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PLANTING THE SEEDS OF FUTURE MECHANICAL DESIGN ENGINEERS – LEARNING SKILLS

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ABSTRACT
The learning process of students in mechanical engineering is accompanied with various challenges. A gap in students' fundamental learning abilities, such as learning competences and self-organisation skills is revealed. These fundamental lacks impact the students' performance in engineering design lectures as well. One example is that students have difficulties in searching for and extracting useful knowledge for design tasks on their own from literature. This paper introduces and evaluates a model consisting of three pillars, each of them representing processes performed to contribute to the development of students' fundamental learning skills. The first pillar, being a kick-off, is a study group connection platform during which students have the opportunity to find adequate study partners and form study groups. Individuals and groups can then participate in subsequent offers. The second pillar refers to learning tutorials during which students have the possibility to learn and try out learning strategies. Reflection about the personal learning behaviour is a core element of these learning tutorials. These should ultimately help students develop and deepen their learning capabilities to be able to cope with any exam and organise themselves efficiently. The third pillar serves the purpose of linking the general learning strategies to specific subjects to be studied, such as engineering design courses. The fundamental learning abilities are not only considered to be essential for successful studies, but also regarded as beneficial for professional life. Recommendations for future engineering design education will be outlined.

Keywords: Fundamental learning skills, study groups, mechanical engineering education, learning strategies, tutorials for efficient studies.

1 MOTIVATION

Several studies have demonstrated that engineering students are exposed to many challenges during their studies. These challenges include lack of social affiliation [1] or lack of practical experience with machine parts [2] for example. These challenges mirror on the success of their studies – remarkable drop-out rates is one hint for this. Moreover, data collected and evaluated at the research institute has demonstrated that mechanical engineering design students often fail their exams in their first semesters and have to take a second or third attempt to pass the exam. Whereas some students can manage demanding situations fairly well, others experience more severe consequences such as quitting their studies, as they are not able to handle the encountered difficulties. It is therefore important to address these problems ahead of time.

Analysis of literature [1, 2, 3] and feedback from various stakeholders, such as students, tutors and researchers of the research institute and respective others dealing with design education, have demonstrated a lack in students' abilities with regards to learning competences and self-organisation skills for effective studying. These are coupled with difficulties in specific technical courses – fundamental lacks in learning skills shadow on the success in mechanical engineering design education, too. One example is that students find it challenging to search for and identify useful knowledge for design tasks on their own from books or find it demanding to document clearly essential results of consultation with regards to their design projects. It was also mentioned that there is a potential for improvement in the management of accomplishing technical mechanical design projects. These include the determination of the content and structure, writing style including expression of language and correct quoting techniques, misleading expectations on the level of achievement necessary to pass the project, understanding of the task to be solved, an underestimation

of the workload and required preparation and improper time management as well as a general lack in understanding the principles of engineering design and the basic machine elements which is also expressed by insufficient technical drawings.

2 PROJECT AIMS AND FRAMING CONDITIONS

2.1 Project aims

Overall, the additional learning offers should contribute to lower the drop-out rates in engineering and reduce the number of students who fail exams. Another aim of the introduced concept is to increase the quality of engineering education such that higher qualified students will graduate. Students shall be motivated for the engineering profession.
In specific, the courses offered shall

- improve the networking among students and their dialogue to researchers,
- build and maintain a continuous platform (tutorials) for fostering mutual support particularly during the exam period,
- impart learning methods and strategies, notably for successful completion of the exam period,
- accompany and support, especially during the exam period.

2.2 Target group

A target group based on studies has been defined and the concept addressed to the same. So Bachelor students belonging to the mechanical engineering deanery at the university (mechanical design engineering and naval architecture) in the early phases of their studies who failed one or more exams in their first semesters are addressed. The addressed students should further be motivated to improve the personal learning behaviour. However, it is postulated that the courses would help students pass any exam disregard the course of studies, as the concept aims to develop students' fundamental learning skills and this should enable them to cope with any exam.

3 PROPOSED SOLUTION CONCEPT

3.1 Three pillar model for enhancing learning skills

The three pillar model for enhancing students' fundamental learning skills which consists of three platforms is introduced to accomplish the above mentioned aims. Whereas the study group connection platform and learning tutorials support any student independent of their course of studies, the subject-specific application support is specifically designed for students attending a certain lecture and therefore they are assumed to benefit them the most. Tutors, usually experienced students of higher semesters with remarkable reflection skills, prepare and lead the tutorials. They are all trained beforehand on the general concept as well as the specific tutorials they hold. Continuous supervision and final feedback is an important part of the model to further improve the concept. Constant development of the first introduction of the concept in 2011 took place with regards to feedback.
Each pillar can be attended individually, though the programs' contents are built on one another and it is recommended to participate in each pillar for maximum benefit. The concept shall help to create and constantly develop mechanical design engineers' fundamental learning skills. It is important to plant the seeds of future mechanical engineers through enabling them develop a core of general abilities to cope with various educational situations.

3.2 Study group connection platform

The study group connection platform is the first pillar of the three pillar model for enhancing learning skills. It is held as a kick-off event to all subsequent tutorials. It is not necessarily easy for students to find adequate study partners with whom they can work effectively.
This event provides the opportunity to meet other students and facilitates forming study groups. Students are invited to assemble in a hall or room of enough space to allow a high number of students to move around and search for study partners. First, a passive part with a short presentation on the three pillar model and the procedure of the study group connection platform is given to students. Students are also given hints during this presentation on possible criteria to choose study partners, such as if the learning intentions and exams are corresponding or a schedule fitting to all study partners can be arranged. To facilitate finding partners interested to study for the same exams, students

are provided with coloured markers – one colour representing one subject and are presented a plan of the assembly room divided in accordance with the subjects. As the study group is open to students of any course of studies, the amount of subjects may be quite high to organise within one event in one room. Therefore, it has proven useful to assign colours to the most important subjects (e.g. those with high number of students failing the exam) individually, combine subjects (e.g. those two with higher number of students for example from subject A and subject B, as students who fail A tend to fail B too and would like to study for both in a group) and allow for one colour representing "others". Another aid is the division of the room into exactly those colours such that participants wanting to study for the same exam can gather together physically quickly.
Students can make use of the colour system during the following active phase – students are now encouraged to move around, talk to others and find study partners. The study group connection platform ends with groups having formed. Students register as groups with their contact data in prepared sheets. The prepared sheets already allow to register for subsequent tutorials as a group or individually. Up to six students is recommended for registration in a group.
After this physical study group forming phase, the groups are registered on the online learning platform of the university. Open groups can be filled by students joining the online platform at a later point in time. As one subject may be attended by students from various courses of studies in Bachelor's or Master's degree, this kick-off event fosters communication between various levels of studies too. From this point onwards, it is up to the students' initiative to organise themselves and start studying as a group.

3.3 Learning tutorials

Interactive learning tutorials of different length and in small groups are offered. Learning tutorials serve the purpose of "grounding" the students with regards to their capabilities, analyse their existing repertoire on learning strategies if available, identify and assess their current difficulties with regards to studying in order to discuss them with peers and trained tutors. These tutorials highly depend on the active participation and contribution of the participants – tutors should be well prepared to cope with situations in which participants first have to be motivated in order to open themselves and share personal experiences. Topics treated during these tutorials include, but are not limited to

- learning techniques and strategies
- use of modern technologies for studying
- time management
- personal goals
- motivation
- procrastination
- priority management
- studying individually and in groups
- studying during the semester
- formulation of criteria when (not) to go to an exam
- hints on how a formula sheet to use in exams can be written efficiently and timely
- tips & tricks to exam reviews
- hints to other supporting offers of the university

3.4 Subject-specific application support

The learning skills should find application during studying within the semester and during focused exam preparation. Subject-specific application support is offered to students such that they can have a platform to exchange ideas with others studying and apply their learning abilities to subjects such as in mechanical engineering design. The offers belonging to this category differ in content and the form in which they are offered to students. These offers can be held in parallel to or after learning tutorials. Usually, the respective experts from the subject area are included in the planning and implementation of these offers. So far, exam simulations and subject-specific tutorials for various subjects are offered. Exam simulations offer students the possibility to experience a mock exam process under similar conditions to the real exam ahead of time. This shall help participants in starting to study on time and realise quickly personal areas to improve. The exam simulation is based on personal feedback from tutors and researchers to participating students and is accompanied by several elements such as short

inputs to formal aspects to exams or specific learning techniques for the respective subject. This phase is successful the moment students gain a realistic attitude towards their performance and can deduce potential areas of personal development. Simulations can be combined with tutorials too.
To illustrate the structure and contents of subject-specific tutorials, engineering design tutorials are outlined in the following. Subject-specific tutorials are offered based on the revealed need to improve students' technical understanding of machine elements and mechanical systems as well as the need to enhance self-organisation abilities during subject-specific learning and projects. Tutorials with one tutor and about 20 students are held. Due to high interest, tutorials with same content are offered several times. These tutorials are designed such that they comply with students' background and the corresponding design education at the university. Design education with lectures, auditorium exercises, engineering design projects and product development team competition is enriched by these interactive tutorials in small groups which allow personal feedback. Within the scope of these subject-specific tutorials, different approaches are made to impart knowledge to students. A focus on linking theory with practical experience to students is present. Elements of these tutorials are for example

- short theoretical inputs to topics discussed in lectures and auditorium exercises
- interaction with mechanical parts or functional mock-ups
- experienced students as guests who share their experiences and critical reflections about how they prepared for the mechanical design exam or mastered engineering design projects
- tips & tricks to design project related self-organisation.

Short theoretical inputs refer to the contents which are based on either current lectures' topics to have timely the opportunity to catch up and deepen knowledge, or refer to past lectures' contents required for the design project as a repetition or future contents to allow more practical applications to assess subject matter ahead of time. Usually, the tutorials take place in the machine part exhibition [2, 4, 5], where students find a collection of various mechanical machine elements and functional mock-ups. This does not only allow for a context-related learning environment, but especially opens possibilities for visual as well as haptic analysis of industrial machine parts and interaction with functional mock-ups for a better understanding of functionalities. Oral reports from guest students who have accomplished all design projects demonstrate students' different ways to organise their learning process and manage to accomplish all the technical challenges of the project, such as designing working machine systems like gears and drawing by hand or using 3D-CAD tools. Participants can direct their questions to the guest students and discuss together best practices with regards to technical and organisational issues. Self-organisation tips and tricks refer to hints given to the participants about how to search effectively for useful literature, how to approach the preparation of a design exam and which specialties should be considered (such as the use of specific pens or papers for the drawing exam for instance).

4 EVALUATION

The results of the first two years of the implementation have been evaluated quantitatively (Figure 1). A study group connection platform, learning tutorials and subject-specific application support as tutorials with focus on mechanics I and mathematics I (due to high number of students failing the exams) and some other subjects were offered in the first years. The exam success rate was calculated for students who passed their second exam attempt for each of the subjects in focus. A distinction between project participants and non project participants was made. To give an example, project participants had a 90% higher pass rate than non project participants in mathematics I in year 2012. In the same year, mechanics I had a 140% higher pass rate for students who participated in the project in comparison to non project participants. In 2011 and 2012, project participants had higher pass rates in their second attempt for both the mathematics I and mechanics I exam in comparison to non project participants.

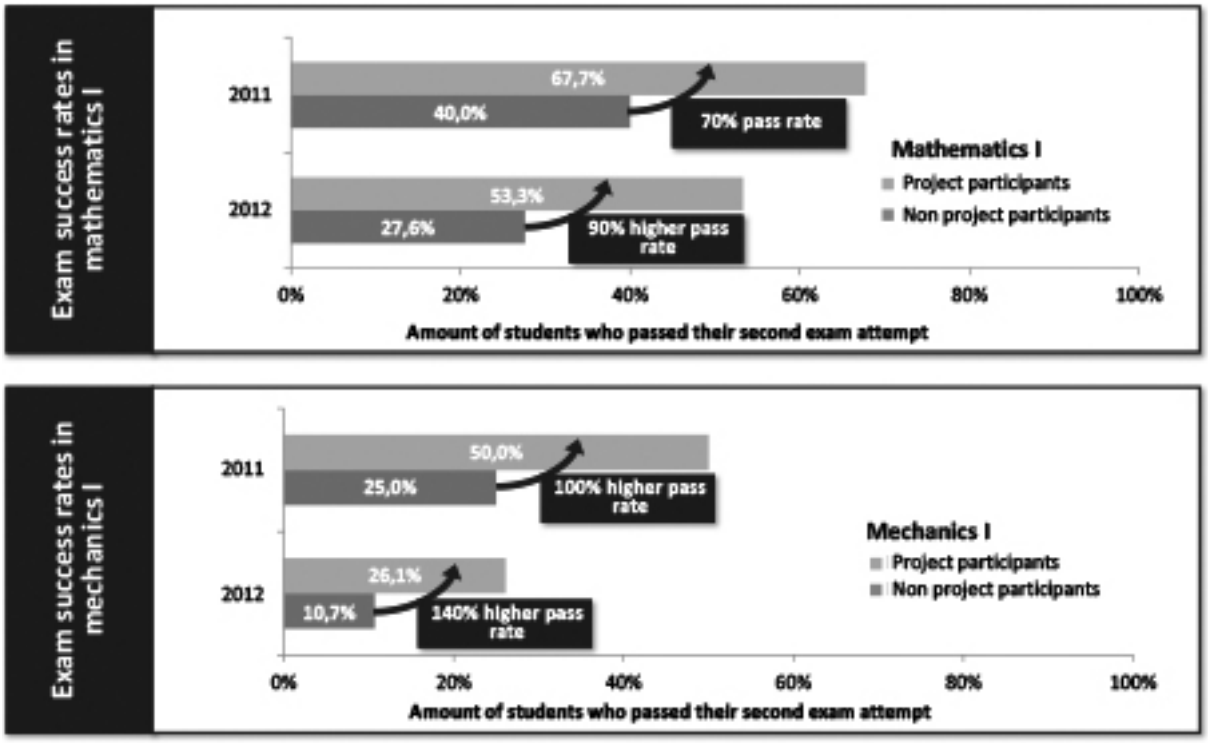

Figure 1. Quantitative evaluation of the three pillar model for enhanced learning skills [with reference to 6]

Qualitative feedback on the mechanical engineering design tutorials reveals that especially oral reports of students who finished their design projects and/or passed engineering design exams were of particular interest to students. Furthermore, the input to the efficient use of 3D-CAD systems and the functional mock-ups was received positively. However, a focus of the tutorial contents to the ongoing engineering design project and more calculation instructions were requested. In the future, more evaluations will be made and assessed in order to adjust the concept based on current needs of the stakeholders.

Limitations to these evaluations exist. For the quantitative evaluation, students who participated in any pillar of the offered three pillar model were taken into account. Experience showed that students do not necessarily attend all the platforms of the three pillar model such that other conclusions can also be drawn. Students participating in these tutorials may have been the ones who are highly motivated to pass the exam. It can be concluded that the level of support and effects achieved may differ from one case to the other. Nevertheless, it needs to be emphasized that positive feedback after the study group connection platform, learning tutorials and the subject-specific application support demonstrates that the three pillar model as a whole, but also individual platforms of it, influenced the learning habits of students positively and supported them in passing the exam.

5 SUMMARY AND IMPLICATIONS FOR MECHANICAL DESIGN EDUCATION

This paper has presented a three pillar model consisting of three platforms to support students' learning and develop their fundamental learning skills and self-organisation. A study group connection platform, learning tutorials and subject-specific application support is introduced. After students have the possibility to find adequate study groups in the connection platform, learning skills can be enhanced through participation in interactive learning tutorials which help to improve students learning techniques and their self-organisation. General learning strategies can be built upon during application of these to subjects as mechanical engineering design in subject-specific application support, which can be exam simulations or interactive tutorials as well. Positive quantitative as well as qualitative feedback has illustrated its effectiveness. It can be concluded that it is important for mechanical engineering design students to be able to organise their own learning process and be in contact with fellows. The fundamental learning skills are considered to be key to mastering any subject. Therefore, mechanical design education should include opportunities which support students learning. Students should be supported in facilitation of finding study groups, learning general

learning strategies and applying these general strategies onto specific subjects. Elements which have proven to be of help to students, such as oral reports of students in higher semesters who have passed the respective exams can be included also in regular courses, e.g. lectures, laboratories, projects, without having to introduce an entire three pillar model as already individual elements of the platforms proved successful. It is crucial that these supporting mechanisms are introduced, maintained and improved in accordance with feedback, for some students may have difficulties in the beginning but can become very good learners and successful in professional life later on. In the future, evaluation can be focused to students typology and their exam score. Their feedback needs to be extended and the concept needs to be adapted accordingly. It is crucial to critically view feedback with regards to didactical, organisational and subject-related requirements. The three pillar model is also applicable to other courses of studies within engineering in general as well as beyond engineering. Case-specific adaptions with regards to the target group and the goals can help to further develop possibilities to support students of various courses of study. Finally, this research has also shown another option to integrate a machine part exhibition into instructed tutorials and thus facilitate students understanding in mechanical engineering design.

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