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How To Make Calculus Assignments Not Boring? Designing Calculus Assessment With The Constructive, Contextual, Collaborative, And Self-Directed Principles Of Problem-Based Learning.

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1 MOTIVATION

Engineers use science, technology, and math to solve problems. Usually, engineering students take calculus, a core discipline in engineering programs, as one of their first mathematical courses. This course lays the required mathematical foundation for classical engineering courses such as thermodynamics, kinematics, and fluid mechanics, mathematical follow-up courses, such as systems theory and control, differential equations, and mathematical modelling, as well as fashionable topics, such as data science and artificial intelligence. Bluntly, there are three key tools in calculus: limits, derivatives, and integrals. As learning outcomes, engineering students need to learn how to use these tools for simple exercises and to apply these tools in a broader context to improve their problem solving skills. However, as one of the most challenging courses in engineering programs (Biza et al. 2022), students have difficulties mastering these learning outcomes. One reason could be the traditional teaching and learning methods that are still often employed for these basic courses, neglecting the fundamental principles of Problem-Based Learning (PBL) in course design and delivery (Freeman et al. 2014).

2 OBJECTIVES

This workshop aims to introduce the attendees to 1) the PBL system implemented at Maastricht University and 2) our vision on assessment, which includes *meaningful assessment* and assessment being in line with the *constructive*, *collaborative*, *contextual* and *self-directed* (CCCS) *principles* of PBL (EDLAB 2023). We illustrate these ideas through three short examples of assessments developed for a calculus course in the BSc Circular Engineering at Maastricht University. In the second, and larger, part of the workshop, attendees will have the opportunity to explore how they can apply these concepts to the assessment components in their courses through a PBL way. In particular, the intended learning outcomes (ILOs) are: 1) attendees can **describe** the PBL paradigm and the CCCS principles; 2) attendees can **recognize** the CCCS principles in assessments of other courses; and 3) attendees can **implement** the CCCS principles in their own course assessments. These courses do not necessarily have to be mathematical courses!

3 BACKGROUND AND RATIONALE

PBL at Maastricht University (UM) is a student-centered teaching method that promotes active learning and critical thinking (EDLAB 2023). While various implementations exist, the essence of PBL revolves around four key learning principles: constructive, contextual, collaborative, and self-directed learning (Dolmans 2019). Constructivism emphasizes the activation of prior knowledge and building new knowledge on top of it. Collaboration focuses on working together in small groups to share knowledge and perspectives. Contextualization highlights the importance of understanding the real-world context in which problems arise. Self-Directed Learning encourages students to take ownership of their learning process, set goals, and monitor their progress. Teachers act as facilitators, providing guidance and feedback rather than solely relying on frontal teaching. This approach will produce graduates with strong problem-solving skills, critical thinking abilities, and the ability to work in diverse teams (Anggraeni et al. 2023, Boelt et al. 2023).

One of the fundamental principles of the UM vision on assessment is that the assessment is *meaningful* for the students' learning process, meaning that the evaluation should provide relevant and valuable feedback to both student and teacher. In addition, assessment should align with the learning objectives and activities. Meaningful assessments should be fair, unbiased, and transparent, providing clear criteria and standards for evaluating performance. It also implies authentic assessments designed to resemble real-world situations and tasks closely. Authentic assessments help students develop skills relevant to their future careers and provide them with a sense of the relevance of their learning. Teachers can also use the information to adjust their teaching strategies and improve the effectiveness of their instruction.

4 WORKSHOP DESIGN

The workshop consists of three activities plus a pre- and post-workshop assignment. Materials for all activities can be downloaded via this link: https://surfdrive.surf.nl/files/index.php/s/K5FaMlkoxvrW1yx. In the pre-workshop assignment, we ask participants to prepare a case by thinking about a possible assessment that they currently use in their course or an assessment that they wish to (re)design for their course according to the CCCS principles. In order to prepare the case properly, we provide a one-page template in the workshop materials, which can be found via the aforementioned link. Additionally, attendees receive a terminology list for PBL and CCCS concepts and a description of three assessment examples from a calculus course to help them prepare their case. Completing the pre-workshop assignment prior to the onsite workshop is beneficial for the workshop experience of the participant *and* other participants, but completion is not mandatory and does not limit participation in any way.

During the workshop, we briefly cover the pre-workshop assignment in the first part (10 minutes) to ensure all attendees have the same understanding about the basic concepts (ILO1). In the second and largest part of the workshop (40 minutes), attendees participate in an interactive and collaborative exercise where they attempt to recognize the CCCS principles in their assessment or explore strategies to implement the CCCS principles by discussing in small groups (ILO2+3). During this process, the workshop organizer will provide guidance and feedback. In the final part (10 minutes), we will discuss several ideas in the plenary session.

In the spirit of open education, the post-workshop assignment provides the attendees with the materials to organize a similar session for their colleagues to facilitate further development and innovation as well as to continue the discussion after the workshop. As part of the post-workshop assignment, we ask the participants to fill out an evaluation form to assess the quality of the workshop and to reflect on the CCCS principles as a guiding tool for designing their own assessments.

The workshop design nicely reflects the PBL-style because attendees gain knowledge by combining prior knowledge and new experiences (constructive) through small-group discussion (collaborative) about assessment components from their courses (contextual) with an organizer that acts as a guide on the side instead of a sage on the stage (self-directed). The workshop is an extension of existing inhouse educational events for teacher training programs and continuous development programs.

The workshop targets STEM teachers, who want to learn to integrate PBL and CCCS principles in their practice. Participating in the workshop requires no prior knowledge about calculus nor about PBL and CCCS. Participants are encouraged to complete the pre-workshop assignment that provides all relevant information prior to the workshop.

5 SIGNIFICANCE FOR ENGINEERING EDUCATION

The CCCS principles are relevant design principles for engineering education as they can ensure proper alignment with the goals and demands of the engineering profession. Constructive learning emphasizes that learning is an active process where students gain knowledge by combining prior and new knowledge, which are essential engineering skills. The ability to collaborate effectively is critical for engineers, and the PBL approach, which emphasizes collaboration, can help students develop this skill. Contextual learning is particularly relevant for engineering as many engineering problems are context-specific and require understanding the broader socio-technical context. Self-directed learning is essential for engineers as it fosters lifelong learning and professional development. Furthermore, literature seems to indicate positive student perceptions for a variety of PBL activities and educational programs w.r.t. generic skills (Boelt et al. 2023).

6 RESULTS OF THE WORKSHOP

The workshop attracted 14 participants that focus on engineering education, but have diverse backgrounds: engineers, mathematicians, physiscist, etc. They were also of diverse academic positions, such as PhD, post-doc, professor, lecturer, etc., but also company employees such as Mathworks.

The participants took a short survey (N = 14). They rated the following statements from 1 to 5 where 1 means “I strongly disagree and 5 means “I strongly agree.”

Statement	**Rating**
The workshop was useful to me.	4.3
I learned something about PBL/CCCS.	4.1
I will use the CCCS principles in my teaching.	4.0
I will probably run the exercise again with colleagues.	3.3

In the open feedback section of the survey, the participants indicated that they especially appreciated the concrete examples of assessment methods designed using the CCCS principles as they provide a source of inspiration for their own practice. They also enjoyed the hands-on nature and the exchange of experiences in the open discussion setting.

Two points of improvement were also suggested: examples in other disciplines (than math) and a more diverse grouping of participants during the collaborative exercise.

7 CONCLUSION

This workshop enhances engineering education knowledge by providing participants with a framework to describe, recognize, and implement the CCCS principles in their courses. The workshop format encourages dialogue among participants, fostering the exchange of ideas and best practices in engineering education. The post-assignment allows further discussion beyond the workshop.

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