Instilling an *"I can do it"*-attitude towards practical prototyping

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ABSTRACT

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A recent survey predicts the following skills to become increasingly important for the Danish industry ([1] Danish Ministry of Higher Education and Science, 2018):

- The ability to collaborate (also across disciplines)
- The ability to develop new processes and products
- A general understanding of technology
- The ability to acquire new knowledge when needed

These findings underscore the existing notion that our economy hinges on the successful education of *collaborative problem solvers* and *tech-innovative thinkers*. Answering this educational need, DTU's innovation incubator (Skylab) features excellent prototyping workshops with skilled and welcoming staff – i.e. the ideal environment for our engineering students to team up and pursue their own innovative ideas, tackling acute technological problem solving in the process. I will present the new bachelor-level course *Biomedical Prototyping*, which harnesses Skylab as a learning environment to help students *see and seize* the plethora of creative possibilities at the interface of technologies ranging from *biology* and *optics* through *microcontroller programming* to *welding*. By instilling an "*I can do it*"-attitude, or, a *growth mindset* ([2] Dweck, 2008), the course aims to inspire students to pursue their own ideas, at their own initiative during their studies – thus, strengthening their qualifications and fitness to shape the future job market.

Figure 1. [DTU-Skylab, November 2017]. Thirty BSc-students have assembled their five separate prototypes into a single functioning unit: A confocal laser-scanning microscope.

Biomedical Prototyping is a 5-ECTS course, challenging its 30 participants with the collaborative construction of a high-tech instrument (a confocal laser-scanning microscope). Based on the participants' individual interests, they are split into five teams, each responsible for designing and building a specific part of the microscope. For example, one team may be asked to produce a fluorescent biological sample and a computer-controlled mechanism for positioning the sample appropriately relative to the microscope objective. As shown in **Figure 1**, the five teams assemble their products into a single (hopefully) functioning unit at the end of the course.

While this project/problem-based learning experience lets the participants hone their abilities to acquire new knowledge when needed ([3] de Graaff & Kolmos, 2003), I highlight three additional pedagogical elements, which are central to the course and its alignment with current needs for skill development: **(1)** The course eliminates competition and encourages *interdisciplinary collaboration* between participants, by giving each team a different challenge and a

clear motivation to communicate between teams. If the teams do not communicate, their five separate prototypes will not assemble into a functioning instrument ([4] Handelsman *et al.*, 2007). **(2)** The course encourages *creativity/risk taking* by basing assessment on each participant's grasp of the *prototyping process* rather than the quality of his/her *prototype-product.* Thus, allowing participants to experiment with new approaches *and* making the course inclusive of participants with limited hands-on experience. **(3)** At the end of each 4-hour course session, each team presents their concrete experiences in plenum. This knowledge-sharing and the ensuing feedback/reflection can give the participants a basis for improving their prototypes in the following session, setting in motion a series of engineering design cycles or (in a learning context) *experiential learning cycles* ([5] Kolb & Kolb, 2017): try → fail → learn → try again.

In an exam-situation, it is not straightforward to assess whether a participant's mindset has become better geared to "pursue his/her own ideas in practice". Thus, *constructive alignment* between this intended learning outcome and assessment is difficult to establish ([6] Biggs & Tang, 2011). Constructive alignment is sought with exam-questions like "what does this specific component of the microscope do and how could we improve its implementation?". An engaged participant will be able to *explain*/*evaluate* the prototype component and *synthesize* a *practical plan* for improving it. While this declarative and functional knowledge only allows to gauge a participant's *ability* to engage in practical prototyping, it does not reveal his/her attitude towards engaging. As outlined in **Figure 2**, course evaluations indicated profound learning outcomes. In this encouraging light, I now plan a deeper investigation of what, exactly, the participants are learning and how they fare with self-motivated practical projects in the future. Additionally, I will investigate the potential prospects of implementing a series of sister-courses at DTU, allowing to mix students from different engineering specializations between the courses.

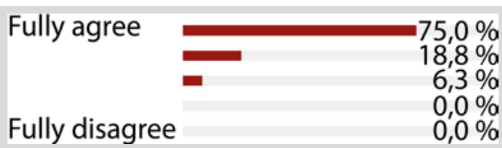

Figure 2. [2017, course evaluation] Responses to the statement "*I learn a lot in this course*". 16 respondents.

At ETALEE 2018, I will kindle a discussion by posing a (maybe controversial) statement and a question: *Practical prototyping represents a highway towards developing a future-proof engineering mindset. Yet, too often, practical prototyping is hidden away in master-level courses and/or in not-for-credits extracurricular activities, which appeal more to students with an intrinsic "I can do it"-attitude than to students who need to develop that attitude. Why is practical prototyping not mandatory in the bachelor-level engineering curriculum?* I am excited to learn how the audience reacts to this statement. Likewise, I am excited to discuss other initiatives, which have used practical project-based prototyping at an early stage in the engineering curriculum.

[1] Uddannelses- og Forskningsministeriet (Udvalg om bedre universitetsuddannelser), *Universitetsuddannelser til fremtiden, Ref. 7.5.3 Virksomheders vurdering af fremtidigt kompetencebehov (pp. 199-200)* [Eng: Danish Ministry of Higher Education and Science, *University educations for the future, Ref. Chapter 7.5.3*], ISBN: 9788792572844 **(2018)**

[2] S.C. Dweck, *Mindset and math/science achievement*, Prepared for the Carnegie Corp. of New York-Institute for Advanced Study Commission on Mathematics and Science Education **(2008)**

[3] E. de Graaff & A. Kolmos, *Characteristics of problem-based learning,* International Journal of Engineering Education, Vol. 19, No. 5, pp. 657-662 **(2003)**

[4] J. Handelsman, S. Miller, C. Pfund, *Scientific teaching, Ref. The power of group learning (pp. 28-29)*. ISBN: 978-1429201889 **(2007)**

[5] A.Y. Kolb & D.A. Kolb, *Experiential learning theory as a guide for experiential educators in higher education,* ELTHE: A Journal for Engaged Educators, Vol. 1., No. 1, pp. 7–44 **(2017)**

[6] J.B. Biggs & C. Tang, *Teaching for quality learning at university (4th edition), Ref. 6. Constructively aligned teaching and assessment (pp. 95-110)*, ISBN: 9780335242757 **(2011)**