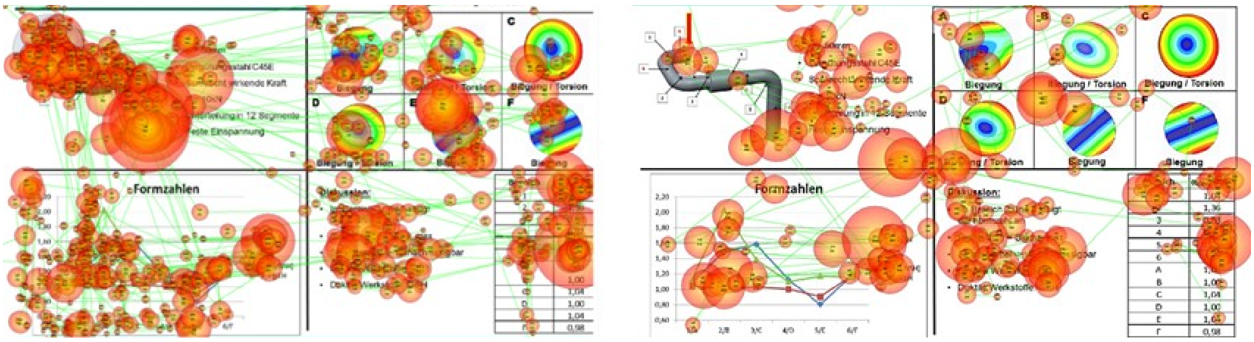


Figure 2: Heatmaps Q1-Q4 of the expert (left) and of an above-average test person (right), (Source: own presentation)

## 5. Eye-tracking when viewing technical diagrams

Technical diagrams are a form of representation that is not sufficiently appreciated in scientific studies. The evaluation of the eye-tracking analysis for viewing the technical diagram (Q3) resulted in the following average time shares of the test subjects: 48 % for the curves, 31 % for the legend, 11 % for the title, 6 % for the x-axis and 4 % for the y-axis. Fig. 3 shows a section of Fig. 2 where Q3 is enlarged. Here the expert's higher appreciation of the diagram is clearly visible.

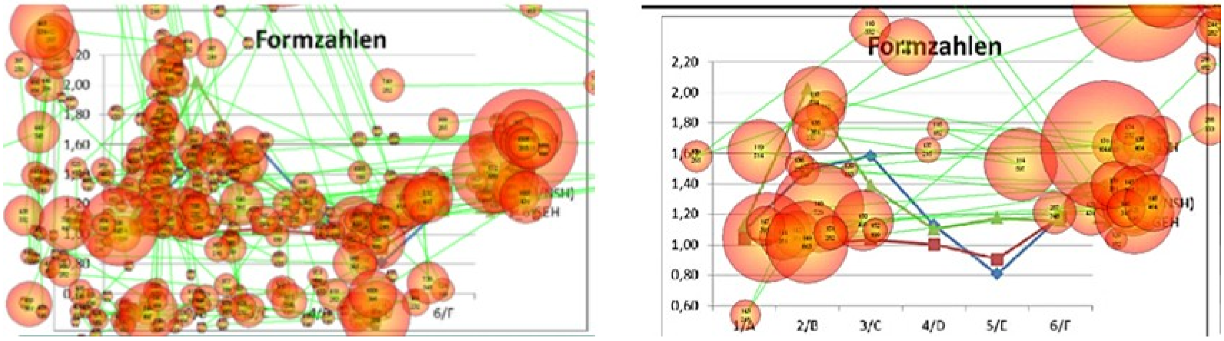


Figure 3: Heatmaps Q3 of the expert (left) and of an above-average test person (right) (Source: own presentation)

## 6. Eye-tracking for reading and understanding technical drawings

For this experiment, the students were observed finding solutions for a typical task in the field of "Technical Drawing". The investigation focuses on a component that is not very complex (Fig. 4). The subjects receive the front and top view of these workpiece. They must decide which of the four side views presented the correct one is.

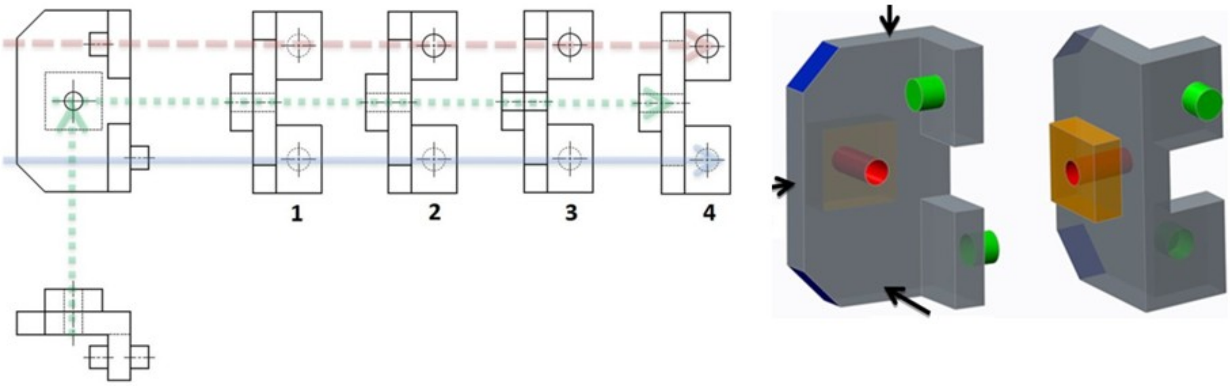


Figure 4: Possible procedure and representation of front view and top view of the component as well as the four side views from the left for selection (Source: own presentation)

Although the rules for finding a solution are extremely simple (visible edges are marked with a solid line, invisible edges with a dashed line), only 47% of the test persons indicated the correct solution.
The evaluation of the eye-tracking data shows that only one third of the students takes time for a detailed examination of the front view and top view. A further third begins too quickly to find a solution. The last third did not recognize the decision criteria for finding a solution. This is indicated by the high number of fixations and/or many saccades.

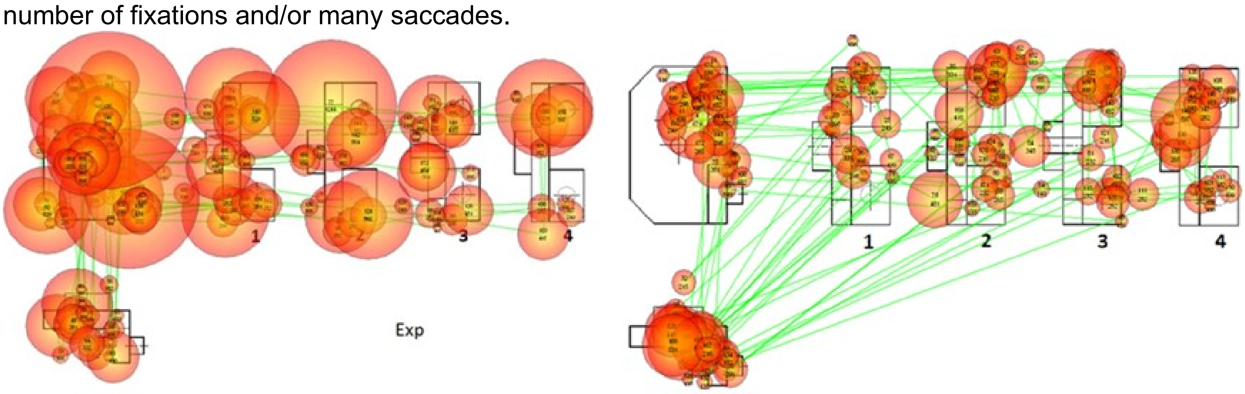


Figure 5: Heatmaps of the expert (left) and a test person (right) viewing a technical drawing (Source: own presentation)

Fig. 5 shows examples of the heat maps of the expert (left) and a test person (right). The saccades of the proband seem confused and imprudent. The large number of saccades indicates an existing uncertainty. The person did not take sufficient time to examine the cylindrical sections in side view. The top view was examined in detail, which was not desired.

## 7. Eye-tracking during the analysis of an assembly drawing

In a further investigation, the students were observed using eye-tracking technology and a video camera in the analysis of a component drawing. The present drawing consisted of different views and sections. In the first task part, they were to use these to describe the function of a parallel gripper (Fig. 6). In the second part, they were to name the disassembly steps. It was to be assumed that a certain, worn component would have to be replaced (task of a final examination of the vocational schools in Baden Württemberg).

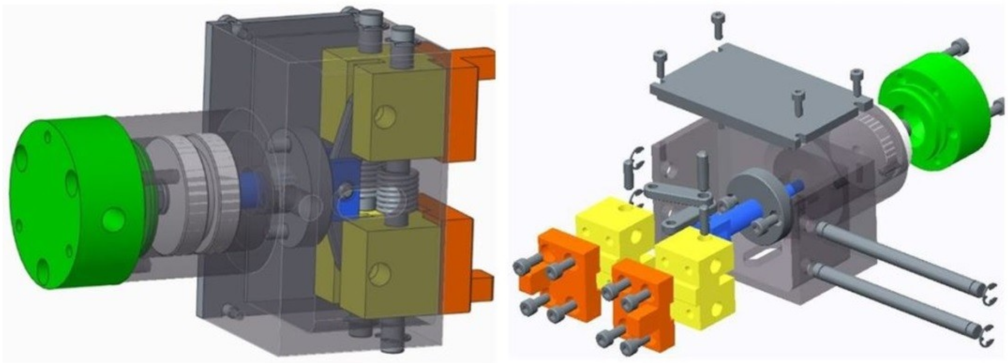

Figure 6: CAD model of the parallel gripper (Source: own presentation)

The results of the video recording should be related to the heat maps in order to identify possible connections between what is seen and what is spoken. In addition, the number of technical nouns and verbs used by the probands should be investigated.
According to the authors, the function of the mechanical assembly can be explained verbally using fifteen different technical nouns and six different technical verbs in a time of 150 s and the disassembly of the components can be described using nine technical terms and five technical verbs in a time of 120 s [5].
This experiment is the continuation of the 100 s micro presentations. The students were asked to explain to another person what they had learned during the solution of a previous design task. The fact that the test subjects were not only recorded using the eye-tracking method, but also with a video camera, made it possible to analyse the connection between eye movement and "loud thinking". The working hypothesis that the eye movements follow the thinking process was strongly supported.
The results of the previous design task had shown that almost all test persons were able to solve it. The deficit was not in the understanding. However, many students showed a lack of ability to present their own understanding to a third person in a structured and comprehensible way. Likewise, most of the probands hardly used any technical terms. The video recordings show an average use of five technical nouns and three technical verbs per solution. This applies to both the functional and disassembly descriptions. Often the item numbers were mentioned instead of a correct technical term. Instead of a correct technical term, a colloquial term was repeatedly used.
Furthermore, the following findings from the previous tests were confirmed:

- The available time is far from being exhausted (functional description: approx. 66 s, description of disassembly: approx. 77 s).
- The lack of structure in the spoken sentences was reflected in restless and "confused" eye paths.

Fig. 7 (left) shows an example of the heat map of a test person in the functional description. Many short fixations and saccades indicate a lack of specialist knowledge. This is confirmed by the video recording, which shows the use of only one technical noun and one technical verb.
Fig. 7 (right) shows an example of the heat map of another test person in the disassembly description. It shows long fixations in the AOIs, especially on the front view. The person takes a lot of time to look at the views in detail. The video recording shows a structured approach and the use of many technical terms.

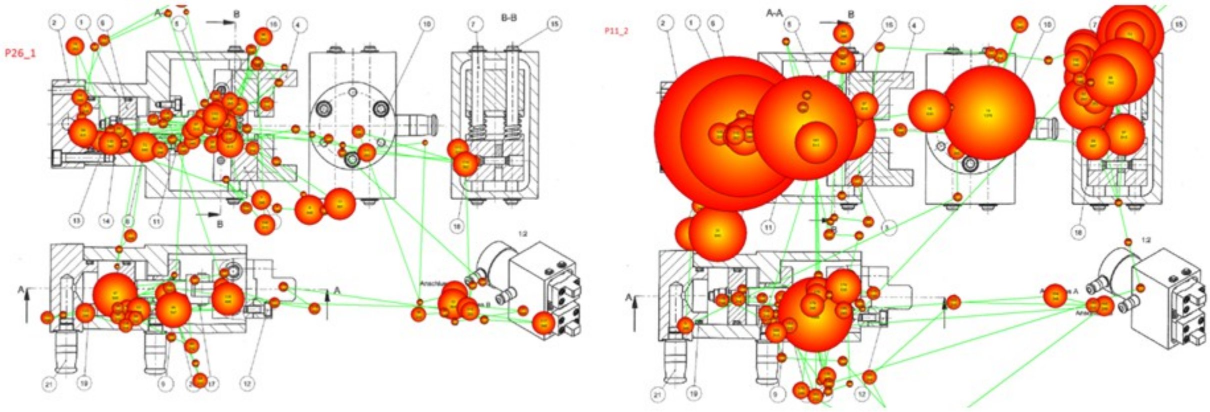


Figure 7: Heatmaps of the assembly drawing of two test persons: Functional description (left), Disassembly description (right), (Source: Own illustration)

## 8. Conclusions

From the empirical investigations presented here, conclusions were drawn about the visual approach of students in the analysis, interpretation and presentation of technical representations in pictorial and textual form. The following basic statements can be made:

The ability of students to independently acquire knowledge from technical representations is insufficient. Deficits were observed in the ability to concentrate and abstract, in logical thinking and reasoning, and in the ability to structure.

Furthermore, students seldom make full use of the time available to them to cope with theoretical tasks and often deal inadequately with a task. They clearly underestimate the importance of correct technical expression using technical terms, as well as the use of illustrations, especially technical diagrams.

In contrast, good skills and persistence in solving practical tasks have been demonstrated.

From the authors' point of view, therefore, two teaching tasks are to be solved with priority:

Through a strong practical orientation with interesting projects and the use of IT tools, which are intuitively used correctly by most students, motivation and "inventiveness" are to be awakened and promoted and early experiences of success are to be created, in order to cause "stamina" for the training of the necessary key competencies.

The encouragement of practical and personal competences must be constantly driven forward and their teaching must take place in a balanced manner parallel to the technical and methodological competences.

The transferability of the achieved results to other technical tasks is part of further investigations.

## References


[1] Daryusi, A.; Köhler, G.: "Empirische Untersuchungen zum visuellen Wahrnehmen beim Lesen und Verstehen technischer Zeichnungen. 14. Kolloquium Konstruktionstechnik, KT2016, 06. – 07. Oktober, 2016 in Rostock, Shaker Verlag Aachen, S. 47-58, ISBN 978-3-8440-4732-5

[2] Stumpf. H,; Fay, E.: Schlauchfiguren. Ein Test zur Beurteilung des räumlichen Vorstellungsvermögens. Göttingen u. a,: Hogrefe 1983

[3] Daryusi, A.: Förderung der Raumvorstellung in der Konstruktion. HS Offenburg, Institut für angewandte Forschung, Forschungsbericht: fif, Ausgabe Nr. 20, S. 18-20, 2017

[4] Daryusi, A.; Schröder, N.: Neue Wege zur Stärkung der Präsentationskompetenz und Teamfähigkeit in der Technikausbildung. In: lernen & lehren, 28. Jahrgang (2013), Heft 111 (3/2013), S. 127-132, ISSN 0940-7340

[5] Daryusi, A.: Blickbasierte Analyse einer Baugruppenzeichnung. Im Tagungsband: Digitalisierung in der Techniklehre. Wege zu technischer Bildung. 12. Ingenieurpädagogischen Regionaltagung 2017, 11.-13. Mai an der 2017 TU Ilmenau, Druck: Uni. Siegen - UniPrint, S. 157-164, ISBN 978-3-9818728-1-1