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A BLUEPRINT FOR RESEARCH-LED TEACHING ENGINEERING AT SCHOOLS: A CASE STUDY FOR TAYLOR'S UNIVERSITY

MUSHTAK AL-ATABI, MARWAN M. SHAMEL, REBECCA LIM X. Y.*

School of Engineering, Taylor's University, No. 1 Jalan Taylor's
47500 Subang Jaya, Selangor DE, Malaysia
*Corresponding Author: XiaoYien.Lim@taylors.edu.my

Abstract

Although it is expected that research conducted at universities and institutions of higher learning will have some positive impact on the teaching quality, the literature seem to point in another direction. Available literature reports zero correlation between teaching and research. However, this need not be the case and a number of recommendations to create a positive correlation between teaching and research are proposed. This paper outlines a framework that utilises the Grand Challenges for Engineering and CDIO to create a clear link between teaching and research in Taylor's School of Engineering. Aligning the academic staff research objectives to the Grand Challenges, creates a sense of purpose that extends beyond the academic staff to their students. Ensuring that students' projects and other CDIO activities are derived from the academic staff research interests help creates a learning environment in which research and teaching are integrated. This integration is highly desirable as it benefits both the students and the academic staff.

Keywords: Research-led, Teaching, Grand challenges for engineering, Human motivation.

1. Introduction

Universities are entrusted with educating students at advanced levels. Generally speaking, the society expects variety of outcomes from the universities including contributing to economic growth of a nation through fostering new ideas and training a dynamic workforce. Most of the world universities today are places where both teaching and research take place side by side. Research can have a positive impact on teaching through creating an informed and enthusiastic academic staffs that are aware of the latest developments in their field of specialisation and can use their research findings and experiences to inform, inspire and empower their students. This can be achieved, for example, through using real research cases in the classroom to increase the lecturer's credibility and elucidate the importance of the studied topic in shaping the future technology. On the other hand, involving the students in research activities, at an appropriate level, has the potential of giving them a personalised and unique learning experience, allowing them to develop skills that are difficult to develop using traditional teaching activities, such as scientific inquiry and critical thinking.

Although it is logical for universities to systematically integrate their research and teaching activities allowing the synergy between them to both flourishes, the research-teaching link seems to remain elusive. Empirical investigations, mainly using surveys, have provided no conclusive evidence for a link between the two roles [1-4]. In a Meta analysis of 58 studies, Hattie and Marsh [5] derived 498 correlations between research and teaching. However, they reported a zero relationship between the two at the individual academic and department level. In a later study, Hattie and Marsh [6] clarified that the zero relationship does not imply that there is no excellent researchers who are also excellent teachers at the same time, nor that research does not have the potential to impact teaching, but rather the study points out the lack of a systemic approach that can foster a positive relationship between the two.

Jenkins and Healey [7] performed an extensive study on institutional strategies to link teaching and research and they found no case studies of institutions that have directed specific strategies to ensure that the institutional research policy is directed to support the undergraduate curriculum. However, a growing awareness of the potential benefits of bringing teaching and research closer to each other results in a range of institutions that have intervened to do so more effectively. A framework on how teaching can be linked to research was also proposed by Griffiths [8] as shown below:

- Research-led teaching: The curriculum content is designed by the academic staff based on their research interests. The teaching focuses on transferring information about the research findings to students with little impact on building students capabilities in conducting research or understanding of the research process.
- Research-oriented teaching: The curriculum is designed and delivered in a manner that emphasises developing research and inquiry skills in the students.
- Research-based teaching: The curriculum is designed with inquiry-based activities at the centre. This is intended to get the students to achieve the learning outcomes mainly through the research and inquiry activities that they perform rather than through traditional information transfer.
- Research-informed teaching: This refers to the effort of improving teaching through performing research into the teaching and learning process itself.

Healey [9] expressed the first three relations mentioned above diagrammatically along two axes, one representing the level of students' involvement in research (ranging from being audiences to participants), while the second axis represents the research emphasis (ranging from content to processes). He also introduced the category of "research-tutored teaching". This is shown in Fig. 1.

Jenkins and Healey [7] proposed that an institutional framework to develop a research-teaching nexus involves creating awareness of the nexus through an appropriate departmental mission, pedagogy and curriculum that enable the nexus, policies that support it and staff to bring it to life. Jenkins et al. [10] argued that the 'research-teaching nexus' is central to higher education and student intellectual development and staff identity can and should be developed by departments focusing on the 'nexus' and putting clear policies to develop it. Clearly, a research-teaching nexus is very desirable and central to the success of an institution of higher learning. However, this nexus is not automatically occurring and needs to be nurtured through clear departmental mission, strategies and policies. This paper showcases the framework that integrates research and undergraduate teaching in the School of Engineering at Taylor's University, Malaysia. The framework attempts to capitalise on both the CDIO (Conceive-Design-Implement-Operate) initiative principles and the Grand Challenges for Engineering.

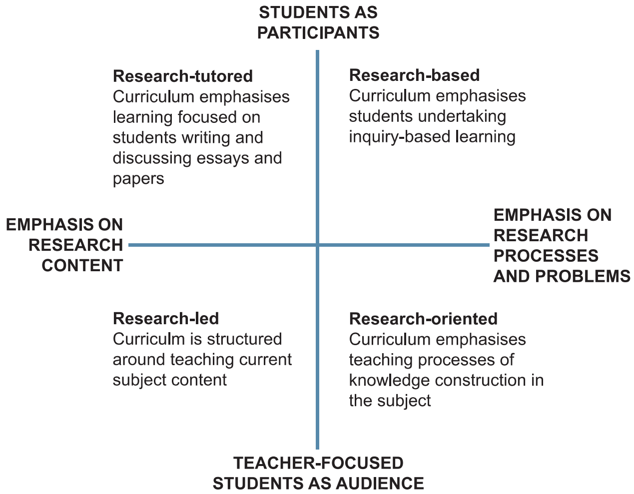

Fig. 1. Curriculum Design and the Research-Teaching Nexus [9].

1.1. Taylor's school of engineering

Taylor's University is a private Malaysian institution of higher learning. The School of Engineering offers three undergraduate programmes in chemical, electrical & electronic and mechanical engineering. The School prides itself with being students-centred and adopting the Project-Based-Learning approach where the students are required to take a Design Module each semester for the first three years of their 4-year course study. This is stimulated by employing the CDIO framework. Each Design Module requires the completion of a significant group design project that provides students the opportunity to perform variety of inquiry-based, design and build activities. In the fourth year, the students are required to undertake a research based final year project where quality research work of publishable standard is expected. The students will present their findings in a conference end of semester eight called Engineering Undergraduate Research Catalyst Conference (EURECA).

1.2. Human motivation

In order for any operational framework to be successful, it is imperative that people are motivated to embrace and adopt it. Although a reward-based motivation system is normally used to encourage individuals to change behaviour, and embrace a specific framework, Frankl [11] indicated that the ultimate motivation of humans is the search of meaning. While what drives individuals may be obscured by more extrinsic motivations, ultimately they are searching for a meaning or a purpose for whatever they are doing and for their very existence. Frankl published his finding in a book entitled “Man’s Search for Meaning” in 1963 and since then a lot of research work in the area of human motivation arrived at similar conclusions [11]. Drawing on four decades of human motivation research, Pink [12] in his book “Drive: The Surprising Truth About What Motivates Us” identified two types of motivations, intrinsic and extrinsic. Intrinsic motivations are far lasting and more sustainable. To achieve the intrinsic level of motivation, individuals need to have autonomy over what they do and a purpose that guides them and they believe in allowing them to pursue mastery of whatever they do. So it is autonomy, mastery and purpose that ultimately create the environment that motivate human beings. This is only true when a baseline of a fair and consistent reward system is established in the first place [12].

The objective of this paper is to develop a framework for Research-Led-Teaching at the School of Engineering at Taylor’s University. It is also hoped that this framework is universal enough so other similar schools can easily adopt it. The framework is designed to be self-motivating for academic staff to adopt. This is done in accordance with the work of Pink [12]. It is worth mentioning here that an academic environment, at least in theory, is better prepared to use the autonomy-mastery-purpose motivation model as it is supposed to provide abundance of these three elements.

2. Creating Research Purpose through the Grand Challenges for Engineering

To affirm the purposeful nature of the engineering research done at the school, the research objectives were aligned to the Grand Challenges for Engineering announced by the National Academy for Engineering (NAE) in 2008. These fourteen Grand Challenges must be addressed if humanity hopes to achieve a sustainable, economically robust, and politically stable future for the future generations [13]. These challenges, that range from the most basic to the extraordinary and encompass four Grand Challenge themes, represent the frontier in what technology needs to solve in order to serve humanity. Helping humanity make it through the trying times can be a very powerful, inspirational and motivating research theme for both academic staff and students alike. . The Grand Challenges are summarised below.

Theme 1: Energy and Environment

1. Make solar energy economical
2. Provide energy from fusion
3. Develop methods for carbon sequestration
4. Manage the nitrogen cycle
5. Provide access to clean water

Theme 2: Health

6. Advance health informatics
7. Engineer better medicines

Theme 3: Security

8. Prevent nuclear terror
9. Secure cyberspace
10. Restore urban infrastructure

Theme 4: Learning and Computation

11. Reverse engineer the brain
12. Enhance virtual reality
13. Advance personalised learning
14. Engineer the tools of scientific discovery

The Taylor's School of Engineering research groups are encouraged to declare the Grand Challenge(s) they are addressing and establish clear research objectives respectively that are aligned with the challenges. It was notices that majority of the academic staff/researchers were supportive of the initiative to streamline their researches with the four themes.

2.1. Research autonomy

Self-determination and independence is recognised as one of the strong intrinsic motivators. Pink [12] identified four areas where autonomy should be observed, Task, Team, Time, and Technique. A motivated individual is one who is able to decide which task that (s)he does, with whom, at what time and has freedom over the way the task is performed as long as the objectives are achieved. To ensure that autonomy-encouraging environment prevails, Taylor's School of Engineering academic staff members have total control over the research groups that they wish to form, participate or join, their research methodology and funding sources. This was communicated clearly and beforehand to all the academic staff.

2.2. Mastery and Research

Flow is a mental state when an individual is highly motivated, immersed, energised and focused on the task in hand [14]. The state of flow is achieved when an individual is having a mastery level skill to perform a challenging task. Flow and other mental states are shown in Fig. 2.

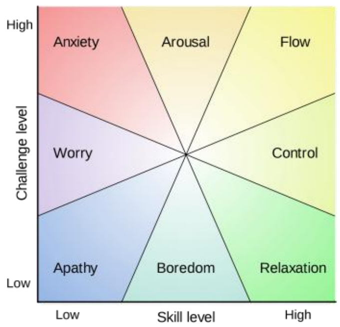

Fig. 2. Mental State in Terms of Challenge and Skill Levels [14].

Research often provides an opportunity to achieve the state of flow as it often represent a challenging task that requires a high level of mastery. Research is often highly enjoyable by academic staff. They are often very motivated to perform it and proud to share its finding with the world.

2.3. Research-teaching nexus

Taylor's School of Engineering developed a research structure that mainly consists of 7 research groups. Table 1 shows the different research groups and the Grand Challenges they address.

Table 1. Taylor's School of Engineering Research Groups and Grand Challenges Addressed.

No.	Taylor's School of Engineering Research Groups	Grand Challenges
1.	Taylor's Technology Innovation Centre (TTIC)	1-14
2.	Energy Research Group	1, 2, 3
3.	Environment and Water Research Group	4, 5
4.	Health Research Group	6, 7
5.	Security Research Group	8, 9, 10
6.	Computer Intelligence Applied (CIA)	11, 12, 14
7.	Teaching, Research, Innovation and Learning (TRIaL)	13

In order to ensure that the research-teaching nexus is built in, besides performing research in their areas of expertise, members of staff in these research groups are expected to perform the following duties

1. Adopt related core and elective modules: This includes developing, updating and teaching these modules. This will ensure that modules are updated and delivered in a manner reflects the latest research findings and applications. Staff members are encouraged to include aspects of their own research finding into the module. This will help make the modules more interesting to learn and increase the lecturers' credibility.
2. Offer early years design projects to the students: Taylor's School of Engineering is a Project-Based Learning school where students are involved in a design project every semester (semester one to six). Research groups are expected to provide the students with suitable design projects creating awareness among the students of the existence of the research groups and the importance of research as an academic and intellectual activity. The students will see themselves as members of the research groups sponsoring their design projects and this will enable them to see the value of the research done by their lecturers.
3. Offer Final Year Research Project: Every final year student (semester seven and eight) is required to undertake a major research project and write a conference paper as a mandatory requirement for graduation. These research findings are to be presented at the School's annual Engineering Undergraduate Research Catalyst Conference (EURECA). Aligning the final year projects to the research interests, capabilities and objectives of the research groups are desirable in optimising resources and achieving the overall research objectives.

The projects in duties numbered 2 and 3 are designed in a way to comply with Bloom's Taxonomy from the knowledge till evaluation level.

This framework is depicted schematically in Fig. 3. The figure shows a donut-like shape where all the research groups are driven by addressing the Grand Challenges and they act as an interface between the student-centred Taylor's teaching framework and outside the academic region. The students sit at the centre of the framework where variety of research-led curriculum, such as EURECA conference, annual projects, Grand Challenge Scholar Programme, research-led modules are designed and directed at them. On the other hand, the research groups connect with the outer world, raising research funds, collaborating with the industry and community and disseminating knowledge through publications and consultancy. The donut-like framework is published in the school research website to the public and it is expected to attract talent students (under/post graduate) to the school research-led teaching activities allowing the students to choose the challenge theme, researcher, or project. This method will generate engineers who join Taylor's Engineering programme to polish-up their dream challenges throughout their studies. It is believed that this will not only expose students in real problem solving, it also develops the staff in learning and acquiring new knowledge. Besides, it is envisioned that with this framework, academic staffs were motivated to deliver higher research outputs through working with international professionals, indirectly attracts and expand the research group members and ultimately establish a research-based institution. With the continuous effort putting in research and teaching, it is also anticipated that Taylor's School of Engineering academic staff would be able to put out textbooks or handbooks that compile the lecture notes, tutorial questions and research case studies to deepen the students interest and learning process for each modules.

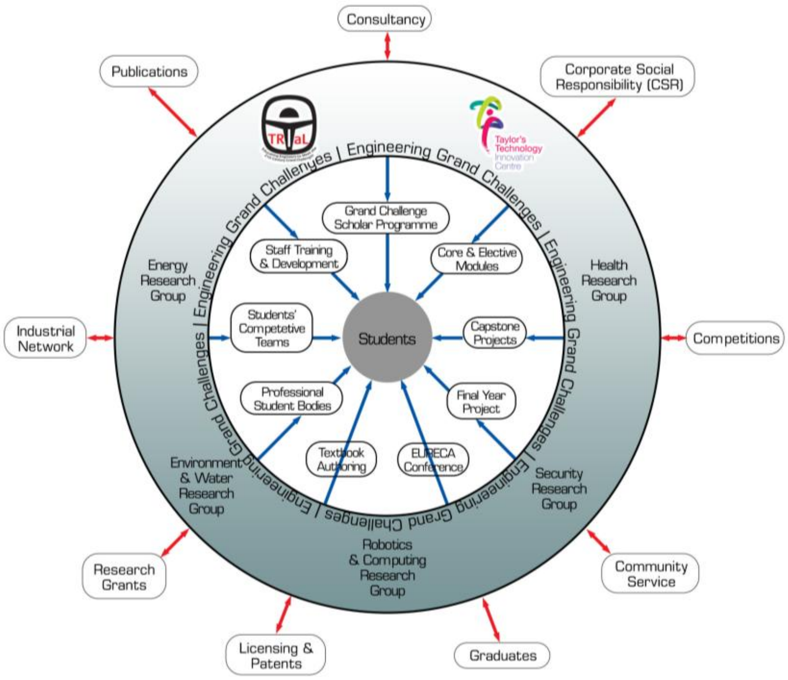

Fig. 3. Taylor's School of Engineering Research-Teaching Nexus Proposed Framework.

3. Conclusions

A framework that is crafted to integrate research into teaching and optimise the available resources including the lecturers' time and expertise is presented. The framework is largely based on the human motivation showed in Frankl, Csikszentmihalyi and Pink studies. The framework has the students at the centre where the research activities are designed to cascade towards the students through curriculum design and delivery, project supervision and the direct involvement of students in the research activities. In order to provide a strong sense of purpose to drive the whole process, research groups were structured based on the Grand Challenges for Engineering. Taylor's School of Engineering academic staff members generally were very supportive of the proposed framework.

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