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RESEARCH BRIEF

Re-engineering an Engineering Course: Exploring the Affordance of Flipped Classrooms for Transformative Teaching, Learning, and Workplace Competency

Elaine Khoo[1], Mira Peter , Bronwen Cowie

Wilf Malcolm Institute of Educational Research, The University of Waikato, New Zealand

Abstract: *This research brief is investigating the extent to which a flipped classroom model enhances student learning of threshold concepts (TCs) in an undergraduate engineering course at a New Zealand university. This project extends the team's previous research confirming the effectiveness of the TC theoretical framework across multiple disciplines including engineering.*

*Keywords**:** flipped classrooms, engineering education.*

Successful engineering graduates not only need to have a flexible understanding of engineering principles and practices but also need to be able to work in teams, to communicate well, to self-assess to improve their abilities and performance, and to work in contexts that can be risky and uncertain (Adamson & Darling-Hammond, 2012; Meier, Williams, & Humphreys, 2000). Current trends in engineering education call for the development of students' "generic engineering competencies" rather than separating generic competencies from engineering competencies (Male, 2010). It is crucial that tertiary educators develop curricula that enable students to develop these capacities during their undergraduate studies to support student capacity to contribute to a country's economic competitiveness and societal well-being and enhance student employability (Crossman, & Clarke, 2010; Hernández-March, Martín del Peso, & Leguey, 2009; Ministry of Education and the Ministry of Business, Innovation and Employment, 2014).

In response to the above, our two-year project (2015-2016), funded by the New Zealand Ministry of Education's Teaching & Learning Research Initiative (TLRI), is investigating the extent to which a flipped classroom model enhances student learning of threshold concepts (TCs) in an undergraduate engineering course at a New Zealand university. This project extends the team's previous research confirming the effectiveness of the TC theoretical framework across multiple disciplines including engineering (Peter, et al., 2013).

The *flipped classroom* is an innovative variant of student-centred learning with the potential to address the issues raised in the international literature. In a flipped classroom lecture materials are usually assigned as take-home tasks, accessible through online modalities. This allows the lecturer-student class contact time to be devoted to addressing student questions and problem solving in teams (Houston & Lin, 2012; Strayer, 2012). Flipping the focus of class time allows students to take increased responsibility for their own learning through active investigation both in and out of class time. This changes the class time focus and dynamics from the transmission of knowledge to one involving collaborative, interactive learning and just-in-time teaching (Bonk & Khoo, 2014). It provides more flexibility for lecturers and students to participate in discussion and collab-

[1] Corresponding author. Wilf Malcolm Institute of Educational Research (WMIER), NZ E-mail: ekhoo@waikato.ac.nz

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orative and guided problem solving activities in ways that are known to address student misconceptions and support the mastery of threshold concepts (O'Toole, 2013). These approaches are also known to support the development of the skills needed for 21st century graduates (OECD, 2012).

In our project, TC learning will be a focus for the flipped classroom. Meyer and Land (2003; 2006) introduced the notion of threshold concepts (TCs) as those concepts that students need to master in order to think like a subject specialist. TCs have been linked to ontological shifts (i.e., changes in identity) and shifts in subjectivity that come with the reconfiguration of a learner's prior conceptual framework (Meyer, Land, & Baillie, 2010). These changes are consistent with the goals of tertiary education for engineers (Ministry of Education and the Ministry of Business, Innovation and Employment, 2014). Given the current goals for tertiary education, to better prepare students to apply what they know in new and creative ways in the real world and novel situations (Tertiary Education Commission, 2013), it is imperative that students master TC, competencies and practices in order to reinforce their conceptual development and bolster "threshold actions" within and outside the classroom. Current identification of TC and competencies in engineering has broadened beyond content/technical knowledge to include skills, such as teamwork (i.e., thinking and working together), and communication, both oral and written, that are important to 21st century engineering practice (Male, Bush, & Chapman, 2011; Male & Baillie, 2014). Building on this trend, we postulate that a TC-based flipped class pedagogical approach to teaching and learning can enhance first year students' learning of TC technical competencies and generic skills necessary for engineering graduates in the 21st century. Our research design to address this aim is elaborated next.

Research Design

The three objectives of our research project are: (1) to examine the effects of the flipped classroom on students' learning of hard to grasp TCs (Meyer & Land, 2003), (2) to explore the 'affordances' (defined as the perceivable opportunities for an organism to perform action; Gibson, 2001) of a flipped classroom model of teaching in a first-year compulsory electronic engineering paper, and, (3) to examine the impact beyond the classroom of the flipped class on the development of students' workplace competencies.

Using a design-based research (DBR) process (Collins, Joseph, & Bielaczyc, 2004) involving practitioner-led cyclical processes of planning, design and implementation of a TC-based flipped pedagogical approach, the research team will collaborate with lecturers in an introductory electronic engineering course to develop and trial a flipped class model. This is intended to help students learn TCs and develop the generic competencies needed such as the ability to communicate well, process information effectively, think logically and critically, and adapt to future changes with the overall aim of increasing their workplace competency and future employability.

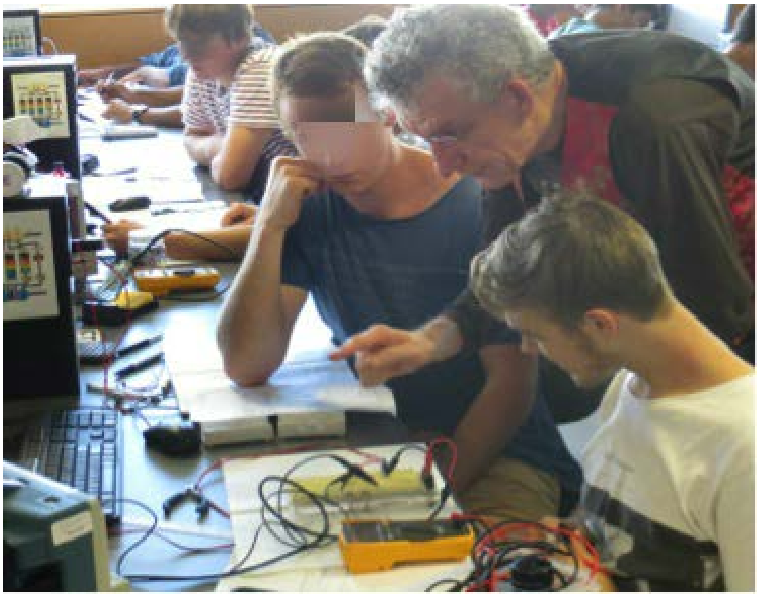

Figure 1. *The lecturer interacting with students in the lab.*

A series of themed "Khan Academy Style" videos (Khan Academy, 2015) is being developed as a replacement for traditional 50-minute lectures. The videos are created with careful reference to recommendations from cognitive principles shown to be effective in multimedia learning (Sorden, 2005). Students will be able to access, view and review the videos from the course Moodle website (Moodle is our university online learning management system) to engage with the new course material outside of class time. They will be reminded to watch the videos prior to attending weekly practical laboratory sessions in which their learning would be put into practice. The weekly three-hour laboratory sessions will be extended to four hours to allow for small group problem solving activities and more personal instructor interaction. In this way, students' role evolves from a passive recipient of knowledge to that of an active knowledge constructor. Concomitantly, the instructor's role also changes from that one of a dispenser of knowledge to guiding and mentoring students to deeper levels of thinking and higher levels of knowledge application.

Data from multiple sources will be collected: (1) lecturer interviews, (2) student focus group interviews, (3) student surveys, (4) observations in the flipped classroom, (5) video analytics of student access strategies to the flipped class videos developed by the team, (6) student access and usage logs in the university learning management system (Moodle), and (7) student achievement data. The analysis will focus on examining the impact of the intervention by tracking changes in lecturer pedagogy and student in-class and workplace learning and development. Statistical analysis will be conducted on the quantitative data to show differences and trends in student achievement and perspectives. Qualitative data will be analysed using thematic analysis to develop themes through inductive reasoning (Mutch, 2005). New videos will be developed and the research activities will be refined and revised in the second year of the study.

Figure 2. *Students working on a collaborative problem-solving task.*

Expected Outcomes of the Project

No other studies that we are aware of have attempted to integrate a TC-focused teaching with a flipped class approach in engineering education. We expect the outcomes will contribute to enhancing our understanding of the ways and extent a flipped class model can foster deep learning of TCs and support learning and transfer of relevant skills into workplace practice. The findings will further help refine guidelines for student workplace competencies and assessment against a robust competency-based criteria for engineering graduates. Such evidence can be used to inform policymakers and practitioners about future implementation and funding opportunities intended to enhance tertiary teaching and learning.

For more information about the project, contact the principal investigators, Dr Mira Peter (mpeter@waikato.ac.nz) and Dr Elaine Khoo (ekhoo@waikato.ac.nz). The project website can be found at:

http://www.waikato.ac.nz/wmier/research/projects/how-flipped-classrooms-afford-transformative-teaching,-learning,-and-workplace-competency

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References

Adamson, F., & Darling-Hammond, L. (2012). *Policy pathways for 21st century skills*. Stanford, CA: Stanford University, Stanford Center for Opportunity Policy in Education.

Bonk, C. J. & Khoo, E. (2014). *Adding some TEC-VARIETY: 100+ Activities for motivating and retaining learners online*. Retrieved from http://tec-variety.com/

Collins, A., Joseph, D., & Bielaczyc, K. (2004). Design research: Theoretical and methodological issues. *The Journal of the Learning Sciences, 13*(1), 15–42.

Crossman, J. E., & Clarke, M. (2010). International experience and graduate employability: stakeholder perceptions on the connection. *Higher Education*, *59*(5), 599–613. doi:10.1007/s10734-009-9268-z

Gibson, E. J. (2001). *Perceiving the affordances: A portrait of two psychologists*. Hillsdale, NJ: Erlbaum.

Hernández- March, J., Martín del Peso, M., & Leguey, S. (2009). Graduates' Skills and Higher Education: The employers' perspective. *Tertiary Education and Management*, *15*(1), 1–16. doi:10.1080/13583880802699978

Houston, M., & Lin, L. (2012). Humanizing the classroom by flipping the homework versus lecture equation. *Paper presented at Society for information technology & teacher education international conference*, Austin, TX.

Khan Academy (2015). Khan Academy. Available at https://www.khanacademy.org/

Male, S.A. (2010). Generic Engineering Competencies: A Review and Modelling Approach. *Education Research and Perspectives. 37*(1), 52–84.

Male, S.A., & C.A. Baillie. (2014). Research guided teaching practices: Engineering thresholds; an approach to curriculum renewal. In A. Johri & B. Olds (Eds.), *Cambridge Handbook of Engineering Education Research* (pp. 393–408). New York: Cambridge University Press.

Male, S.A., Bush, M.B. & Chapman, E.S. (2011). An Australian study of generic competencies required by engineers. *European Journal of Engineering Education*, *36*, 151–163.

Meier, R.L., Williams, M.R., & Humphreys, M.A. (2000). Refocusing our efforts: assessing non-technical competency gaps. *Journal of Engineering Education, 89* (3), 377–385.

Meyer, J.H. F., & Land, R. (2003). Threshold concepts and troublesome knowledge: Linkages to ways of thinking and practising within the disciplines. In C. Rust (Ed.), *Improving student learning, improving student learning theory and practice - 10 years on* (pp. 412–424). Oxford, England: OCSLD. Retrieved from http://www.tla.ed.ac.uk/etl/docs/ETLreport4.pdf

Meyer, J., & Land, R. (2006*). Overcoming barriers to student understanding: Threshold concepts and troublesome knowledge*. Oxon, England: Routledge.

Meyer, J.H.F., Land,R., & Baillie,C. (Eds.). (2010). *Threshold concepts and transformational learning.* Rotterdam, The Netherlands: Sense.

Ministry of Education and the Ministry of Business, Innovation and Employment. (2014). *Tertiary education strategy 2014-2019*. Ministry of Education and the Ministry of Business, Innovation and Employment, Wellington: New Zealand.

Mutch, C. (2005). *Doing educational research: A practitioner's guide to getting started.* Wellington, New Zealand: NZCER Press.

OECD (2012). *Education at a Glance 2012: Highlights*. OECD Publishing. Retrieved from http://www.oecd.org/edu/highlights.pdf

O'Toole, R. (2013). *Pedagogical strategies and technologies for peer assessment in Massively Open Online Courses*

(MOOCs). Discussion Paper. University of Warwick, Coventry, UK: University of Warwick. (Unpublished).

Peter, M., Harlow, A., Scott, J., Johnson, M., McKie, D., & McKim, A. (2013). *Re-envisioning tertiary teaching and learning of difficult concepts: How "threshold concepts" afford understanding of problematic ideas*. Retrieved from the Teaching and Learning Research Initiative website: https://www.tlri.org.nz/tlri-research/research-progress/post-school-sector/re-envisioning-tertiary-teaching-and-learning

Sorden, S. D. (2005). A cognitive approach to instructional design for multimedia learning, *Informing Science: International Journal of an Emerging Transdiscipline, 8*, 263-279.

Strayer, J.F. (2012). How learning in an inverted classroom influences cooperation, innovation and task orientation. *Learning Environments Research*, *15*(2), 171–193.

Tertiary Education Commission. (2013). *Growing the pipeline of work- ready engineering graduates*. Wellington, New Zealand: Author.