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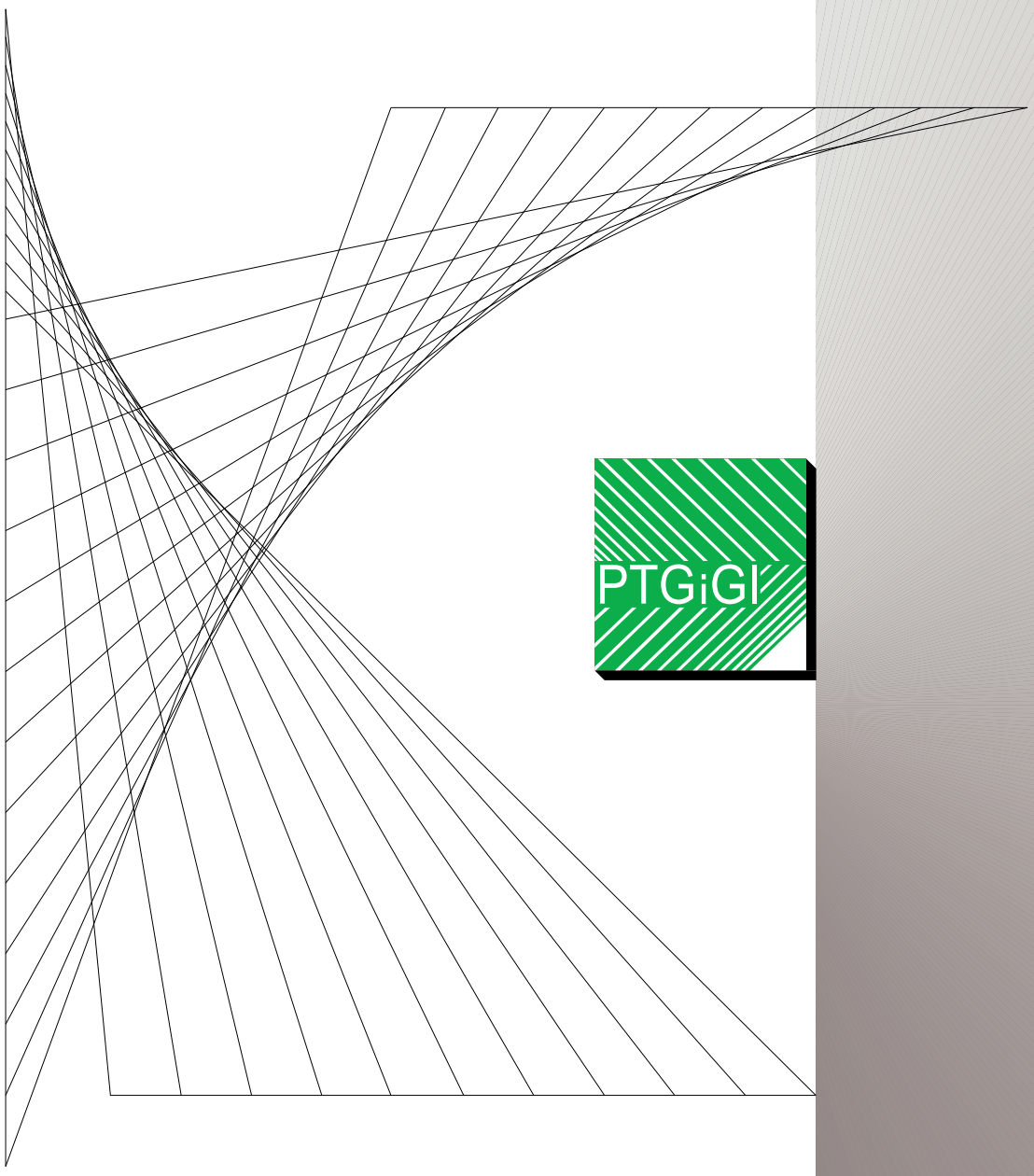

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FACILITATING INDIVIDUAL LEARNING PROCESSES WITH ADVANCED INSTRUCTIONS

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Abstract. Individual learning processes are most successfully activated and intensified when a variety of combinations of instructions and exercises is being used in conveying basic knowledge. Thus we have developed a didactic concept that provides a sophisticated, though compact access to spatial-geometric thinking using CAD software. This concept based on advanced instructions has proved successful for a great number of first-year university students of engineering sciences.

In this beginners' course the students will deal with examples of extraordinary complexity guaranteeing an increased motivation. The content of this course is structured according to the conditions of the learning process rather than with respect to thematic considerations. The fact that knowledge transfer and application are clearly separated facilitates and supports the learning process.

Most favorable conditions for learning will be realized if the students can cut their own paths with respect to their individual originality and capability. The learners will have to assume responsibility for their own learning process. This concept makes it possible for participants to choose between various offers during the course of classes, to evaluate their own personal experience and to opt for appropriate versions of learning - leading all students to identical outcomes.

Keywords: advanced instructions, blended learning, CAD education, didactic conception, individual learning, learning processes, soft skills

1 Introduction

As we have presented at the 12th international conference of E&PDE in Trondheim, Norway, 2010, the new bachelor program for Mechanical Engineering at RWTH Aachen University, Germany requires multi-system CAD-teaching in large classes for a total of 1400 students per year [1]. While the Institute for Engineering Design (Institut für Konstruktionstechnik - ikt) organizes the curricular CAD courses for two different software products (SIEMENS NX and PTC Pro/Engineer Wildfire) within the semester, the Institute for Geometry and Applied Mathematics (Institut für Geometrie und Praktische Mathematik - igpm) offers an alternative class on additional software (Autodesk Inventor) during the semester break. In order to develop spatial thinking CAD software and soft skills are applied, trained and encouraged and thus form additional basic qualifications for all academic studies. The institutes of the RWTH Aachen University and the University of Applied Sciences Aachen collaborated in a comparative case study.

Being an optional class often chosen by freshmen as a pre-course to their studies, the RWTH course “Introduction to spatial–geometric thinking using CAD in Engineering Sciences” has to handle the differing capabilities and capacities of the participants in order to minimize the amount of breakups at an early stage. Accordingly - apart from modeling techniques and software characteristics - further important aspects had to be taken into account:

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- considering all participants - regardless of their entry level
- getting across superordinate contents and promoting soft skills - in spite of limited time
- structuring the course to guarantee best mentoring - large groups of 200 and more participants notwithstanding
- encouraging all participants to succeed in the required level of proficiency – albeit through varying efforts [2].

As these processes can be differentiated between gaining knowledge and translating it into action, the course program is structured into a lecture and an exercise part. The fundamentals of the class "Introduction to spatial–geometric thinking using CAD" are constructional inputs which systematically induce the objectives, at certain points being amended by background knowledge of adequate depth. The constructional inputs are processed in different ways; some feature a direct execution without preparation and others promote a preliminary examination of the issues detached from software application. The latter indeed require more time but secure a solid understanding and a long-term memorization. Following practical experience the self-determined application of knowledge is organized into six levels with decreasing guidance and increasing autonomy: During the first levels the common example is redone with adequate offers, then three additional projects are introduced for a transfer phase. Due to this variety of examples the participants independently carry out different complex constructions even beyond the pure units, thereby clearly realizing the outcomes and getting prepared for a first, entirely self-contained design project. For additional facilitation the exercises are to be completed by learning groups of four participants supporting each other. Thus individual weaknesses can be counterbalanced by others' strengths: Problems that cannot be solved individually are to be discussed within the group and solved together [3].

2 Development of concept

2.1 Approach

In their curricula universities and colleges have to accommodate the variety of freshmen while at the same time ensuring a common level of knowledge as the basis for further expertise. Analyzing a variety of educational models currently used in teaching unveils the fact that mainly the facets of purely conveying and accomplishing knowledge are in the front. Concurrently the didactical research highlights the individuality of learning processes for example by defining certain types of learning or study phases. Neuroscience yields important insights leading to a new concept of learning: The learning process, from a biological perspective, is designed as a function of attention, motivation and emotion [4] and must be based on cooperation and interaction [5]. In reality, however, an appropriate consideration of these aspects is often lacking. Especially in the field of E- or Blended-learning the main emphasis is put on the factual level since the implementation of content is a major challenge, not least because of the continuing technical development [6].

Along with the presented course program "Introduction to spatial–geometric thinking using CAD" a new concept is introduced which equally respects the factual as well as the emotional, the rational as well as the relational level in teaching [3] in order to achieve autonomy and self-determination, to facilitate social integration and experience of competence, and to give a suitable support for an individual-related focus on students.

2.2 Criteria

In combining the experiences from existing courses with the current state of research, the following criteria have been identified as essential for a future concept:

- the rational learning process as a measure for selecting, structuring and linking subject matter
- the individual learning process as a measure for preparing and integrating the presentation and application of knowledge
- the collaborative learning process as a measure for dynamics, confidence, objectivity and creativity and
- their interaction with the general conditions as a measure for sustainability and persistence of the learning process

By these means the concept and its methods are deepened, completed and developed in the context of the class “Introduction to spatial–geometric thinking using CAD” in order to ensure a variety of options on the interfering layers of the didactic concept for all involved in the learning process:

- The student, the teacher and the topic are to be connected with each other and with their learning environment. Allowance is made for different situations, types and phases of learning as well as for effectiveness and feasibility by choosing from individual options out of a wide range of forms of teaching and learning.
- Through offering various media basic knowledge is prepared comprehensively and sustainably while using a structural layout of the presentation to ensure continuity for participants and lecturer.
- For later application a structured and regular practice of the contents is required. Therefore differentiated offers for training in groups or project work are provided.
- In order to enable an interaction between applied teaching and self-determined learning, levels independent from subject matter such as personal or organizational issues have to be taken into account for the conceptual cooperation.
- The participants’ experience of competence as well as the lecturer’s confirmation of competence can only be achieved by a mutual examination of the learning success. Thus, the individual evaluation of objective criteria must be an integral component in the development of basic knowledge. The results will be used to optimize the applied methods.

2.3 Individual Learning

Most favorable terms for learning are realized if each learner can cut his or her own path according to his/her originality, capacity and needs. The conception of “Introduction to spatial–geometric thinking using CAD” provides the participants with the possibility to choose appropriate offers and thereby to assume responsibility for their own learning process. In spite of the limited general framework of a University course for 1400 students each student is able to develop a personal way of learning depending on his/her own proficiency by combining the various offers.

To hint at the range of ways to achieve the common purpose the “most popular”, the “most expeditious” and the “most efficient” variants as well as three examples for paths adapted to special types of learners are presented in Figure 1.

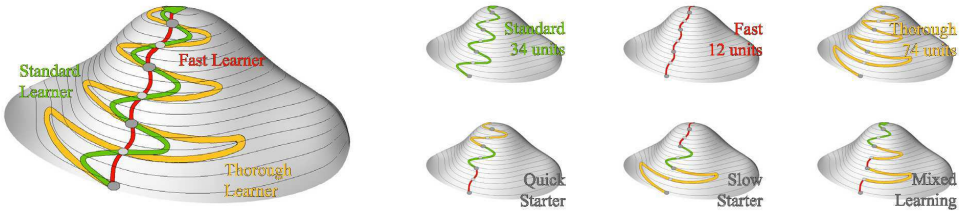

Figure 1: Types of learners

- Standard learner: The participant attends the in-class presentation (90 min), finishes all levels of learning (210 min) and profits from the advantages of the learning group. In order to process all 5 units and the according exercises in this „most popular“ variant the student needs 34 teaching units (45 min/unit).
- Fast learner: The participant watches the video presentation (45 min), skips certain repetitive levels but finishes all further levels of learning (50 min) nearly without individual support. To process all 5 units and exercises “most expeditiously” the learner needs 12 teaching units. A participant with previous knowledge reads the lecture notes (30 min) and completes the highest levels (each 15 min) within approximately 8 teaching units.
- Thorough learner: A participant who needs a very “thorough” education as his or her “most efficient” variant takes all offers of knowledge input (210 min), finishes the levels of learning by revising some of them several times (460 min) and profits from individual support by group members as well as tutors. Thus, the student needs approximately 74 teaching units.
- Quick starter: Participants with precognition can skip the beginning phase and start directly with higher levels of learning. As soon as it appears to be obvious that they are increasingly in need of practice and support they can restart with the first levels that present the content more comprehensively and explain the approach in greater detail.
- Slow starter: According to our experience gained so far, a lot of participants start the first exercises by working through all levels. In the course of time they successively achieve routine in spatial thinking, in using the software, and in their self-evaluation. In the end these participants will directly start to work on the exercises on higher and more challenging levels.
- Mixed learner: All other paths can be realized similarly with the different levels of learning.

2.4 Evaluation

In addition, different tools for evaluation allow participants to reflect their personal expectations, results and experiences before, during and after class: Students will for instance enter the time needed into an online form and then recommendations regarding certain steps for repetition will be given. These assessments simultaneously serve both learner and lecturer:

- The learners will measure their self-perception according to objective standards and will clearly realize their own status compared to the course program. The learners’ ability to determine the learning process autonomously will strengthen their personal feeling of competence. Especially the quantity of individual demand for support serves as an objective criterion for the participant: If it is high the student will be encouraged to deal with both the offers of knowledge transfer and knowledge application once again.
- The lecturer can either monitor single persons and tutor their learning process purposefully, or can observe the whole class to control the output of his/her own efforts and to modify his/her methods if necessary. If – without tutors’ support - several participants are lost at the same step of the construction method, this passage will be modified in order to prevent the following class from facing the same problem. Thus, it is also guaranteed that the participants succeed increasingly often even within E-learning, i.e. without the presence of tutors.

Very high grades in students’ polls demonstrate the high acceptance of this teaching method. An important criterion of quality is met if the attendants are able to handle both the exercises and the transfer without support.

3 Concept as course program

3.1 Preparation of knowledge

To substantiate the prepared subject matter according to the objectives different examples of projects were chosen. A construction method was developed for either passing through all necessary and helpful facets, using the smartest and fastest road to success, or presenting alternative approaches based upon didactical concerns [7]. Thereby, dealing with the content is structured by considerations of the learning process instead of thematic taxonomy. For the different phases of units and exercises five types of instructions with increasing detail were devised. These correspond to useful decisions while developing the work materials: deciding on subject matter and tasks, selecting an example, collecting planning materials, defining the geometric strategy and thoroughly documenting software input. In separating knowledge transfer and knowledge application learning processes are automatically facilitated and even more students can be supported according to their needs.

3.2 Different types of instruction

The construction method is documented in a variety of ways for different educational programs while retaining the principle contents and structures within the case study in collaboration with the ikt [1]: a beer dispenser. In order to convey the subject matter advanced instructions for the different components of the first project are prepared in 5 units. These instructions are supplied to the students online as videos (enabling them to pause, to repeat or to skip if required) or as images of single pages from the lecture notes (the abstraction simplifies the detection of central principles). Alternatively, the software inputs are written down in class: the tutor fills in the gaps in the lecture notes at the overhead projector, the attendants repeat this with their paper versions. Experience shows that a high degree of concentration as well as an intensive process of dealing with the subject matter is achieved by the simultaneous processes of listening, watching and acting while adapting the lecture notes; even more, the collective experience of being in the same situation promotes the students' perseverance.

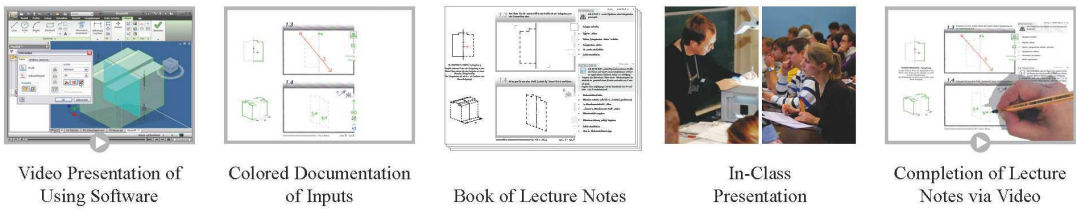

Figure 2: Different types of instruction

3.3 Application of knowledge

According to practical experience the application and examination of knowledge is structured into different levels of learning with adequate offers: First the learner revises the exercises by means of the detailed instructions building up competence by experiencing and reflecting his or her actions. Through the repeated application the student successively gains autonomy and increasingly develops routine, hence building up profound knowledge for the processing of complex examples in the transfer phase when he/she is no longer occupied with issues of the software input.

As individual weaknesses and strengths are supposed to be balanced out among the participants, another important component of the process is to form learning groups

of four participants each where problems and questions arising during the application can quickly be solved [3]. Mutual explanations accelerate and deepen the learning process, lead to an extensive independence from support services and develop the students' soft skills. Exercises consisting of single components which are solved by one participant each and finally joined to an assembly strengthen the cohesion of the group even more. This bidirectional support can only to some extent be realized in the context of E-learning e.g. by providing chat rooms.

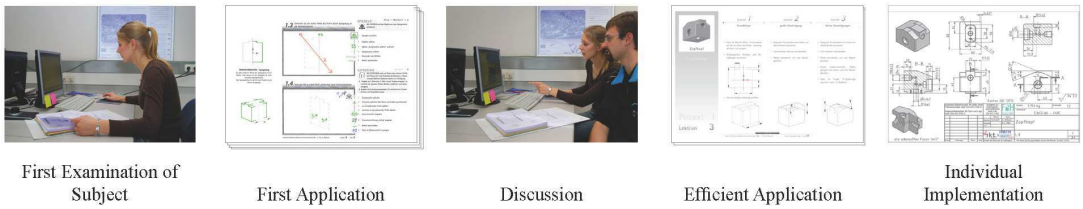

Figure 3: Types of application

3.4 Transfer of knowledge

Additional examples and projects follow after each unit, on the basis of which the participant can try out what he/she has learnt by implementing the detailed instructions. On these levels the advanced learner can put his or her acquired independence from the instructions to the test: Competence is further broadened by solving new tasks (such as design guides, dimensioned production drawings, photos, textual settings or even own designs). Decreasing in their amount of detail these instructions are to enhance the autonomy during the transfer phase as well as to limit the required amount of time. By means of varied projects the learning success motivates the participants additionally. Apart from the transfer of learning the exercises require a good cohesion in the learning group. Thus, the transfer levels can be handled in any order within the bounds of the units. Finally, the highest level represents the footbridge towards the successful application of the software for real tasks in the course of studies and profession: acquired knowledge and competence can be put to the test during the realization of individual design projects based on the students' own creativity.

3.5 Individual support

Based on the instruction various categories of issues can be differentiated: careless mistakes during input, individual difficulties in comprehending certain steps of construction, problems caused by accidentally changed program settings or issues independent from the construction method. Hence, it is also necessary to develop adequate support services tailored to individual requirements. These are provided during in-class presentation by partners and tutors, during E-learning and for self-help through the different instructions as well as various online offers.

Figure 4: Types of support

4 Conclusion

4.1 Quality and effort management

In addition to the achievement of individual learning processes, the absolute separation between knowledge transfer and practical realization at the computer results in an exceedingly advantageous cost-benefit ratio for the in-class course. In spite of the great number of participants the lecturer has to present subject matter in the lecture hall only once. Exercises take place at various times in different computer pools; even here, the concept for individual learning makes it possible that 40 participants can be easily supported by one tutor. For online offers a list of frequently asked questions and their answers is presented on our website.

The considerable effort in time and personnel for the development of the topics, the realization of the instructions as well as the conception of further exercises charge off fast through the high number of participants reached through the cooperation of our institutes.

The available amount of money determines to what extent the program can be presented. Due to this the different types of instructions can also be understood as stages of expansion.

4.2 Prospect

As we have shown differentiated forms of teaching and exercises based on constructional instructions can encourage individual learning: Achieving the same outcomes obviously takes less time for students of high-capacity than for those without previous knowledge and with a greater need for exercise.

But due to the fact that all participants have to assume responsibility for their own learning process each one is assured of competence and expertise and, even more, of social integration, as group work and mutual support is especially promoted. This, despite the voluntariness of a pre-course, leads to the particular high acceptance of in-class offers at RWTH Aachen University where students can experience a faster access, greater support and a deeper feeling of success being part of a large group.

Another achievement of this concept results in the development of a clear geometric strategy being independent from a certain software. According to this basic principle transfer courses for a fast access to other software can easily be processed. By using the main case study of the beer dispenser as the basis for different learning offers, the transfer to other software is also considerably facilitated for the participants: they will profit from the knowledge of exercise matters, geometrical basics and similar principles.

In addition, as stress is laid upon the graphic conception, the course program which was verbalized in German for RWTH Aachen University can be translated into other languages with relatively low effort. Even today an English dictionary is available on the website of the course.

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INDYWIDUALNE NAUCZANIE A CELOWANY SYSTEM INSTRUKCJI

Uczenie się jest formą poznawania rzeczywistości i to taką, która może się dokonywać w różnorodnych, wieloaspektowych formach takich jak: zdobywanie nowej wiedzy, przyswajanie informacji, ćwiczenie nowych umiejętności oraz zastosowanie tych umiejętności w praktyce. Proces uczenia się, jeśli jest wspomagany różnorodnymi formami aktywizacji uczącego się i przynosi zazwyczaj określone i oczekiwane efekty kształcenia w postaci utrwalonych umiejętności. Wychodząc z powyższego założenia, autorzy artykułu stworzyli koncepcję programu nauczania, który można scharakteryzować jako zamknięty i skompaktowany system kształcenia w zakresie nie tylko geometrycznego modelowania trójwymiarowego ale też polegający na wspomaganiu „myślenia przestrzennego" w środowisku programu CAD. Jak wykazały badania ankietowe, zastosowana koncepcja nowoczesnego programu nauczania, oceniona została bardzo wysoko przez studentów pierwszego roku studiów inżynierskich.

Opisywany w niniejszym artykule kurs dla początkujących w zakresie modelowania komputerowego składa się szeregu zaawansowanych zadań projektowych, które motywują do eksploracji możliwości pakietu graficznego, a których celem jest wykonanie poszczególnych, trójwymiarowych, modeli obiektów. Struktura kursu została tak zaplanowana, by trudność podejmowanych projektów była zgodna ze zdolnością do przyswajania kolejnych etapów wiedzy, bardziej niż z uwagi na logiczną sekwencję tematów realizowanych w procesie projektowania. Sukces opisywanego tutaj kursu wynika z faktu, iż przekazywanie określonego pakietu wiedzy zostało wyraźnie oddzielone od umiejętności jej zastosowania w celu realizacji praktycznego zadania. Najbardziej bowiem efektywne wydają się te metody, które pozwalają studentom na indywidualne poszukiwanie rozwiązań zgodnie z ich predyspozycjami i indywidualną kreatywnością. Wymogiem staje się tutaj personalna odpowiedzialność za wykonanie podejmowanego zadania i samokształcenie w określonym zakresie. Zaproponowana koncepcja pozwala studentom wybierać zadania na każdym z kolejnych etapów kształcenia, tak by umieć jak najlepiej odnieść się i dostosować do uzyskanego wcześniej poziomu wiedzy. Możliwość wyboru jednej spośród wielu zaproponowanych opcji pozwala każdemu ze studentów uzyskać takie same efekty kształcenia po ukończeniu opisywanego tutaj kursu.