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Combining mathematical revision courses with hands-on approaches for engineering education using web-based interactive multimedia applications

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Abstract

In engineering education, it is beneficial for students to acquire practical experiences with real-world relevance. Although solving engineering problems requires the comprehension of the mathematical backgrounds, many practice-oriented teaching approaches concentrate on the practical engineering part, but neglect the underlying theory. This work combines enhanced theoretical learning with practical experiences through interactive multimedia applications in the context of robotics. It consists of a blended learning scenario which offers at least a threefold benefit: It supports teaching of theoretical and methodological aspects. Required background knowledge in mathematics and physics is directly available. And acquired knowledge can be brought to life by programming tasks and visualizations. Interactive 3D visualizations and web applications illustrate complex technical facts and Matlab or Octave code, respectively, can be executed online for computations and simulations. All offers are accessible 24/7 via web browser without any dependency on additional software. Beside for integration in classroom teaching, the platform can be individually used by students for targeted learning and filling of knowledge gaps. As e-learning platforms are highly accepted by students and have a positive influence on the students' performance, we expect to enhance our teaching with the new platform providing practical and theoretical offers tightly linked together.

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Keywords: Blended Learning; E-Learning; Web Applications; Visualizations; Robotics; Engineering Education.

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1. Introduction

The American Engineers' Council for Professional Development had once defined "engineering" as *The creative application of scientific principles to design or develop structures, machines, apparatus, or manufacturing processes, …* (Engineers' Council for Professional Development, 1947). In spite of this orientation to applications today's engineering programs still concentrate on teaching of theoretical and methodological aspects of engineering very often neglecting their application to real-world problems. On the contrary experts on engineering education have emphasized that efficient learning environments should have real-world relevance and encourage meaningful reflection on authentic tasks (Herrington, Reeves, & Oliver, 2014). The implementation of this demand contrasts with the requirement of thorough mathematical knowledge to solve engineering problems (Firouzian et al., 2014). Therefore practice most effectively enhances permanent and applicable knowledge if the underlying theoretical fundamentals are priorly known and comprehended.

In undergraduate engineering degree programs mathematics and technical courses are typically taught in parallel. Starting with fundamentals, the respective contents are developed over the semesters independently or build up on other courses of the same program. On the level of master's programs it should be easier to incorporate practical aspects: sound engineering qualifications and advanced mathematical knowledge as basis for further technical concepts should be existing. Nevertheless, master's students are often no longer able to apply mathematical fundamentals acquired in the first semesters of undergraduate programs (Rojko, Jezernik, & Španer, 2003). If international students are present the problem becomes even bigger: due to differences in undergraduate degree programs, the gap between expected and prevalent mathematical knowledge gets wider. Hence, the heterogeneity of the students' knowledge exacerbates the theoretical classroom teaching as well as the usage of laboratories for practical experiences.

2. Teaching robotics

In robotics courses the need for hands-on approaches is obvious. Many practice-oriented teaching approaches follow the learning-by-doing principle. Rubenstein, Cimino, Nagpal, and Werfel (2015) provide personal robots to the students for introductory programming and robotics teaching. This allows for individual implementation and testing of algorithms both at university and at home. But since only simple low-cost robots are affordable for students, possible applications are limited to basic functionality. For further applications, more complex robotic manipulators (Gutiérrez, Reséndiz, Santibáñez, & Bobadilla, 2014) or entire robots (Weinert & Pensky, 2012) are required, which leads to high financial demands and restricts the usage geographically to the university or laboratory, respectively. To face the access problem, real experimental setups often are accessible via internet and can be controlled remotely through an interface. These remote laboratories (Prada, Fuertes, Alonso, García, & Domínguez, 2015) offer practice independent of time and place, assuming a computer running the required software. The drawback of remote laboratories is, however, that the number of concurrent users is limited to the number of available real setups (usually one). Thus their usage is not really time-independent, but dependent on the number of possible users, their usage frequency and the average time of occupancy. Dogmus, Erdem, and Patoglu (2015) have presented an interactive virtual tool usable without real hardware to configure and simulate robot applications. Users do not need to know about the implementation and mathematical details, but can concentrate on the actual functionality and its outputs. Drawback of such approaches is the necessity of installing the software on a computer, which increases the inhibition threshold of students to use the offer. Some virtual labs even require industrial or commercial software packages (Gonzales, Mahulea, & Kloetzer, 2015) limiting the usage to computers in the university or involving a great deal of expense.

All these practice-oriented approaches focus on the engineering part and provide practical experience, but neglect the underlying mathematics and physics. Therefore, many universities provide extracurricular mathematical bridging courses, what involves a high workload for students as well as for teachers. One approach that addresses the mathematical fundamentals integrated in an engineering course is presented by Rojko et al. (2003). The authors provide a web page with additional material to the related undergraduate robotics course including explanations of