Embedding Indigenous perspectives in a first-year engineering design challenge course

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ABSTRACT

CONTEXT

As a practical discipline, engineering should create fit for purpose, user centred solutions. In Australia, it is increasingly important that engineering projects support the interests of Indigenous communities, who are often underrepresented in engineering and design teams (Goldfinch & Kennedy, 2013). This requires understanding of Indigenous perspectives and knowledges in engineering curriculum so that students in all disciplines (Leigh et al., 2014) become more culturally capable professionals, delivering projects that are respectful and inclusive. Currently, students have limited opportunities to learn about Indigenous perspectives within an engineering context (Goldfinch et al., 2017).

PURPOSE

This project aims to support students to become more confident in understanding Indigenous perspectives and culture within a design context, by developing case study resources, class discussions and opportunities for reflection, to support the Engineers Without Borders (EWB) design challenge embedded into a first-year engineering course.

APPROACH

Five EWB design challenges were selected to meet the course learning outcomes and provide the best opportunity for engagement with Indigenous perspectives. Case studies were integrated into an e-Portfolio workbook to offer examples of Indigenous engineering, community considerations and design applications. Students were asked to reflect at four key touch points during the design process and self-assess their cultural competency and understanding of Indigenous perspectives.

OUTCOMES

Results suggest students interacting with workbook resources including case studies, studio discussions and reflection embedded within the curriculum and design process assists students to design solutions that are user centred, respectful of Indigenous perspectives, and therefore more fit for purpose. Students self-assessment of cultural competency increased over the teaching term by 2.5 units (1-10 scale) with the greatest increase occurring in the problem scoping phase of the design process.

CONCLUSIONS

Respect and understanding of how social and cultural factors influence the design process are essential graduate attributes for professional engineers. This paper outlines an authentic approach to embedding Indigenous perspectives into a foundational engineering design challenge course, as a first step towards transforming engineering curriculum and the professional engineering landscape to be more inclusive of Indigenous perspectives.

KEYWORDS

Aboriginal and Torres Strait Islander, Indigenous, engineering design process, EWB Challenge, first year engineering, cultural competency

Introduction

As a practical discipline, engineering focuses on creating effective and efficient solutions which are fit for purpose and recognise the needs of the community in the design process. In Australia, it is increasingly important that engineering and design projects support the interests of Indigenous communities, who are often underrepresented in engineering and design teams (Goldfinch & Kennedy, 2013). The engineering profession will be stronger with a more diverse workforce, and to do this greater respect for other cultures is required (Friesen & Herrmann, 2018). Understanding of Indigenous perspectives and knowledges in the core engineering curriculum is needed so that students of all engineering disciplines graduate as culturally capable professional engineers (Goldfinch et al., 2017; Leigh et al., 2014; Prpic & Bell, 2018).

The National Best Practice Framework for Indigenous Cultural Competency in Australian Universities defines cultural competence in Higher Education as *“student and staff knowledge and understanding of Indigenous Australian cultures, histories and contemporary realities and awareness of Indigenous protocols, combined with the proficiency to engage and work effectively in Indigenous contexts congruent to the expectations of Indigenous Australian peoples”* (Universities Australia, 2011, p.171). Furthermore, cultural competence includes “*the ability to critically reflect on one’s own culture and professional paradigms in order to understand its cultural limitations and effect positive change*” (Universities Australia, 2011, p.171). Engineers Australia engineering competencies also now recognise the importance of cultural competency in designing successful projects (Engineers Australia, 2011; Goldfinch & Kennedy, 2013). Embedding Indigenous perspectives into engineering education for the benefit of all students is also recommended by Leigh et. al (2014). Although there have been efforts to revise engineering curriculum (Goldfinch & Kennedy, 2013), there are limited opportunities to learn about Indigenous perspectives (Goldfinch et al., 2017).

Design education teaches engineering students to develop skills and practices to find the “best” solution rather than the “right answer” (Godfrey & Parker, 2010). An analytical way of thinking, taught in many engineering courses, focuses on convergence to identify the right or correct answer or solution, however the design way of thinking emphasizes divergence which creates possible answers through connecting and integrating ideas and seeing the big picture (Goldberg & Somerville, 2014). The ‘design mind’, as Goldberg & Somerville (2014, p. 101) explain involves “a willingness and capacity to imagine what does not exist, to think generatively, and to make unexpected connections”. This presents an opportunity to embed Indigenous knowledges and perspectives as it encourages students to seek to understand community needs and explore alternative ways of thinking to find the “best” solution.

Design courses are useful for exploring concepts such as ethics and sustainability (concepts key in embedding Indigenous perspectives) as they can be taught in a practical way and more likely to engage engineering students (Godfrey & Parker, 2010). Design courses are also a useful place to embed Indigenous perspectives as key courses in the curriculum and the place where an “engineering way of thinking” is formed (Godfrey & Parker, 2010). It presents an opportunity to develop skills in understanding the conditions, constraints and opportunities when engaging with Indigenous communities before attempting to offer solutions (Goldfinch & Kennedy, 2013). Providing students with rich and valuable learning experiences is critical. Afterall, “engineers are responsible for imagining what has never been and then doing whatever it takes to bring these visions to reality” (Goldberg & Somerville, 2014, p. 103).

Purpose

In Higher Education, authentic learning includes tasks that cognitively challenge students to solve problems and to emulate the critical thinking of professionals working in real-world contexts (Herrington, Reeves, & Oliver, 2014). This project aimed to support students, completing the Engineers Without Borders (EWB) challenge embedded in a first-year engineering design course, by increasing understanding of Indigenous perspectives within a design context. Students gain insight of how incorporating the social and cultural needs of a community contributes to better design outcomes and higher standards of professional practice, to develop stage 1 engineering competencies (Engineers Australia, 2011). This project will identify if supporting e-Portfolio, case study resources and critical reflection can assist students to develop greater awareness of Indigenous perspectives and to learn professional skills for working in a culturally diverse industry. These opportunities for students to develop a critical lens in engineering will also help break "the silence of the subjectivity of the dominant world view" in higher education (Matthews et al., 2016, p. 16).

Approach

Approach to embedding Indigenous perspectives

A tripartite approach, in which the three interactive dimensions of curriculum design, knowledge, values/attitudes and skills, are essential to facilitate development of students' cultural competency as future practising professionals (Universities Australia, 2011). The approach used to embed Indigenous perspectives is outlined in Table 1 and follows the key components outlined by Kennedy et al. (2016) including: 1) starting with a new philosophy, 2) exploring the design process through Engineering, Dominant, and Indigenous perspectives, 3) consider an Indigenous worldview, 4) engaging with Indigenous peoples and 5) tailoring the learning environment. This approach guided the redesign of activities to support the student's development of cultural competency while completing the EWB design challenge.

Table 1: Learning and Teaching strategies embedded into the course based on the Key components for embedding Indigenous Perspectives (Kennedy et al., 2016)

Key Component	Learning and Teaching Approach	Learning and Teaching Activity
1) Starting with a new philosophy	• Strengths based instead of deficit view (Goldfinch & Kennedy, 2013) • Indigenous peoples as the first engineers and included in the design process • Focus on designing with and not for communities	• Case studies to complement five selected EWB Challenge theme areas embedded into an e-Portfolio • These case studies explore: ○ historical and current examples ○ stories and experiences through linked content
2) Exploring the design process through the three different perspectives	• Presenting diverse perspectives throughout the course activities • Exploring Engineering ways of knowing, Dominant ways of knowing, and Indigenous ways of knowing (Leigh et al., 2014)	• Guest lecturers (Indigenous and Non-Indigenous) • Panel discussion with industry professionals/engineers who work/worked with Indigenous communities/organisations
3) Consider an Indigenous worldview	• Reflecting on and discussing an Indigenous worldview	• Studio discussions and debriefing • Personal reflections through e-Portfolio workbook
4) Engage with Indigenous peoples and their communities	• Engaging with Indigenous peoples through content and including Indigenous teaching staff	• Indigenous staff member on teaching team • Indigenous voices/perspectives privileged in case studies
5) Tailoring the learning environment	• Providing resources and support for students to explore at their own pace, allowing learning to evolve within the individual student/group • Creating a safe learning environment	• Case studies are designed for students to explore throughout the course at their own pace • Content can be updated adapting to students needs • Studio discussions and reflective activities

Project Selection

The EWB Design Challenge in 2020 is set in Cape York in partnership with the Centre for Appropriate Technology (CfAT) providing an opportunity for engagement with Indigenous perspectives. Five projects were selected from 24 possible EWB design challenges that best met the learning objectives of a large first-year engineering design course (>200 students) and provided the greatest opportunity for students to engage with Indigenous perspectives (Table 2). Changes were made to the course learning design and additional supporting material was developed to embed Indigenous perspectives more deeply in the course.

Development of e-Portfolio and supporting resources

e-Portfolios have successfully been used within this course to support the engineering design challenge. e-Portfolios are well-suited to the iterative nature of the design process, providing an informal talking point for checking-in with groups' design thinking and a repository for interactive design resources that can be 'live' updated (Michael et al., 2019). An e-Portfolio therefore was a good fit for integrating Indigenous perspectives into the design course by including a new tab of case study resources (Table 2) and reflection exercises. Indigenous voices were privileged through the case study content, during the studio discussion, lecture content and other aspects of the course. We led by example in being clear to students that we are not claiming the knowledge as our own but connecting students with Indigenous perspectives. The case studies (Table 2) offer examples of Indigenous engineering and design applications that prompt conversations of Indigenous culture, history, and perspectives, a similar approach discussed in Friesen and Herrmann (2018).

Table 2: Alignment of case study topics with the EWB Design Challenge areas

EWB Design Challenge Area	Case Study topic
Transport and access	Songlines and trade routes
Structures	Keeping Places
Energy (specifically refrigeration)	Fish traps (engineering food storage)
Water management	Cultural values of water
Conservation and land management	Firestick farming

Measuring cultural competency

To determine changes in students' cultural competency throughout the course, several measures outlined by Deardorff (2011) were used including direct evidence (e-Portfolio, Critical reflection, and Presentations) and indirect evidence. Students responded to questions, through the e-Portfolio mentioned above, where they provided evidenced examples of how their designs were user-centred and considered Indigenous perspectives. The e-Portfolio also included a "Reflections" tab with critical reflection questions at four key design touchpoints: end of week 1, the week 4 'client pitch' presentation, the week 10 'design review' presentation and the week 12 summative reflection. As part of the "Reflections" tab students were asked at the four touchpoints to self-report on a scale of 1-10 (where 10 is highly competent) their perceived Indigenous cultural competency and provide qualitative statements to support why they selected this rating. Students were encouraged to complete reflections throughout the teaching term, although only the final week 12 reflection was assessed. Students were not marked on the quality or content of their answers, rather on whether they had completed the task and provided evidence to qualify their responses. The students self-assessed cultural competency (SSA_CC) was analysed by week using ANOVA, followed by post-hoc Tukey multiple comparison of means with 95% family-wise confidence level using R. The relationship between SSA_CC and week over time was fit with a linear mixed effects model (LMM) using the lme4 package, lmer call in R (Bates et al., 2015) and box plots using the "stats" package (R Core team, 2018).

Outcomes

e-Portfolios and Critical Reflections

209 students accessed the e-Portfolio, 172 students accessed the case studies section and 209 accessed the reflections section. Most students only engaged with the case study related to their design project (e.g. students working on the Transport challenge accessed the Songlines Case Study), although some students (n=48) did explore more than one case study.

Table 3: Engagement with the case studies

Case Study Topic	Songlines	Keeping Places	Fish Traps	Value of Water	Firestick Farming
Students working on related project topic	35	25	33	47	60
Students who used the case study	66	34	36	52	52

Observed Cultural Competencies in Presentations

The teaching team observed changes in students understanding of Indigenous perspectives demonstrated through project pitch presentations and studio discussions. For example, 36 out of 40 student groups included an Acknowledgment of Country in their week 4 'client pitch' presentations. In the week 10 'design review' presentations all groups except two included this protocol, showing more groups chose to include an Acknowledgement of Country.

Self-Assessed Cultural Competency

Student self-assessed cultural competency (SSA_CC) increased over the twelve-week teaching term, with the standard deviation of those responses decreasing. The greatest increase in SSA_CC occurred between week 1 (5.3±2.03, n=148) and week 4 (6.6±1.83, n=104) when student teams were actively exploring their design briefs and the case study resources in preparation for their 'client pitch' presentation. SSA_CC then increased by a similar amount over the remainder of the course: to 7.7±1.3 (n=58) in week 10 and 7.8±1.32 (n=164) in week 12, representing the culminating 'design review' presentation and final design report respectively (Figure 1). Response rate was high particularly at the beginning and end of the teaching term: 71% (week 1), 50% (week 4), 28% (week 10) and 78% (week 12). Considering the change in SSA_CC response for each student that responded in both week 1 and week 12 the mean change in student response over the entire 12 weeks ∆SSA_CC was 2.5±1.32 (n=104) units. A simple one-way ANOVA identified that there were significant differences ($p<10^{-16}$) between SSA_CC responses over the teaching weeks. Multiple comparison of means (Table) showed that student responses in all weeks were highly significantly different ($p<0.001$, Tukey posthoc) except between week 10 and week 12 ($p>0.05$, Tukey posthoc). SSA_CC was best described by a second order polynomial model for "week".

Table 4 – Multiple comparisons of means for SSA_CC

Week a	Week b	Diff. (a-b)	Upper	Lower	p
1	4	1.3	0.8	1.9	<0.00000001
1	10	2.4	1.7	3.1	<0.00000001
1	12	2.4	1.9	2.9	<0.00000001
4	10	1.1	0.4	1.8	0.000614
4	12	1.1	0.6	1.7	0.0000009
10	12	0.05	-0.6	0.7	0.9975397

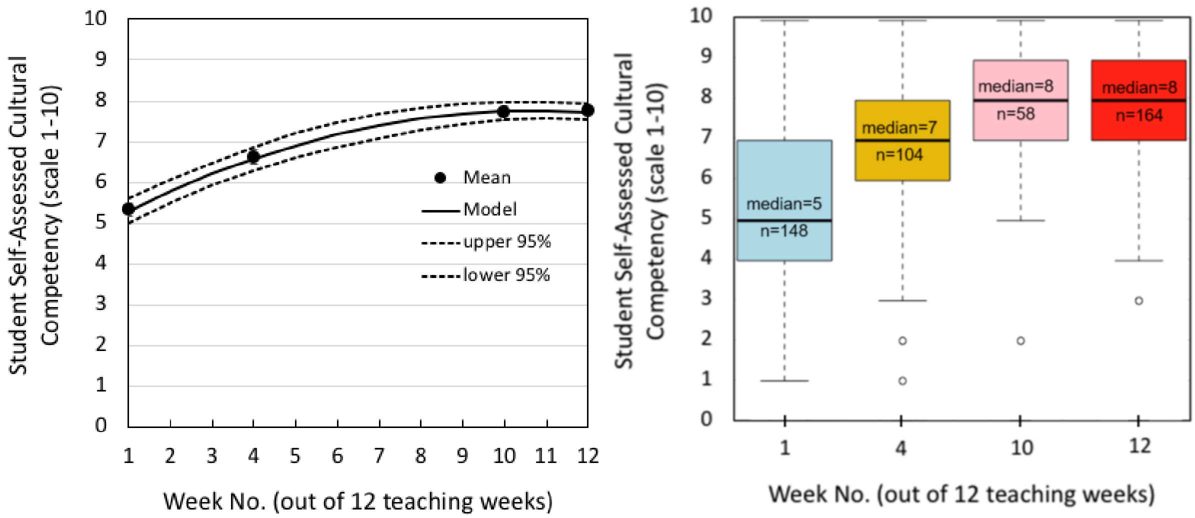

Figure 1 – Student Self-assessed cultural competency (SSA_CC) over 12-week teaching term (a) Linear regression model (solid line) flanked by 95% confidence intervals (dashed lines) and the mean (weeks 1,4,10 and 12) with standard error. (b) Box and whisker plot representing the median and spread of the data at the four milestone weeks.

Discussion

Godfrey and Parker (2010) suggest design courses are a good place to develop an “engineering way of thinking”. Design courses, especially core engineering units, are therefore a good place to start changing the culture within engineering to be more inclusive of diverse perspectives. This initiative aligns with Matthews et al. (2016) “at least” model which proposes an “embedding” course and a “shifting” course. This embedding course has been designed to enable students to explore how Indigenous people are positioned within their profession (Mathews et al., 2016). In this course, the case studies, the explicit teaching, the ongoing dialogue and feedback, the scaffolding, as well as the creation of a safe learning environment, are central to the curriculum design and teaching practices. Case studies and reflection touchpoints support students to develop key skills outlined by Universities Australia (2011) as key to developing cultural competency including “*knowledge and understanding of Indigenous Australian cultures, histories and contemporary realities and awareness of Indigenous protocols”* while also developing “*the ability to critically reflect on one’s own culture”.*

Engagement with the e-Portfolio was voluntary and not directly assessed but students were encouraged to self-explore the case studies. Most students accessed the e-Portfolio at some point during the teaching term and approximately 75% accessed the case study material. The case studies contain mixed media, links to resources and reflective prompts where students can enter text, so engagement is active and provoked by the resource. Goldfinch et al. (2017) state that many other approaches to embedding Indigenous perspectives focus on students learning how to better conduct community consultation. The approach in this course, using an e-Portfolio that combines a diversity of rich resources and reflective practice that supports their design process, encourages students to not just think of Indigenous communities as stakeholders but as an integral part of the whole design journey. This approach avoids the embedding of Indigenous perspectives being perceived as disconnected from what is perceived to be the “real” curriculum” (Friesen & Herrmann, 2018).

This was further enhanced by using an e-Portfolio which allows the content to be updated and edited ‘live’ during course delivery. This creates a responsive and adaptable method of delivery responding in real time to the students’ learning process, an important part of integrating Indigenous modes of learning (Kennedy et al., 2016). For example, during the course a new recorded interview with fire coordinators from the Cairns/Cape York region was added to the firestick farming case study to answer students’ questions asked during the studio discussions.

Several students commented in the week 12 reflections that the new resource impacted their design direction or strengthened their final design, for example: “The design did change over the teaching term, initially, the team was planning on creating a drone […] then changed to a weather box. The design was thought of after watching one of the conversations with the cool burning management team of Cape York when they mentioned weather data was lacking […] The inspiration that conceptualised this design was the mention of an extreme lack in environmental data of which would prove extremely useful for the weather forecasting team in Cape York”. The constantly evolving nature of the supporting materials also creates a collective learning experience where the students and the teaching team are both learners and co-creators (Prpic & Bell, 2018). The value in an adaptive method also allows students to explore the content at their own pace, taking ownership over their learning journey (Goldfinch et al., 2017). While most of the students only explored the case study related to the challenge selected, almost a quarter of the class chose to explore some of the other case studies as well.

Rather than being a tokenistic, “tick the box” type approach (Goldfinch & Kennedy, 2013), the students are taught to see Indigenous perspectives as an essential part of the process, rather than focusing on disparity, appreciating that engagement with Indigenous peoples adds value to engineering and vital for creating the “best” design for communities (Goldfinch et al., 2017). For example, one student said in the final reflection, “[the case studies] showed that there is more than one issue, and that there is more than one way to solve the issue, but the hardest part is figuring out what the best option is”. Another student reflected, “while initially I thought it was just about providing benefits for the user, I realize now that it also has to do with keeping in with the cultural needs and wants of the user, and making sure that they are both able to use it and want to use it”.

As part of the reflections, a survey question was used to measure self-assessed cultural competency. This was not based on any published scale or tool as a validated measure for measuring Indigenous cultural capability in engineering was not found in the published literature. Therefore the assessment of cultural competency is not objective, and the value in assessing cultural competency is in the relative differences perceived by students as they moved through the Engineers Without Borders (EWB) challenge. The results clearly demonstrated an increasing trend in student self-assessed cultural competency over the twelve-week teaching term. This was strongest in the first four weeks when students were exploring resources and their problem briefs in the divergent phase of the engineering design process, with these increases softening over the remaining 8 weeks when students were consolidating the technical aspects of their designs. Due to the high response rate from students particularly at the beginning and end of the teaching term which was >70% of the total student cohort, there is a high-degree of confidence in the results that students overall perceived a 2.5/10 unit increase in cultural competency over the teaching term accompanied by highly significant differences (positive trend) between teaching weeks 1, 4 and 12. While this does not objectively indicate a certain level of attainment of cultural competency, it perhaps indicates positive engagement in cultural perspectives as part of the engineering design process.

In addition to the reflections, students demonstrated their learning through direct evidence in the presentations. Although they were not asked to, many chose to include an acknowledgement of country, a practice that demonstrates students’ knowledge of protocol and respect for Indigenous peoples (Jones et al., 2018). Even more groups included this practice by the end of the course. These observed changes in students’ actions also demonstrate evidence of learning cultural competency during the course (Deardorff, 2011). Further exploration of this direct evidence in the presentations and e-Portfolio, as well as exploration of emerging themes from the reflections will be explored in future research.

Conversations about Indigenous perspectives and engineering design had also occurred between members of the teaching team for many years prior to the course changes discussed which created an atmosphere of safety and trust. Ad hoc conversations between the teaching team within the studio environment resulted in discussions about cultural aspects and how the students were responding to the added content. This allowed for continuous evaluation, reflection and learning within the teaching team (a mixture of Indigenous and non-Indigenous staff) in tandem to the students' learning. We hope this process of shared exploration and learning will continue to evolve over coming years as part of a relationship-based approach to course improvement (Michael, 2019). The case studies were developed by one Indigenous staff member with the aim will be to add more content to the case studies to fill gaps where resources are not available and connect with more Indigenous engineers and engineering projects. This will in time present a greater diversity of Indigenous perspectives as it is important to respect the differences across communities and recognise that there is no singular view or pan-Indigenous perspective (Friesen & Herrmann, 2018). This course, unfortunately, also did not have the opportunity for direct interpersonal interaction with the communities that students were designing for, at the request of the communities involved in the EWB challenge. In absence of direct engagement, this approach provided the opportunity for students to engage with case studies to develop an understanding of Indigenous perspectives and contributions to engineering while also developing self-awareness through reflexive practice (Prpic & Bell, 2018). Exploring an Indigenous perspective is a complex and sensitive process and efforts to embed Indigenous perspectives need to start from foundational knowledge and experience (Goldfinch et al., 2017). Therefore, this project presents an initial foundational step towards transforming engineering design courses.

Conclusions

Respect and understanding of how social and cultural factors influence the design process are essential graduate attributes for professional engineers. This paper outlines an authentic approach to embedding Indigenous perspectives into a foundational engineering design challenge course, as a first step towards transforming engineering curriculum to improve students' cultural competency and to be more inclusive of Indigenous perspectives.

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