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Abstract

Integration of 3D printing and gamified didactics in medical imaging education

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3D printing has revolutionized various industries, serving as an essential tool for product development up to small-scale production. In the medical field however, this promising technology is slowly making its way into various applications such as creating phantoms, visualization of pathologies for medical or patient education, custom implants or point-of-care applications. However, its potential for the education of medical students as well as future biomedical engineers is manifold. This paper elucidates the multifaceted integration of 3D printing in the pedagogical framework of biomedical engineering education, with a specific focus on the lecture: *Medical Imaging*. The lecture consists of three elements: a) a lecture for teaching the theoretical foundation and algorithmic understanding needed to understand medical imaging techniques b) an interactive seminar for discussing exercises or questions related to the theory c) a voluntary practical proficiency in 3D modeling with the aim of creating an 3D model out of a real life CT or MRI DICOM dataset. The main learning objective of the practical part of the lecture is the transformation of 2D medical images into 3D objects that can be viewed within VR or transferred into haptic 3D printed models. The learning journey from the provided dataset to the 3D printed anatomical model includes several intermediate steps and inherent challenges. The use of opensource software tools for segmentation, digital post-processing and print preparation plays an equally important role as the skills needed for performing the printing process on affordable consumer grade 3D printers and mechanical post-processing. These are secondary learning objectives that target to train the practical skills and methodological competence of the students. The practical training is enriched by different didactical aspects and gamification elements to stimulate motivation, adherence and to intensify the learning effect. A good example of this is the group task within the course to print and assemble a complete human skeleton, including the joint connections, having to deal with poor image quality or artifacts in the image data, or the need to provide treatment for pathologies (e.g., fractures) with individually customized implants or osteosynthesis materials. Students, therefore, have to reactivate and facilitate knowledge of prior medical and technical lectures, such as anatomy and physiology, chemistry and material science, and construction elements.

The course concept is very successful, which is not only evident in the high number of participants in the voluntary offering (85% instead of the usual 40%), but also reflected in the interaction with the students and the results of the accompanying evaluation. Students recognize the relevance of the learning objectives and feel better prepared for their future careers. They particularly recapitulate anatomical fundamentals and CAD to solve the tasks and invest more time and effort compared to other lectures. From the perspective of the lecturer, students show a high level of motivation, they significantly improved professional communication (e.g., the use of correct anatomical terms) as well as exam results compared the prior lecture before the introduction of the described course concept. The skills acquired during the practical training regarding additive techniques in the medical context can be transferred to other issues in the field of biomedicine, along with the acquired social and problem-solving skills.

AUTHOR'S STATEMENT
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