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Using an informal competitive practical to stimulate links between the theoretical and practical in fluid mechanics: A case study in non-assessment driven learning approaches

Robert William McClelland Pott[a,*], *Karin Elizabeth Wolff*[b], *Neill Jurgens Goosen*[a]

[a] *Department of Process Engineering, Faculty of Engineering, Stellenbosch University, Banghoek Road, Stellenbosch, South Africa*
[b] *SARChI Work-Integrated Learning Research Unit, Cape Peninsula University of Technology, South Africa*

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A B S T R A C T

This study outlines a practical intervention in a second-year fluid mechanics course. The practical was designed using the framework of Legitimation Code Theory, with the aim of stimulating active links between the theoretical and practical (in this case pump and piping networks, head loss and application of the energy equation), through a group-based competitive, informal, interactive learning event. The effect on students' perceptions and anxiety were recorded, and it was seen that students' perceptions of workload, anxiety and time pressure decreased. Substantial evidence of cumulative learning was noted, both during the practical session, as well as in student responses. And while the data do not conclusively elucidate the extent and timeframe over which this benefits the students' results, what is clear is that participants both critically engaged and were enriched by the practical. The project lays the foundation for similar theory- and application-linking practicals based on a non-assessment paradigm.

1. Introduction

In the face of increasing 21st century engineering complexity (UNESCO, 2010) and specialisation, engineering curricula are being pressurised to 'face both ways' (Barnett, 2006): towards the theoretical knowledge base and increasingly complex application contexts. Thus, one sees more theory and more practice being introduced into an already full curriculum. At the same time, however, high failure and dropout rates (Council for Higher Education, 2013), as well as industry complaints about graduate inability to 'apply knowledge' (Griesel and Parker, 2009) suggest that the theory–practice divide needs attention if we are to improve engineering education. Muller (2009), citing Becher and Parry (2005) refers to the distinction between 'know why' (theory) and 'know how' (practice). This relationship is crucial in curricula, and linking these in the students' minds develops the knowledge base necessary to be a good professional engineer.

It is common in university engineering education to focus teaching heavily on the theoretical, examine on the basis of worked examples and (for instance) show videos of physical examples. Indeed, in well-resourced institutions, it is common to find technology-based learning platforms (Rooch et al., 2016): providing access to YouTube videos, recorded class or laboratory demonstrations, and even simulation software

* *Corresponding author*.
E-mail addresses: rpott@sun.ac.za (R.W. McClelland Pott), wolff@schoolofengineering.co.za (K.E. Wolff), njgoosen@sun.ac.za (N.J. Goosen).

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such as that used by Gynnild et al. (2007). These approaches are designed to demonstrate the application of theory to practical contexts, but often essentially represent passive activities for the student—a learning mode which does not foster deep or long term learning (Najdanovic-Visak, 2017). Unfortunately, this robs the student of an important linkage between what is fundamentally an applied science and the theory that is rigorously covered in class.

A space for students to experience and develop an intuitive feel for the theoretical material is needed in developing the students' understanding and allowing the student to more fully undergo cumulative learning (Maton, 2013). Kolb's experiential learning theory (2014) expands on this notion: he sees holistic learning as the integration of experience, perception, cognition and behaviour. Indeed, work by Abdel-Salam et al. (2006) in a fluid mechanics practical context, and Chen et al. (2016), in their experiential practicals, illustrates that active participation is key in learning experiences. For this reason, laboratory practicals remain an integral part of university engineering curricula. However, the prevalence of assessment-driven learning in the practical context often results in the students not critically engaging with the equipment and demonstrated phenomena, but rather opting for a superficial and targeted learning approach—taking their measurements and samples, with little deep understanding being generated (Chin and Brown, 2000; Louw, 2016; Ram, 1999; Young et al., 2006). Moreover, the use of competition, and team work, has been suggested to improve learning outcomes, motivation, student participation and stimulation (Delgado and Fonseca-Mora, 2010; Lefebvre et al., 2009; Zou and Ko, 2012).

In addition to the importance of bridging the divide between the theoretical and the practical, another important parameter in student success is their attitude: their motivation, anxiety, and perception of ability (Jones et al., 2010; Savage et al., 2011). Not only is their attitude linked to success, but it is often an indicator of the type of learning they are likely to pursue: deep, strategic or surface (Entwistle, 2000). Our students experience great pressure during the course of their studies, and those students without a positive outlook towards their work, the course, and the material are at a disadvantage (Brown et al., 2015; Fadali et al., 2004), and less likely to engage in 'deep' learning.

The intervention outlined in this research aimed to enable deep learning, cause the fundamental connection of theory to practice and to stimulate student interest, engagement and motivation through a group-based competitive, informal, problem solving, interactive learning event. In order to succeed the students needed to grapple with, understand, and apply the theory of pump curves, pumping networks and pressure losses, to achieve a practical solution to the open-ended (but constrained) problem. We hoped to, firstly, positively affect student attitudes through the practical, and secondly to demonstrate that a successful, learning-rich practical environment can be achieved using a non-assessment driven philosophy.

2. Context

This study was conducted within the second year of a four-year chemical engineering degree programme at a research-intensive traditional university in South Africa. The programme is International Engineering Alliance (IEA)-aligned and accredited by the Engineering Council of South Africa, a signatory of the Washington accord. As such, while there are context and societally specific aspects within this programme, research conducted with these cohorts is likely to be broadly applicable to other global institutions and engineering programmes. Indeed, the challenges facing many of the world's engineering educators are the very same that we experience—needing to teach ever more content, within smaller time-frames, to larger classes.

The course in which we ran this practical instructs second year chemical engineering students in the fundamentals of fluid mechanics. The course deals both with conceptual, more abstract topics such as the mathematical description of flow using the Navier–Stokes equations, and with more practical calculations and topics, for example, pressure drop calculations, design and calculations around piping networks and pump sizing.

However, many students have had little opportunity to interact with the types of equipment that make up the most basic elements of chemical plants. They have not seen a ball-valve, or considered the implications of fittings or material selection when constructing piping networks; they have little intuition when it comes to the effect of pipe size on pressure loss or how to correctly select a pump or connect pumps in networks to achieve required flow rates or pump heads. One way to overcome this gap is to expose the students to appropriate practicals.

The curriculum in the second year does include fluid mechanics practicals, where the students develop the operating curve for a pump, simulate cavitation, and determine the friction factors of various pipes and fittings. These practicals aid in filling the gap between knowledge and intuition, and help to bring the students' experience in line with learned theory. However, the practicals are set up in such a way that the students are very constrained in how they can engage with the equipment. They are instructed on how to vary the flow rate and measure the head developed, or shown incipient cavitation, but they have little opportunity to experiment, dismantle, reassemble, examine and generally experience the constituent equipment. Prior observation and assessment suggests that the absence of such an opportunity is much to their detriment and appears to manifest as inadequate linking of theory and potential application.

In addition, these practicals are assessed through written reports, and student interviews and anecdotal evidence suggest that students practice 'surface' and 'strategic' learning (Entwistle, 2000). They do not fully engage with the practical, but rather focus on taking only those readings, measurements and observations which will allow them to fulfil their report writing task—a task they find onerous and frustrating, partially since they have little deep understanding of the systems that they are now writing about. The *status quo* is therefore failing to enable deep learning, failing to cause the fundamental connection of theory to practice and failing to stimulate student interest, engagement and motivation.

This lack of deep learning then manifests itself either as poor throughput rates for the module (e.g., faculty statistics show that over the period 2011–2015, this module ranked 9th highest for failure rate among 41 modules in the 4-year Chemical Engineering programme at the university) or further into the programme; for instance where final year students are unable to link the theory they have learnt over the course of the programme with practice when they need to work in the laboratory independently during their final research project.

In order to appropriately design practicals, interventions, and teaching methodologies which address the issues