

Developing 21st Century Skills in Engineering Studies with E-Learning

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Abstract—Engineering studies are often too focused on the development of engineering skills. This results in graduates with deficits in 21st century skills, such as complex problem solving, teamwork, or communication skills. To address this issue, sophisticated concepts need to be introduced, to attractively include 21st century skills into engineering curricula. In this paper we present related concepts which we have applied in our engineering studies and discuss their benefits and drawbacks according to our experience. We also provide recommendations about integrating 21st century skills courses into engineering curricula.

Index Terms—21st Century Skills, Engineering Education, E-Learning.

I. INTRODUCTION

Industry trends show an increased need for highly skilled software engineers, having a blend of both technical and professional skills. While technical skills include domain-specific knowledge, such as programming, mastering computer networks, and developing electronic components, professional skills are related to competencies needed for a profession beyond technical skills. Examples are complex problem solving, teamwork, and communication skills—skills that can be applied in different areas, jobs, and situations. Therefore, they are also referred to as 21st century skills, emphasizing their growing importance for modern employees contributing to the 4th industrial revolution [1, 2].

Due to the main focus in engineering studies on developing rigorous technical expertise, the time devoted to professional skills in an engineering curriculum is often very limited. Being underdeveloped among many graduates, they are frequently essential differentiators between applicants for a job position. The successful applicants must be able to communicate their ideas, to show intercultural competencies, to work in teams, and to demonstrate problem solving skills.

The goal of this paper is to address the possibilities of integrating 21st century skills into an engineering curriculum. To achieve this, we will present different existing e-learning based approaches and evaluate their strengths and weaknesses based on our experiences in two concrete study programs at our University, the Bachelor study program Computer Science and Digital Communications and the Master study program Software Design and Engineering.

We have conducted an extensive literature survey on different best practices for integrating 21st century skills into engineering studies. However, while we were able to find many contributions stating the importance of developing 21st century skills for engineers, there are only

a few concrete examples of how these skills can be systematically developed across any curriculum.

We have also invited representatives from leading national and international industry partners and collected inputs on important skills of future engineering graduates. They confirmed the importance of 21st century skills, putting them even above technical skills, because companies can quickly compensate some deficits in technical skills via targeted courses, offered internally or externally. The development of 21st century skills, in contrast, usually takes longer time and thus should be forced in any kind of study, in particular in engineering studies.

From these inputs, we selected a set of 21st century skills for our two study programs. The next challenge was to find an optimal way to integrate them into the curricula of modern engineering studies, because we were facing difficulties among students to recognize the importance of 21st century skills.

Based on our experience we provide a set of recommendations for using blended learning concepts for introducing professional skills into curricula of engineering studies in this paper. They should help to create successful e-learning environments for education of future engineering professionals.

II. TEACHING 21ST CENTURY SKILLS

Employees of the 21st century are required to apply their knowledge and skills in unknown and evolving circumstances. This is particular true for engineering jobs, as people in these jobs are usually dealing with interdisciplinary projects in rapidly changing and globally distributed environments. To be prepared for the future, engineering students need to develop a broad spectrum of skills and competencies besides technical skills. Several studies highlight skills such as critical and creative thinking, problem solving, as well as communication and collaboration skills [3, 4]. Students have to learn to think in more integrated ways, considering interconnections and relations between the perspectives of different disciplines.

One of the main reasons for students' low acceptance of courses related to 21st century skills in engineering studies is a lack of recognition of their relevance. Engineering students are usually curious to learn about engineering topics and oversee the importance of 21st century skills in professional environments. Therefore, the introduction of 21st century skills in an engineering study is kind of a trade-off between the attractiveness of the curriculum for students and the attractiveness of graduates for companies.

In our study programs, we address this issue with several different methods, depending on the topic and on the semester in the study. These methods can be structured into four categories:

- **Isolated**—courses for 21st century skills are held independently from other courses.
- **Module**—here we interconnect a 21st century skill course with an engineering course in a module, with a single grade for the module.
- **Integrated**—the focus of a course is on development of engineering skills. However the application of some of the 21st century skills is necessary to successfully complete the course.
- **Interdisciplinary**—the course is a complex project among several disciplines, like engineering, health, manufacturing, or law. The success of the project directly depends on 21st century skills of the students.

In the next subsections, we will discuss some examples and how e-learning can be applied in each of these categories.

A. *Isolated*

Isolated courses are the traditional way of teaching 21st century skills. In our study programs, we offer these courses in the last two semesters for 21st century skills that are difficult to combine explicitly with other courses offered in that semester. Examples are “Business Administration”, “Legal IT Aspects”, and “Entrepreneurship”.

In these courses, e-learning concepts include an e-learning platform with distance learning exercises without a particular focus on engineering topics.

B. *Module*

In this category, we have combined 21st century skill courses with a suitable technical course, starting with the first semester. For example, in the first semester of the Bachelor study we combined the course “Team Work” with the course “Programming 1”. Thus, students first learn theory on teamwork and do different team exercises. Afterwards they apply selected methods in the context of a programming course, solving different programming exercises in small groups. Special attention is given on how teamwork is organized, extent of collaboration, and conflict resolutions. For both courses, students receive a single grade, depending on their performance in both courses. This way the students are immediately able to realize the added value of the professional courses.

Subsequently, in each of the first four semesters of our Bachelor study and in the first two semesters of our Master study we introduced at least one such combination. First results show a high acceptance of this concept among students.

We combined our “Complex Problem Solving” Master level course, for example, with the “Software Integration” course, expecting from students to apply complex problem solving methods on problems in a real software integration project. In a mix of in-class and e-learning units, the students work on defined tasks, supported by their lecturers. The course comprises several modules, each of which starts with an e-learning supported distance-learning phase, followed by an in-class unit to deepen the obtained knowledge. After the last module, the students apply their complex problem solving skills on a concrete software

integration project. A detailed description of this concept can be found in [5].

C. *Integrated*

The learning goals of integrated courses include development of both, technical and 21st century skills. For example, in our mobile learning based course “Mobile App Development” the technical skills are taught explicitly in a lecture part, whereas 21st century skills are implicitly required for the tutorial part. This allows students to apply 21st century skills in a technical environment immediately.

We designed this blended learning course module by integrating a set of selected teaching methods. In particular, we combined mobile learning with Just-in-Time Teaching (JiTT) elements, learning diaries, project-based learning, coaching and peer learning. In this e-learning concept, smartphones and tablets serve a triple didactic function, as the primary learning medium, as the programming and testing medium, and as the communication and collaboration medium. Parts of our course concept have been published in [6-9].

In addition, in several courses we organize an e-learning supported hackathon event [10], which supports team formation, and provides an opportunity to creatively develop and assess ideas via virtual or face-to-face interactions. It increases motivation of the participants to put a lot of effort into realizing their ideas [11], which are usually related to software development.

D. *Interdisciplinary*

In this category of courses students are working on concrete problems from different disciplines. The particular tasks originate from our industry partners and reflect real-life issues. The students are supervised by both, our lecturers for engineering subjects, and representatives of our industry partners, for subjects related to the specific discipline. The permanent interaction among different stakeholders fosters the development of the 21st century skills, such as complex problem solving, teamwork, as well as communication and presentation skills.

E-learning environments are primarily used for communication, collaboration and documentation. The students are able to get feedback on the progress of the projects frequently, and to react on possible changes. According to our observations, this reduces the risk of a project failure.

III. RECOMMENDATIONS

After the first semesters where we have implemented different categories for teaching 21st century skills, we derived a set of recommendations for introducing 21st century skills into curricula of engineering studies. They should help to create successful curricula for education of future engineering professionals.

First, we consider the administration efforts for each category. Administration efforts include additional efforts for coordination between the lecturers.

Our experience shows that these efforts are low for *Isolated* category courses, moderate for *Integrated* category courses, relatively high for *Module* category courses and very high for *Interdisciplinary* category courses. On the other side, the integration level between engineering and 21st century skills also differs among the categories. Fig. 1 illustrates the administration effort and the integration level

of each category. The size of the bubbles corresponds to the number of courses in our curricula of that category. As we can see, the most courses apply the *Integrated* approach, followed by *Module*, *Isolated* and *Interdisciplinary* approach. This is because *Interdisciplinary* category courses are suitable for students in higher semesters only, whereas other categories are rather distributed over the study.

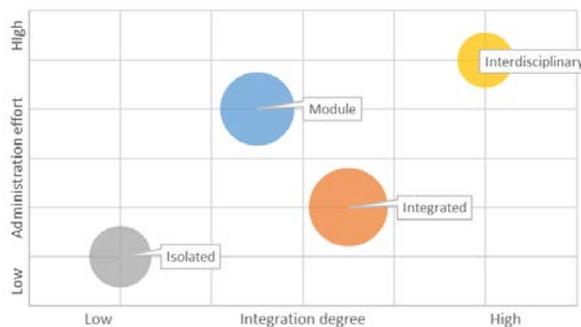


Figure 1. Categories for 21st century skills

We recommend including 21st century skills in the curriculum starting with the first semester. In the past we were faced with low motivation of our students—primarily interested in technical areas—for 21st century skills courses. To mitigate this issue, we interconnected 21st century skill courses with technical courses and combined them into modules, which are commonly evaluated and graded. Therefore, we recommend to start with *Module* category courses in earlier semesters of an engineering study to increase students' acceptance of 21st century skill courses. Thereafter, *Integrated* and *Isolated* category courses can be gradually introduced. In the advanced semesters of the study, *Interdisciplinary* category courses can be introduced, since students have at least intermediate knowledge in both, engineering and 21st century skill areas.

E-learning concepts can help to lower administration efforts, as they support communication and coordination between lecturers as well as between students and lecturers. Furthermore, they can serve as knowledge repository, making best-practices examples and lessons learnt structured and available for everyone.

IV. CONCLUSION

In an engineering study, the development of 21st century skills is gaining on importance. Therefore, integrating 21st century skills in engineering curricula is a challenging task. In this paper, we discussed four categories of integrating 21st century skills in engineering studies. We also provided recommendations and examples for the integration of each category. In our future work we will further apply e-learning concepts and investigate to what extent they can reduce the administration efforts of some of the categories.

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