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TRAINING PRODUCT DEVELOPMENT METHODS IN A WORKSHOP SETTING DEPLOYING HIGHER EDUCATION DIDACTICS

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ABSTRACT
The paper reports on applying teaching and learning methods from university didactics can to support a systematic planning process and the didactics-based execution of a PD workshop session in an MSc programme, leading to repeated top score evaluation results. The hypothesis is that a systematic approach of planning, evaluating, and considering feed-back allows applying the didactical concepts.

Keywords: Product development, didactics, course evaluation, engineering education, workshops

1 INTRODUCTION

University didactics have advanced both in theory and praxis and attracted an increased awareness by professors and teachers as well as the scientific communities. Universities establish compulsory course and programme evaluation procedures, aggregate according comparative indicators, and link the evaluation results to the allocation of resources. The hypothesis is, that a systematic approach that starts with planning the workshop, ends with the evaluation, and considers feed-back for the next workshop cycle, allows considering the didactics concepts. Thus, a one-day workshop for training product development (PD) methods in an interdisciplinary setting has been developed from scratch. The objectives were to consider the didactical and the content-related aspects.
The application of teaching/learning approaches and methods from university didactics is explained. The aim is to support the systematic planning process and the didactics-based execution of such a workshop. The example is taken from an MSc programme. First the motivation and objectives of developing the workshop will be presented, then the approach taken is discussed, considering the aims and the didactics concepts applied. The workshop setting, concept, and outline are explained, then the procedures and results of the evaluation are described.
The authors strived to close a gap in the course portfolio of their institute. So far, an MSc-level lecture "Methodical Engineering Design" is given which covers PD methods and takes two terms (2 x 14 sessions of 90 min). It includes exercises in the lecture room, which are thematically aligned with the lecture parts. However, they are inevitably disrupted by these parts. The intention was to improve the preparation of the students for the exam by an additional, voluntary workshop and to establish a continuous setting for training the PD methods within a type of workshop. The primary target group comprised the participants of the lecture. The secondary target group included students doing their major in engineering design and those interested in this topic from other majors. All of them are in Master of Science level study programmes of different faculties: mechanical engineering, automotive engineering, industrial engineering, and a few from aerospace engineering.

2 STATE OF THE ART AND CONTRIBUTION

The CDIO initiative focuses on defining curricula for engineering education in order to support educating the next generation of engineers. It does not cover didactical methods in detail [1]. The European Bologna Process or the American ABET Engineering Criteria 2000 programme changed the perspective on curricula from inputs (*teaching content*) to outputs (*learning outcomes*; [2]-[4]). Text books on engineering design and PD do not tell how to teach the methods they explain (e.g. [5]). References on didactics provide teaching methods/ for selective application on engineering design and PD projects (e.g. [6]). We contribute a best practice example of developing and executing a workshop for PD methods by deploying a higher education didactics approach to reason the workshop setting.

3 APPROACH BY DIDACTIC CONCEPTS

Developing the workshop was understood as developing a "didactical product". This proceeding was familiar for the authors, since being experts in methodical PD. As many relevant aspects of the workshop as possible were made explicit in this discursive approach. It is based on a didactical point of view. It is summarized by the following list of individual steps that are covered in the given sections: Identify aims of the session (§ 3.1) and boundary conditions for designing the session (§ 3.2), consider involving the students (§ 3.3), select appropriate didactical methods (§ 3.4), choose the appropriate learning/teaching content (§ 3.5), choose the appropriate learning/teaching methods and media (§ 3.6). These steps are to be made iteratively and concern aspects that dependent on each other.

3.1 Identifying aims of planning the session

At first the aims and boundary conditions for the workshop were analyzed as described in the following paragraphs. The items given in bold are relevant in general (and kind of prescriptive), the subsequently listed items are descriptive and concretize the characteristics of this workshop example. The latter items are possibly relevant to more than one aspect, thus they might appear several times.

Expectations of the teachers: close gap in course portfolio; provide additional, voluntary preparation for exam; comprehend content of the lecture; provide students not involved in the lecture with a basic practical experience in applying methods; recruit students for theses in the department/working group;

Desired use for the students: content of lecture is comprehended; preparation for exam is improved; understanding of methods and competencies in applying them are improved; provide practical experience in applying methods independently in a team; understand limitations and problems in applying PD methods and learn to cope with them; experience team-work in PD; achieve self-confidence when applying these methods; train presenting results ad-hoc in front of audience;

Expected quality improvement of the teaching programme and related aspects: close gap in existing course portfolio; provide an alternative teaching/learning setting to allow for involving with the same topic with different approaches; represent relevant research areas of the institute to students; arouse students' curiosity and enthusiasm for the topic 'product development';

Target group: all students in master programmes of mechanical, automotive, and industrial engineering with respect to the actual curricula; students of the aforementioned whose major is PD, which are interested in improving their knowledge and skills in this area, and which are voluntarily willing to possibly spend more time than necessary to obtain the required amount of credit points; students interested in writing their theses in the department/working group;

3.2 Identifying boundary conditions for designing the session

Expectations of the teachers regarding the participants: certain students are willing to spend additional time on learning about systematic PD and consider participation in such a session as useful; the students have to be knowledgeable enough to participate in the session after having read an instruction manual beforehand, even if not having attended the lecture; students are willing to prepare by reading the instruction manual;

Role of the teachers within the overall setting of the session: preparing an instruction manual, the workshop setting, and all related support materials; ensure the feasibility of the session with regard to the organization, content, and schedule; instruct students; support team work; assume role of the 'expert' or 'critic' in the result presentations; give feedback on the processes and results;

During the concept phase of developing the new workshop teaching sessions of both the own and other institutes were compared. This included different types of sessions such as laboratory exercises or assignments of approximately 2 - 4 hours duration, workshops of 1 - 3 days duration, or student projects in various settings (cornerstones, capstones, several days full time to extending over a term in part time). These sessions related to different contents (e.g. gear box efficiency, viscosity measurement, modelling with clay). The aspects found to be relevant are listed in Figure 1. Additionally, the preferred setting for each of them is named. Nr. 1, 2, and 3 refer to limited resources such as staff, space in lecture rooms, and time. Team work (4) is the preferred work setting. All team members work on the same assignment (5). Teams work individually on the same assignment (6). Intermediate results are presented (7) before lunch. An intermediate or partial solution is not provided (8). The teams are competing (9). Symbolic prizes are awarded after the final presentation (10; 11). A physical model of the product is deployed (12). The participants should be able to prepare for the session within two hours of work (13). Coffee and biscuits are provided in the breaks (14). A written

report is not required from the participants (15). The working group, that hosts the workshop, is introduced shortly (16). It is not intended that students participate only in parts of the session (17).
The session was developed under 'laboratory conditions'. The session should have been completely developed until the first execution, assuming that no major changes have to be made after development has been concluded. All teaching materials and contents that were available in the institute and related to the session could be used to reach this goal. Two PhD students designed the workshop. Two MSc level student tutors supported them. The first aided conceiving the instructional manual, hand-outs for the workshop and detailing the different assignments. The other student was a 'test participant', in order to provide separate feedback about the performance of the each of the sub-assignment and the match between expectations and reality. Each sub-assignment was iteratively improved after testing. Limited resources did not allow a full pre-test with a group of students.

Aspects	Setting
1. Number of teachers	2
2. No. of groups x no. of students in each group	6 x 5
3. Duration of the workshop session	8 hrs
4. Type of work setting	Team work
5. Assignment of tasks within each group	uniform
6. Assignment distribution between groups	uniform
7. Intermediate presentation of results between assignments	Yes
8. Providing prepared intermediate solutions to assignments	No
9. Competition between groups	Yes

Aspects	Setting
10. Final presentation of results	Yes
11. Giving (symbolic) prizes at end of workshop	Yes
12. Deployment of physical models/products	Yes
13. Time required by students to prepare	$\leq$ 2 hrs
14. Providing coffee and biscuits	Yes
15. Written report required from students?	No
16. Introduction of the Institute's Working Group "Methodical Product Development"	Yes
17. Possibility to participate in parts of the workshop only	No

Figure 1. Aspects of designing the workshop session and according preferred settings

3.3 Involving the students

A workshop is a comparatively active and involving setting as compared to a lecture. In this case, the students get involved in several ways: First, they have to prepare for the workshop by reading the instruction manual. They have to solve autonomously the assignments in teams. They practice actively the methods of PD. The teachers assist the students if the students ask for assistance or the teachers observe this need on basis of the team progress. The practicing of methods has the highest share of time. The teacher gives only short plenary inputs to provide the information about assignments, methods, and supplementary materials. The students present their results in the plenum.

3.4 Selecting didactic concepts and methods

The didactic concepts and methods are selected from courses to promote higher education didactics in university level education at the University of Stuttgart. There are more methods beyond this [7].
Two fundamental concepts are **teaching and learning objectives** ('outcomes', cf. [1]). The teaching objectives tell what the teacher aims to teach the students (e.g. use of the method brainstorming). The learning objective describes an observable behaviour or testable knowledge (e.g. the student correctly applies a certain method and knows its prerequisites and limits of application). Every part of a teaching session should relate to a teaching/learning objective. A learning objective relates to at least one teaching objective. The learning objectives allow to observe, whether the related teaching objectives have been reached. Learning objectives that do not relate to observable behaviour or testable knowledge cannot be assessed. Teaching and learning objectives can be hierarchically detailed. Our major learning objectives are: "Students are able to apply in a team the methods presented in the lecture and the instruction manual on an idealized assignment that is typical for PD and solve it goal- oriented under time pressure". The detailed objectives relate to mastering the different PD methods with assistance by the teachers, working in groups, presenting group results, and qualitatively assessing the results of the own group and of others. These didactic methods allow for checking whether the concept is correctly transferred into the organization and the contents of the session.
An **epitome** structures the teaching/learning [8]. It orientates the students in a consistent lecture and relates the content of individual units to the 'global view'. An exemplary epitome can be a flow chart that relates different chapters of a lecture to each other. It can also be a physical object, whose different elements are analyzed one after another. The workshop uses a milk frother as an epitome. At first it appears abstractly as a product to be developed from scratch and then as a physical object to be

taken apart for analysis. This device has a low complexity, is easily understood, and does not require too much prior in depth knowledge about its mode of operation, manufacturing etc. This epitome was embedded in a background story reasoning, why a new device for milk frothing had to be developed.
The **sandwich** method integrates between two inputs by a teacher a phase of active work (**activation**) by the students. In a traditional lecture only input is given by the teacher. This setting is broken up by the sandwich method. Students are enabled to transfer immediately the input into action to improve internalization. Each part of the workshop assignment and the PD method to be trained are introduced shortly. Then the students apply intensively this method. An input on the problems observed by the students and the teachers concludes each method application, followed by the introduction to the next assignment. The sandwich activates the students by involving them and initializes the active application of contents just learned/presented. **Team work** includes several phases: Orientation, fighting for positions/hierarchy, familiarity, differentiation, disengagement. In the workshop this happens implicitly by working on the assignment. An explicit reflection about the effects of group dynamics does not take place. However, this approach appeared to be sufficient for making students at least aware of the problems arising when applying PD methods in groups. **Individual work** takes place during the presentations of the team work results. **Motivation** can be either intrinsically, i.e. governed from intra-personal aspects, or extrinsically, i.e. provoked by external aspects. The 'competition' extrinsically motivates the students despite the time pressure: The teams are told that they are to judge the presentations and results of all groups twice: before lunch break (when they also get to know, that they compete over some symbolical prizes) and at the end of the workshop. The teachers judge the results, too. The competition forces students to represent and defend their own solutions and reflect about them as compared to the other solutions. A new scenario after lunch helps to keep all teams motivated for the second half of the workshop. The performance of the teams after lunch does not rely on their results/ranking before lunch.

3.5 Choosing the learning/teaching content

The lecture at the institute includes a selection of commonly used PD methods with reference to a standard text book [4] and personal experience from industry. These methods are trained in about 9,5 hours of a total of 40,5 hours lecture time. The workshop was planned to last 8 hours. Accordingly, a didactical reduction had to take place. Not all phases of the usual development process could be considered equally. Embodiment and detail designing require very much time, knowledge and supportive material. The assignment should not be to complex. It must meet with the schedule and the prior knowledge of the students, as based on their lectures and preparation with the instruction manual. The selection of methods should not limit to some synthetical assignment that is unrealistic, not demonstrative and/or little motivating. Accordingly, two scenarios were formulated relating to the design of the milk frother. The first covers planning and conceiving a new product, the second deals with analyzing and improving an existing product. The latter relates to methods usually applied during or after the embodiment and detail design. Students are trained in the methods brainstorming, establishing requirements list, compiling function structures and morphological charts, evaluating and selecting candidate solution concepts, disassembling and analyzing a real product and deriving a fault tree, as well as performing a failure mode and effects analysis, finally.

3.6 Choosing the learning/teaching methods and media

In the following we list briefly which learning/teaching methods were linked to the specific contents.

- **Team work**: Applying the individual PD methods
- **Individual work**: Presenting the team work results; judging the presentations of the teams
- **Activation/Sandwich**: Alternating between input – action – (feedback) – input
- **Keynote speeches**: Explaining assignments, scenario changes, feedback/presentations rules
- **Team building**: Participant introduction, establishing teams, querying expectations, having lunch and coffee breaks with all participants
- **Change of learning/teaching methods**: as a meta-strategy comprising the items listed above
- **Didactical reduction**: selecting content of the exercises in the lecture for the workshop

The main learning/teaching media is verbal explanation. Depending on the content technical means support it such as a projector and a visualizer. An instruction manual is handed out before the workshop, printed assignments and forms are spread, and flipchart sheets/pens and self-adhesive notes are at hand. A real milk frother is disassembled with screw-drivers and analysed.

4 THE WORKSHOP

In the first scenario a milk frother for office use has to be conceptualized: The students brainstorm, list the requirements, interpret a given function structure, allocate principle solutions to a morphological chart, and systematically assess and choose the solutions. In the second scenario, beginning after lunch, an existing milk frother is dismantled by each group. A bill of materials is listed and a function structure established. The ways of failure are grouped in a tree, which is evaluated to propose measures for reducing risk according to the FMEA. According to the teaching/learning objectives the students learn about the methods listed in the workshop outline in Figure 2.

08:15	Introduction, clarifying expectations, establishing teams	10:00	Morphological chart	13:30	Function structure	16:45	Risk optimization
08:30	Introducing 1st scenario	10:45	Intermediate presentations	14:15	Failure tree	17:00	Final presentation, award ceremony
08:45	Brainstorming	11:30	Lunch break	15:00	Coffee break	17:30	Feedback session
09:15	Requirements list	12:30	Introducing 2nd scenario	15:30	FMEA	18:00	End
		12:45	Systems analysis	16:15	Risk assessment		

Figure 2. Workshop schedule

5 EVALUATION PROCEDURES, RESULTS AND DISCUSSION

We evaluated the workshop in several ways. During the development phase a student tested the workshop assignments. At the beginning of each workshop we asked the participants for their expectations regarding the workshop. They are compared with the expectations we anticipated. At the end of the workshop we asked whether the expectations were met during the session, and if there were any suggestions for improving the workshop. The presentations of results of the students were used to assess their progress according to the learning objectives. The quality management department of the university provides a standardized questionnaire for such workshops. The findings are discussed in the next section. The first run of the workshop was partially video recorded and peer-reviewed.

The most frequently named expectations are: to train the PD methods, to prepare for the exam in the related lecture, to learn about the compatibility of different methods with each other, to exemplarily apply methods to one product. We found that these expectations met with our own and those, that we anticipated as student expectations. It has not been assessed yet, whether students use the methods afterwards. The univocal and positive attitude of the students to spend more time on this workshop than what is awarded by credit points in comparison to similar sessions was a positive surprise. Furthermore we found that the students were motivated all through the day, according to the concluding oral feedback. The questionnaire uses ordinal scales (Figure 3). Five independent sessions with a total number of participants N = 121 (response rate 100 %) are considered. The worst result for the criteria #1-4 (scale: 1 to 7; optimum: 1) is 1.64, the best 1.07. The overall grade of the workshop is between 1.33 and 1.78 (scale: 1 to 5; optimum: 1). The criteria #6-10 (scale: 1 to 5; optimum: 3) concerning the amount of theory, the number of assignments, the intensity of discussions, the expenditure of time, and the difficulty of the assignments were graded between 2.45 and 3.6.

The assignment is a compromise of task complexity, relevance, group size, and available time. Exam assignments are similar compromises. A workshop objective was to prepare for the exam. The results presented by the students (prepared as a team) would have been sufficient to pass the exam.

So far there are no benchmark results from other workshop evaluations available for comparison due to data privacy of evaluation results. Thus, our positive interpretation takes an absolute point of view regarding the scales. It is backed up by a discussion with the trainers of the higher education didactics center at our university. A trainer pointed out, after assessing the documentation and evaluations results of the workshop, that certain aspects that are relevant for motivating students, have been well addressed: The students perceive being integrated by team working, they appreciate the autonomy of being able to solve the assignment on their own, they feel their own competence when presenting their results, and the assignment emphasizes the relevance of the workshop content in praxis. The correlation and causality between the development procedure and the achieved quality cannot be reasoned on basis of the evaluation results. However, we conclude, that regarding developing a course as developing a (educational) product, is a reasonable and pragmatic approach. It makes the objectives explicit and facilitates documentation. The results of the introducing expectations query, the oral feedback session and the questionnaire show that the workshop suits the context of the session and meets the expectations of the actual participants. Furthermore, the actual and the anticipated group

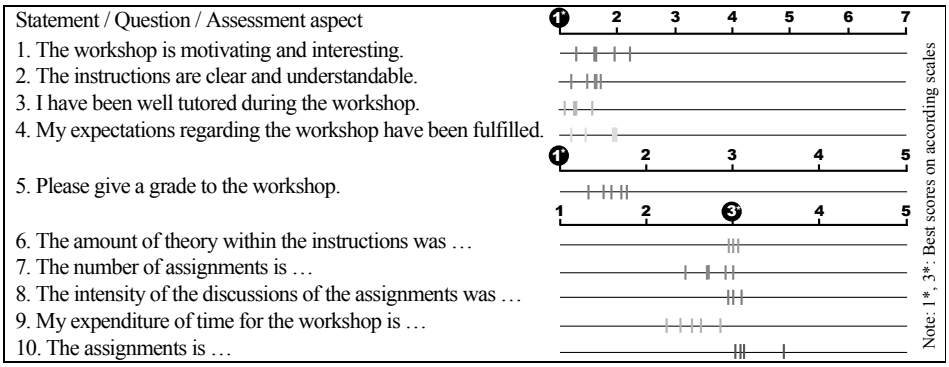

Figure 3. Evaluation results (ordinal scales; #1-4 to be rated from 1 ("the statement is absolutely right") to 7 ("the statement is not right at all"); grading the workshop, #5 from 1 ("very good") to 5 ("insufficient"); aspects # 6-9 to be assessed from 1 ("very high") to 5 ("very low"); #10 from 1 ("very difficult") to 5 ("very easy"); 5 independent sessions; N = 121)

of participants match each other. Team work helps to integrate students with different study programme background. The teams are assigned randomly at the beginning of the workshop with as equal as possible numbers of members. At first this appears rather unpopular every time, but has never been criticized in the concluding feed-back. Often the teams internally split deliberately in pairs of two or three to solve sub-assignments in parallel. We overestimated the expected time to finish the sub-assignments. The students become observably inactive, when they consider a task to be finished. This appeared to depend on the number and size of groups. Smaller groups remain more active, fewer groups get inactive. We cannot quantify these impressions. At these points in time it was appropriate to not stick to the timeline, but to end the active phase and start over the 'sandwich' with a passive input. We observed three effects: i) Practicing certain methods requires a minimum group size. ii) To make teams compete, at least three teams are needed. iii) The expenditure of time for presenting and discussing results and giving feedback depends on the number of teams and team members. It is reasonable rather to shorten the duration of the workshop than demotivating the faster teams by 'idling'. Students ask at first for a master solution to the assignments before or during working on them. But they did not miss them after having discussed their own results and still not having been given 'the' solution. This could indicate that the students were initially unconfident in how to proceed but afterwards were confident with the procedure and result. There have been only one or two obviously passive participants in each session (in as far as passiveness can be quantified at all). The workshops take more time than other sessions which offer the same amount of credit points. This might cause some selection of participants, positively influencing their appreciation of the course with respect to the evaluation results. This selection is at least acceptable, since it supports positively the course of action in the workshop. Choosing the milk frother as an epitome was discussed very controversially due to the simplicity or "low-tech characteristics". However, the students objected rarely to this aspect. The feedback and evaluation results indicate that the desired quality level of the workshop has been achieved. Thus, the hypothesis '*a systematic approach ... allows applying the didactical concepts*' should not be rejected. This approach is not limited to the specific objectives and content of the workshop discussed above as based on evidence from the development of other "didactical products" for teaching engineering design in exercise and tutorial settings.

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