Development of an enquiring mindset in engineering students

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Abstract – The concept of engaged enquiry is discussed in the context of a free elective 'History and Philosophy of Engineering'. Engineering students are often taught traditional discipline specific skills and knowledge in a rigid linear framework. Students that are encouraged to participate in engaged enquiry will develop improved critical thinking and creative problem-solving skills, a deeper understanding of their own learning and metacognition, and ultimately become more creative and innovative engineers. The incorporation of learning activities that encourage engaged enquiry into the greater engineering curriculum is encouraged, to help develop and improve lifelong learning skills and build mindful agency of graduate engineers.

Keywords – Lifelong Learning, Engaged Enquiry

I. INTRODUCTION

Engineering curricula often focuses on the development of technical skills and knowledge, put into context through relevant problems and exercises; but often with little support for the development of students' self-awareness of their own metacognition and epistemological processes.

In the unit of study "history and philosophy of engineering", students are guided and encouraged to develop an increased awareness of their own learning methodologies, with the aim of helping students discover and expand an enquiring mindset.

By critically analysing and challenging their own knowledge and understanding of information, skills and techniques obtained whilst studying engineering, students can become more aware of their own learning attributes, methodologies and shortcomings, building mindful agency. By looking for learning and understanding beyond that which they have already gained, students can seek to strengthen and improve their learning and understanding through engaged enquiry.

This paper outlines the approaches used in the unit of study "history and philosophy of engineering" to help foster and develop an enquiring mindset in engineering students and presents findings from student surveys and informal discussions to evaluate the effectiveness of these approaches.

II. BACKGROUND

Traditional instruction methods in engineering often involve teachers transmitting existing bodies of knowledge to students and tend to follow a linear and piecemeal approach to education, in a somewhat closed and orderly environment. This form of teaching is often conducted within discipline based 'silos' where discrete bodies of knowledge are constructed into a series of courses that take students along an often rigid and linear path to an eventual graduation and entry into the workforce [1].

Whilst this method of teaching may be perfectly valid and acceptable, there remains the possibility to improve student learning outcomes through the development of broader, less discipline specific knowledge, skills and learning methodologies.

Engineering students in particular often have an issue where they have learnt to apply technical knowledge and skills to problems that are stripped of their social aspects, and as a result engineering graduates often end up applying narrow frameworks to complicated, messy problems, that require creative, flexible approaches to problem solving [1].

Current students of engineering have access to an ever-increasing body of knowledge, found just a few keystrokes away on the internet. The global ICT revolution of the past decade has revolutionized the way knowledge is developed, gathered, shared and advanced, with students now seeking answers online as the norm, rather than through more traditional formats such as journals and textbooks.

Rethinking the nature of learning and teaching by creating greater emphasis on the logical process of enquiry in engineering students should help current students and future engineers develop stronger critical thinking, logic and reasoning skills, and as a result help create engineers who are more capable of solving future problems.

III. ENGAGED ENQUIRY/AN ENQUIRING MINDSET

Recently a move towards online, flipped and blended learning strategies in engineering education has led to students' requiring; greater self-motivation to learn, to manage their own learning activities and to interact with more flexible learning pathways. First year students especially find this difficult as their learning prior to University entrance is typically more teacher directed.

Strong student engagement with learning activities is a common aim of educators, with an expectation that students who are engaged in their learning will comprehend material

faster and with ‘deeper’ understanding. Engaged students should also develop stronger foundations for life-long learning, a trait that is especially relevant to engineering students expected to undertake a life time of continual professional development.

Most engineering courses delivered at university level do not actively or explicitly incorporate elements of philosophical enquiry, but rather are focused on the development of technical knowledge, skills and understanding.

Encouraging students to actively analyse their knowledge and understanding, with questions such as; how do they obtain knowledge? where did it come from? is it true? how do I know it’s true? can I improve/expand on this knowledge? can I apply it to different contexts? etc. helping to foster the development of an enquiring mindset, aiding these students to go beyond the ‘average’ engineering student’s level of knowledge, engagement and understanding.

"The enquiring mind of engineers - 'how can I do it better, faster, safer' - has enriched human life on so many levels." [2]

Students that are exhibiting or developing an enquiring mindset undertake activities such as (but not limited to):

- Increased peer-based discussion of learning material and concepts
- Conducting their own independent research to gain a better understanding of the subject matter
- Examining their own metacognitive skills with the aim of actively reflecting on and improving their own thinking processes
- Self-generating an increased level of interest in the subject matter, leading to greater understanding of the material and motivation to learn
- Looking at the bigger picture of how newly acquired knowledge relates to their own existing knowledge, understanding and beliefs

IV. APPROACHES USED IN THIS UNIT OF STUDY

This paper is based on a specific unit of study, ‘History and Philosophy of Engineering” delivered as a free elective for any student at the University of Sydney but aimed at students studying engineering who are interested in gaining a broad overview of the history, nature, and philosophy of engineering. Enrolment levels are approximately 20 per semester, with most students being in their final year of undergraduate study and from a range of engineering disciplines within the faculty of engineering.

A traditional lecture/tutorial-based teaching model is not utilised in this unit; rather every session is delivered with flexibility, driven strongly by student feedback and input. Class discussion of ideas and concepts related to the syllabus form the core basis for learning activities; with the focus and direction of discussion often led by students. Students also have input (within reasonable limits) into the nature and structure of assessment tasks, and corresponding assessment criteria.

Approaches used to encourage and lead students towards enquiry-based learning in this unit of study include:

- Course content that explicitly covers metacognition, critical thinking and the epistemology of engineering,
- Use of open-ended questions to initiate student discussion and debate in small group discussion-based sessions,
- Online discussion to continue and expand in-class discussion topics,
- Online student created blogs with a large degree of student freedom in content creation,
- Presentation to peers of student chosen topic of interest, that often elicits further student discussion,
- Broad and open assessment tasks guided by student input.

The unit starts with a teacher guided form of discussion-based enquiry, with the learning facilitator posing questions and initiating/leading discussions, with the aim of informing and exposing students to concepts and processes involved in philosophical enquiry. As the semester progresses students are provided with progressively less instructor led guidance and encouraged to form a more open style of enquiry, with the aim of improving their own self-motivated enquiry skills.

Learning activities within the course tend to help students develop their skills in metacognition, encouraging them to examine their own learning and thinking processes. Reflecting on their own learning processes leads to deeper and more effective learning, but also lays the ground work for being a more self-directed learner. Students that exhibit a greater metacognitive capacity are better learners; they monitor their comprehension as they learn, reflect on whether a problem-solving strategy is working, and make corrections if they realise they are not on the right track [3].

V. STUDENT FEEDBACK

Informal discussion sessions with students indicate that the students find the course interesting and enjoyable, very different to their regular courses, and engaging - through both the nature of the subject matter and delivery of content. Students appreciate the flexibility in the course structure and the positive reception/incorporation of their ideas/thoughts into the course content and direction [4].

“Engagement in classes. While tangents that occur in class can lead to us falling behind schedule, they are extremely interesting and really lead to challenging my perceptions about what it means to be an engineer - and what my responsibilities will be, especially when relating history and philosophy to major engineering projects throughout the past.”

"It's a very interesting course and encourages me to use my own research skills to supplement what is learnt in class. It's very student-driven, and no maths, which is a nice change... The assessment tasks are also very enjoyable, and I like that they are so self-driven, and you can do them on pretty much whatever you want. The format and small class sizes are also really good."

The course content and structure of learning activities is very different to other more traditional units of study that students have experienced. Students generally find this refreshingly different and this aspect alone often creates an improvement in student interest and encourages enquiry-based learning.

"Open forum discussion was a great change from the normal unit. It has helped me develop skills that aren't really taught by any other subject"

"This was a very unique uos. Rod's units have always been different in a good way. This class was more of a conversation between everyone rather than Rod teaching. This was very enjoyable, and I wish we could have had more classes."

In answer to the question "What have been the best aspects of this unit of study?", (via the formal Unit of Study Survey process) students' comments included:

"This unit of study is one of the best ones that I have come across. The quality of teaching was spot on. This unit should be added as one of the core units. Everything about this unit was excellent and interesting."

"I really enjoyed it. I didn't think I would, but I think it's going to help me be a better engineer."

VI. DISCUSSION

Many engineering students that start their degree do not finish it, and it is possible that some of these students left engineering studies due to a lack of engagement in early, introductory courses, or failed to see the relevance of what they were being taught. Research in learning and teaching in science and engineering indicates that part of the problem lies in the way which these subject areas are traditionally taught, through lectures, tutorials, note-taking, memorization and laboratories with specific instructions, procedures and predictable results [3].

Student-centred instruction, in which learners gain knowledge and understanding through the application of engineering methods and principles, interacting with fellow students under the guidance of an instructor is a core building block of engaged enquiry. Students work on meaningful individual or group tasks and are encouraged to reflect on and think about their own understanding and reasoning. Student centred instructional strategies are more effective in improving students' conceptual understanding, retention of knowledge and attitudes towards learning than traditional lecture based methods [3].

Interactions with the course instructor and other students can help with students' learning, new skills and knowledge can be acquired by working alongside others and engaging in discussion and debate with peers. However, this form of learning is uncommon within engineering education. Students working together in this manner can form a community of learners that can help provide cognitive and social support to its members [3]. In this environment, students share responsibility for learning, thinking and doing and can build on each other's knowledge and beliefs. By challenging each other's thoughts, they help build metacognition. This form of social learning and interaction can have a positive effect on motivation, by making students feel they are contributing something to other students' learning [5] cited in [3].

In the modern globalized engineering work environment, for a graduate engineer to be of increased value and use to an organisation, the possession of an enquiring mind is a valuable attribute, and should lead to improved, more thorough and original engineering. Engineering graduates that exhibit attributes of an enquiring mind should be more creative, innovative and thorough in engineering practice, possessing a broader knowledge base developed through engaged enquiry as a student. Modern engineering graduates are expected to work at developing new knowledge based technologies and skills, and accordingly students need to become expert learners, and educators need to guide these students through assisted discovery [1].

Encouraging the development of an enquiring mind aids students' engagement and levels of self-efficacy, by enabling them to obtain a deeper level of learning and understanding [6]. Students are also more likely to gain a positive attitude towards learning and increased self-confidence [7] and are expected to develop the basis for fundamental enquiry based competencies, which should aid them in future professional careers and improve their own agency and responsibility [8].

Small class sizes in the unit fostered an increased sense of involvement in students, leading to improved student engagement. Class wide discussion proved very effective in generating student interest, and the multidisciplinary nature of the student cohort leads to an improved understanding of the holistic and diverse nature of engineering. Active learning activities such as effective class debate and discussion leads to more engaged students with stronger critical thinking skills [9].

The difference between online and physical in-class engagement is evident; students that may have difficulties speaking in class are often more active in the online environment, and the use of online discussion enables students to provide references and links to information. Students are actively encouraged early on to initiate their own discussion threads, with varying levels of success; some students will only ever reply to existing threads, whilst others engage an enquiring mind-set and actively seek new topics and points of interest to discuss. These are the students that have become engaged enquirers.

The unit is not without issues, predominantly that by encouraging active class-wide student led discussion it can be difficult to keep the unit on schedule; often active and lively discussions need to be stopped and taken online due to in-class time constraints, which can then lead to students becoming dis-engaged with the topic of discussion.

VII. CONCLUSION

Incorporation of approaches to promote and encourage enquiry-based learning into the greater engineering curriculum will aid students to develop lifelong learning skills, build mindful agency and an enquiring mindset, leading to more capable, innovative and future ready engineering graduates.

Students need to develop critical thinking skills and evidence-based thinking to support them in engaged enquiry and effective learning. Universities need to recognize the importance of these skills for the modern engineer and apply tools and methods across the curricula to support knowledge based engaged enquiry activities within the learning environment. Re-thinking elements of higher education beyond a traditional, narrow linear framework is important to encourage knowledge making, future problem solvers out of graduating engineering students.

It is the author's intention to undertake a scholarly longitudinal investigation of the learning outcomes related to this unit, particularly the encouragement and development of an enquiring mind-set in students, and whether it can lead to the creation of 'better' engineers for society.

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