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DIGITALISATION – IS HAPTIC UNDERSTANDING OUTDATED IN THE TEACHING OF GEOMETRICAL PRODUCT SPECIFICATIONS (GPS)?

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ABSTRACT

For the creation of standard-compliant drawings, the international standards system of Geometrical Product Specifications (GPS) is fundamental. This paper provides a current perspective on the teaching of GPS. What teaching approaches currently exist? And do these meet the requirements of educators in vocational schools and universities? Particular attention is paid to the use of commercial learning kits. Is learning through haptic models as well as learning by doing outdated in the age of digitalisation? What are the learning contents and teaching objectives of such learning kits?

To get to the bottom of these questions, a hybrid learning kit, which combines physical models with digital applications, is used and evaluated in a case study with mechanical engineering students as part of a lecture in the field of ISO-GPS [1]. Finally, the findings are presented in an optimised teaching/learning concept. The aim of this study is also to evaluate simple haptic models in the context of teaching GPS content in an increasingly digital society. Can such simple haptic objects still be convincing and help to understand complex issues? Or do students expect the use of technological visualisations from the field of computer vision?

Keywords: Haptic understanding, Geometrical Product Specifications (GPS), teaching approaches, learning kit, engineering design

1 INTRODUCTION

When a component is manufactured, the technical product documentation serves as a means of communication between different stakeholders such as design or development, the customer, production and quality assurance [2]. The technical drawing and/or 3D CAD model should therefore clearly define all the information required for geometrical description and verification [3]. For the creation of standard-compliant drawings, the international standards system of Geometrical Product Specifications (GPS) is fundamental. The primary objective is to describe the function of the component and to minimise the ambiguity in the translation of this function into the technical drawing and the metrological verification.

2 STATE OF THE ART

The fact that the range of possibilities in the description leads to challenges in the application and teaching of the standards system is explained below. An introduction to findings in the field of digitalisation and haptic models is also given and linked to the requirements of educators and learners.

2.1 GPS

Creating technical product documentations in consideration of GPS can be seen as state of the art. But the voluntary nature of the application of standards is undermined by the need to prove, particularly in the event of disputes, that one has acted on the basis of recognised rules of technology. Current figures on ISO standards and standard revisions show the extensive scope, but also the topicality of the GPS standards system [4].

2.1.1 Teaching approaches

An overview of teaching approaches is given in [5]. The approaches are briefly described below, categorised as literature, e-learning, courses at universities and seminars, and more recent approaches are added. Approaches in the field of e-learning include, for example, a multimedia application, a virtual laboratory for verification or a newer educational application using machine learning and short videos [6, 7, 8]. In courses at universities, 3D CAD (with model-based definition), a 3D printed assembly as well as augmented and virtual reality (AR/VR) are used in teaching [9, 10, 11, 12]. Teaching can also cover the use of a learning kit such as [1], which is described in more detail in Chapter 3. In addition to GPS seminars, AUKOM [13] also offers international seminars for training in production measurement technology with certification in companies and at universities. Schuldt et al. [14] developed an approach for the integration of the GPS system in companies using agile methods and a maturity model. However, even with the more recent approaches, only a few can be identified for the teaching of GPS.

2.1.2 Current challenges in application

As a result of the contrast between the characteristics of the standards system, namely its scope and dynamism, and the gap in existing teaching approaches, challenges arise in the application of the standards. Studies around the world, in Bulgaria [15], Poland [16], China [17] and Germany [18, 19, 20, 21], have shown that the main problem is a lack of expertise and skills based on the current state of standardisation.

2.2 Digitalisation vs. haptic models

Some examples of haptic models in STEM subjects are presented in the review by Fouad et al. [22]. In addition, the advantage of using haptic devices to transform previously passive learning into active learning is emphasised. In the area of spatial abilities, Montag et al. [23] shows the positive effects of direct touch-based and dynamic tasks on the success rate and mental effort of students. In particular, the results of the study indicate a significant increase in intrinsic motivation and a decrease in frustration for women in the dynamic/interactive version of the tasks. Visual and visual-haptic models have been developed by Sykes [24] to support the understanding of dimensional magnitude values and tolerance fits. In this paper, the haptic model is defined by an assembly learning kit with physical parts, assembly tools and a digital device user interface, which is described in detail in Chapter 3.

2.2.1 Requirements of educators and learners

The requirements of educators and learners were also part of past surveys [18, 19]. For example, teachers at technical vocational colleges asked for literature with reduced content and clear illustrations, and for support in developing practical examples [18]. University lecturers wanted their teaching to be more interactive, with feedback, better links to other courses and more interaction with other experts and lecturers [19]. Both lecturers and students asked for vivid, practical and up-to-date teaching examples.

3 METHOD

As part of an elective course in the field of GPS (5th semester of the bachelor's curriculum), 25 mechanical engineering students were given a group task involving the standard-compliant creation of a technical drawing on a voluntary basis. A course in fundamentals of engineering design with a focus on technical drawing is mandatory in the 1st semester. A basic knowledge of GPS standards is therefore assumed. The age of the participants, two of them female, ranges between 20 and 35 years. During their one-hour work, they were divided into three groups and subjected to a short knowledge test. This test used multiple select questions to assess their knowledge of concepts, principles and rules, datum system, dimensional tolerancing, envelope requirement and surface texture. Group size was planned so that four to five people would work together at random. Depending on their group assignment, the students then received the following tools, partly from a hybrid learning kit "lever press" [1]: technical drawings, technical drawings and 3D CAD model or technical drawings and a haptic model. All in all, the learning kit contains a physical functional model designed primarily as an assembly exercise. It is also possible to access various digital media within the learning kit. These are technical drawings in accordance with GPS standards, namely drawings of individual components and assemblies as well as an exploded view. Assembly instructions (as a video or PDF), the full 3D model with the option of exploded view and component name identification, a document with basic knowledge on technical drawing and worksheets with solutions can also be accessed. Finally, the three tools were evaluated. On the one hand, it was possible to assign points between 1 and 4 to the tools for the different purposes, so that a maximum score of 20 points could be achieved in each case. How do you rate an "assembly drawing" or "3D CAD model (incl. exploded view)" or "haptic model" as a tool...

- ...to describe the required functions?

- ...to determine the datums/datum system?
- ...to determine the tolerances of size, form, orientation, location and run-out?
- ...to determine the envelope requirement?
- ...to determine the surface texture?

On the other hand, students could indicate which tool they liked and which other tools would have been helpful.

4 RESULTS AND DISCUSSION

At the beginning, the raw data for this case study [25] was checked and processed. Two of the 25 data sets to evaluate the tools had to be removed due to incompleteness. Thus, 25 data sets for the knowledge test and 23 data sets for the tool evaluation could be analysed as they are independent of each other.

The number of correct answers within the knowledge test for the three main groups (green = technical drawings; blue = technical drawings and 3D CAD model and red = technical drawings and haptic model) is shown in Figure 1. As the three main groups exercises were each carried out twice, this resulted in a total of 6 groups. Overall, a range of 3 to 5 correct answers is identified. This results in mean values of 4.4, 4.3 and 4.1 for the individual groups. The mean value of 4.3 for all students is close to the individual mean values, so that a similar level of knowledge in the lecture can be confirmed.

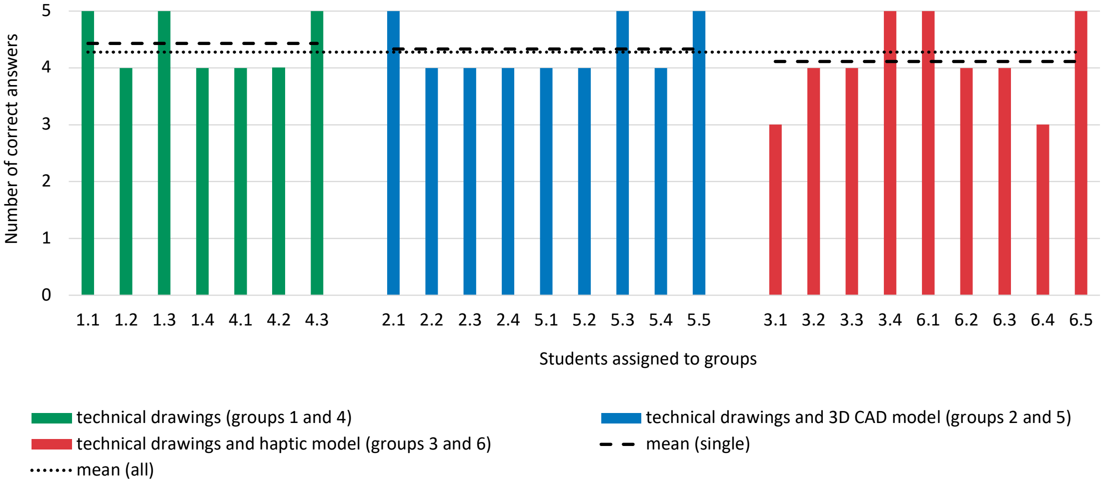

Figure 1. Number of correct answers within the knowledge test for main groups

Looking at the results by subject area (see Chapter 3), the subject of datum systems stands out. With only 17 correct answers, this seems to be the issue where students have the most uncertainties or gaps in their knowledge. In contrast, the question about two-point sizes in the field of dimensional tolerancing was answered correctly in 24 out of 25 cases. In between this minimum (17) and maximum (24) number of correct answers are the scores for the other subject areas: concepts, principles and rules (23), envelope requirement (22) and surface texture (21).

In the next step, students were given the opportunity to rate the three tools, regardless of whether they had used them or not. The results of this rating are presented in Figure 2. For example, the “assembly drawing” receives the lowest average value from the group that had technical drawings as the only tool available during the group work (left in green). Among the groups that used a combination of technical drawings and 3D CAD model or haptic model, the assembly drawing was considered to have more potential. Within their evaluation, the three main groups give the “haptic model” the most points (right). The students' wishes would reflect a similar picture. All the students who had the technical drawing as a tool would have liked to have had the haptic model. In the 3D CAD model group, 13 % of the students were satisfied with their tool, 37 % wanted the haptic model and 50 % wanted a combination of the two. The haptic model tool was considered sufficient by approximately 66 %, 22 % would have preferred the 3D CAD model and one student indicated a desire for a combination. When asked about additional tools, the following were mentioned: a video about the production and usage of the assembly, reference literature, a parts list and a discussion during the exercise.

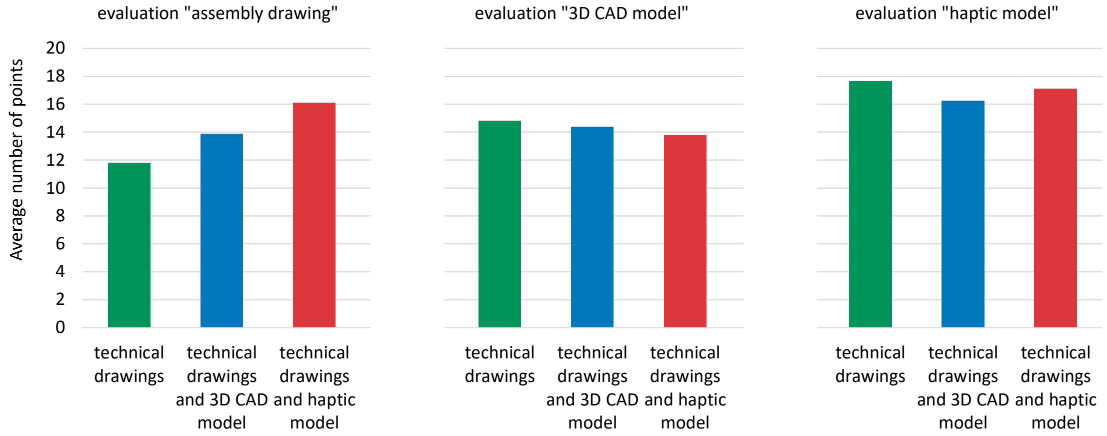

Figure 2. Average of points per main group for the evaluation of "assembly drawing" (left), "3D CAD model" (middle) and "haptic model" (right)

Whether the students' preferred tool, the haptic model, is sufficient and/or should be combined or supplemented, depends on the GPS content to be taught, the desired competences/competencies, and the requirements of the educators and learners. Figure 3 shows the relationship between these four factors in the development of a learning kit or rather an optimised teaching/learning concept.

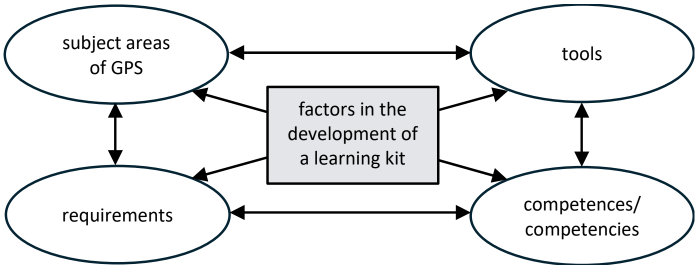

Figure 3. Factors in the development of a learning kit

The content of the GPS standards system can be allocated to various subject areas. The knowledge test (concepts, principles and rules, datum system, dimensional tolerancing, envelope requirement, surface texture) covers these not completely. A more comprehensive proposal for GPS content can be found in [18]. Tools that can be used alone or in combination with the concept include, for example: Measuring equipment and gauges, AR/VR, videos, (learning) games, 3D printing, simulations and model-based definition. It is also necessary to consider the competences/competencies that are to be acquired through the teaching/learning concept. In addition to the competences of the six categories according to Anderson et al. [26], the broader definition according to Heyse et al. [27] in terms of competencies must also be taken into account. What are the requirements for the learning kit and which groups define them? Findings on educators' and learners' wishes have already been presented in Chapter 2.2. Further requirements could be modularity, but also the broadest possible coverage of GPS content. A level structure of the learning concept (as in [28]) or a consideration of prior knowledge may also be required. Based on the students' evaluation, it was shown that haptic models are preferred as a tool for learning GPS, especially for understanding the subject of datum systems. However, the investigated learning kit does not focus on GPS, but on the assembly. Therefore, an optimised teaching/learning concept is presented, which features a combination of different tools. A connection with the verification of GPS is created by enclosing gauges. This will help students to understand the envelope requirement and to carry out a gauge check. By incorporating measuring machines like the Keyence XM-2000 [29] into the concept, the students' competences can be expanded. The previously named measuring machine, shown in Figure 4, is a mixture of coordinate measuring machine (CMM) and hand-held measuring device. Associated features, tolerance zones and deviations can be visualised with the help of AR and the 3D model. After completing this practical training, students will be able to apply their knowledge of measurement methods to the measurement task at hand, understand tolerance zones, evaluate deviations, and be trained in teamwork and digital applications.

Figure 4. Geometrical measurement with a hand-held CMM with AR visualisation

By adding multiple parts produced with different processes to the learning kit students can be sensitised to different manufacturing methods and their deviations in dimensions and surface textures. Due to this component variations students can understand their effect on the functionality and the concept of fits by using punches with different fit sizes. Incorporating videos on topics such as manufacturing, usage of the assembly and measuring equipment and technical drawings can make even more subject areas of the GPS standards system easier to understand and more accessible to students, regardless of time or location. These videos can be made available on a digital learning platform. In this case, a self-assessment could help to individually recommend the digital content that is needed in advance.

Limitations of the case study are the small number of students participating in each group and a similar previous knowledge predetermined by the curriculum at the University of Wuppertal. Results may vary with a larger sample size and the composition of the groups in terms of prior knowledge, i.e. training in a technical profession or core areas in other universities' curriculum.

5 CONCLUSIONS

Student evaluation as part of the case study provides evidence that haptic learning still has potential. In combination with digital teaching and visualisation techniques, the complex field of GPS can be made more accessible. The teaching concept described above now needs to be developed in detail and tested for the examples mentioned above. This also requires further scientific analysis of the proposed concept in terms of feasibility on the one hand and the requirements for the underlying didactics on the other. As a first step, it is necessary to determine the desired competences and competencies for each individual subject area of the GPS standards system. The next step is to identify the present competences and competencies of the individual students. In the long term, implementation may require changes to the overall teaching and learning environment and to the module handbook. This has the potential to link with other engineering subjects and thus improve engineering education in general.

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