Designing an activity that supports the development of critical thinking

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Introduction

The widespread complaint among engineering academics that their students are unable to think creatively or critically (Brent & Felder, 2014) is troubling, as an important purpose of higher education is to develop students' ability to think critically. Not only does this ability aid learning, but critical thinking (CT) also serves as preparation for an uncertain future. CT is of particular importance in the engineering discipline because problem-solving is recognised as being central to engineering practice, and CT is regarded as an important component of problem-solving (Donald, 2002; Sheppard et al., 2008). This paper describes the design of an activity appropriate to assist with the development of engineering undergraduates' CT skills.

What is CT?

CT is a complex phenomenon which is difficult to define. Ahern et al.'s (2012) conception of CT does however provide a framework for designing activities that afford the development of engineering students' CT skills:

> CT is a movement from the concrete, from the factual to the abstract and back again – an ability not only to use knowledge and facts to create ideas, concepts and solve problems, but also to use these developed concepts, theories, and ideas in the real world.

What is mathematical modelling?

Geiger et al. (2022) maintain:

> Mathematical modelling consists of identifying a problem within a real-world context, developing a relevant mathematical representation, determining a subsequent mathematical solution, interpreting the solution within the original context, and evaluating the solution's validity for resolving the problem.

Drawing on the definition of mathematical modelling, this paper argues that engagement in mathematical modelling affords CT. Model-Eliciting Activities (MEAs) are mathematical modelling problems that simulate authentic, real-world, client-driven situations that small teams of three to five students solve in one or two class periods through an iterative process; the focus is on the process of problem-solving rather than the solution, therefore MEAs allow students to hone their interdisciplinary, non-routine problem-solving skills (Diefes-Dux, 2004). Fostering the development of engineering students' CT requires an appropriate learning environment and problem-based learning is regularly considered to be appropriate in this regard. Bowden and Marton (2005) do however express concern, which they explain as follows:

> Our concern stems from the same source as our concern about the virtual campus and the lecture-focused learning environment. We are concerned whenever a teaching method or a learning environment is constructed in ways that do not both stem from judgements about what is needed to support appropriate learning and also allow for dynamic change through professional judgement by teachers interacting with their students.

The six design principles which guide the construction of MEAs – see Lesh et al. (2000) – provide lecturers with the opportunity to give their students support and make changes when so required, thereby addressing Bowden and Marton's concerns.

Intervention

Maaß (2010) classification scheme guides the design and selection of modelling activities according to specific goals, predefined objectives, and target groups. Designing an MEA suitable for twenty first-year students registered for the Extended Curriculum Program in the Department of Electrical, Electronic and Computer Engineering at the Cape Peninsula University of Technology (CPUT) proved relatively easy – an MEA that DeVilliers (2018) had employed for students enrolled for a similar course at the Durban University of Technology (DUT) served the purpose, the MEA was merely adapted for the sake of authenticity. Solving the adapted MEA entailed finding a missing cell phone during the Covid epidemic on the Bellville campus without the phone being answered, but with three cell phone towers – for which the locations were described – picking up the signal. Students took part in teams of four people each and were allowed two weeks to complete the activity. They presented their findings in person on campus via PowerPoint, whereafter their subject lecturers assessed their work according to the graduate attributes assigned to their subject - Communication (professional and technical communication and independent learning ability), Physics (investigations, experiments, and data analysis) and Mathematics (problem-solving).

Findings

Various stages of the modelling cycle afforded students support for learning to think critically and for developing particular graduate attributes. Students received feedback from peers in their group who critiqued their ideas in the process of finding solutions and from members of other groups and lecturers who critiqued similarly during their PowerPoint presentations. Participating lecturers reported that the activity broke down siloes in which they and their students often worked; that they were particularly impressed by how much students learned through the process; that they appreciated the creative ways in which groups solved the problem; and that the students produced high-quality PowerPoint presentations. This qualitative feedback from the lecturers serves in place of a quantitative test that measures the improvement of students' CT skills. Although such quantitative tests exist, they are criticized for not being discipline dependent.

Implications and conclusions

Employing an MEA on a small scale enabled 'flying the plane while building it' – a few days after the project was employed, for instance, it transpired that the role of educators and students in problem-based learning, warranted discussion; to this end, Kurt's (2020) article facilitated this discussion. This MEA was not designed from scratch, but even so, adapting for authenticity, organizing, and executing the project was time-consuming. The MEA nevertheless allowed students to develop skills which lecturers would not have been able to 'teach' them. The lecturers concluded that mathematical modelling should be a permanent part of their programme.

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