School of Civil and
Environmental Engineering

Ethical Civil Infrastructure and Sustainable Environments:

Transforming our educational culture for ethical work within shared environments

UNSW SYDNEY

Motivation and Overview

In 2021, the School of Civil and Environmental Engineering at UNSW is setting out on a vision of championing "Ethical Civil Infrastructure and Sustainable Environments". We anticipate significant consideration of our educational experience and active engagement with our partners spanning industry, government and professional organisations. This document is a synthesis of our thinking on the vision with the aim of outlining specific initial steps to enable implementation.

The vision is timely. With the rising understanding of the impact of technology and infrastructure on human life, the ethical basis for professional Engineering decision-making is more critical than ever. Further, while ethical frameworks are always important, their criticality is even greater when issues involve ***sharing systems***[1] (e.g., environments and resources) which are central to the domains of public civil infrastructure and the natural environment.

We need to help define the future of our profession. Like other professions, Engineers should be engaged to inform policy-level decisions within their respective domains while adhering to robust ethical standards. It is acknowledged that societal perceptions currently differ by profession (e.g., see Table 1). To support continually improving deep ethical consideration, professional and educational institutions must actively shift cultural behaviour. Engineer's Australia (2019) has an explicit code which requires members to: Demonstrate integrity, Practise competently, Exercise leadership, and Promote sustainability[2]. Globally, the American Society of Civil Engineers (ASCE) has a code of ethics that spans considerations for society, natural/built environment, profession, clients/employers, and peers[3]. The UK's Institution of Civil Engineers (ICE) has a code of ethics and a Civil Engineering ethics toolkit that emphasize the public interest in addition to an Engineer's responsibility to decline unethical requests[4].

Given the recognised need by society as well as our representative professional organisations for an increasing mindset of ethical Engineering considerations, we have the following goals in this document with regard to university education:

i. To explore ethical implications regarding the specific domains of Civil Infrastructure and the Environment to deliver sustainability in shared environments
ii. To support a cultural shift within the relevant Engineering professions which emphasises a value on the ethical rather than solely technical consideration ***(we should not define our self-worth as engineers purely from technical mastery)***
iii. To begin to envision the necessary educational structures and processes which will help facilitate an increasing mindset of ethical decision-making

NUMBER OF GOOGLE RESULTS:	
6.3M	"Medical Ethics"
2.58M	"Legal Ethics"
813k	"Engineering Ethics"
WIKIPEDIA ARTICLE LENGTH:	
10,196 words	"Medical Ethics"
3,190 words	"Engineering Ethics"
MODERN FORMALISATION	
1803	First Medical Ethics textbook
1912	First formal Engineering Ethics Code

Table 1. A few comparative numbers

1 Chan J.K.H., Zhang Y. (2020) Sharing by Design. Springer Briefs in Applied Sciences and Technology. Springer, Cham. link.springer.com/book/10.1007%2F978-3-030-43569-1

2 engineersaustralia.org.au/sites/default/files/EA%20Code%20of%20Ethics%202019.pdf

3 asce.org/uploadedFiles/About_ASCE/Ethics/Content_Pieces/asce-coe-oct-2020.pdf

4 ice.saynotoolkit.net/

Ethical Decisions in the Sharing System of Civil & Environmental Engineering

The ethical aspects of practising Civil & Environmental Engineers (including all relevant sub-domains), are too numerous to catalogue fully here for our purpose. Further, it is asserted that ethical decision making is more akin to a way of thinking than a list of appropriate actions and prohibitions. Therefore, we will highlight examples to demonstrate the range and application of considerations which must be considered to enhance our reliance on developing our own ethical frameworks in practicing the profession of Civil and Environmental Engineering. At heart, our ethical obligation is to comprehensively consider necessary ***trade-offs*** which must be made in many important ***professional decisions*** which an Engineer must make. Further, due to trade-offs, we acknowledge that there may be no single correct answer (i.e., there may be multiple ethical options with even more non-ethical options). In fact, as is very well discussed in the philosophical literature, substantially differing viewpoints exists on the fundamental nature of what is ethical that will lead to very different decisions. Briefly[5]: (i) ***Consequentialism*** is highly outcome focused while assuming measurability with an emphasis on what we do versus why we do it (ii) ***Deontology*** focuses on a fulfillment of obligations rather than specific consequences. Numerous additional theories exist such as ***Teleology, Virtue, Contractualism and Existentialism***. Each well-established theory supports an ethical basis for decisions that can vary greatly. Therefore, rather than advocating a prescribed approach within this document, we assert that the most critical concept is this: a decision is reached consciously with explicit deliberation thereby ensuring that the numerous unethical options are avoided (i.e., ethics might not tell you exactly what to do, but it should tell you what not to do).

First, it is important to fully appreciate that ***professional decisions*** are not constrained to highly narrow formalised technical tasks (i.e., "Am I using the correct formulae and method in designing the bridge?"). Professional decisions (judgement) expand much more broadly to encompass questions such as noted in Table 2.

"Should I engage in this project (or take this job)?"
"Have environmental impacts that open my client up to future legislation been fully accounted for?"
"Have I fully vetted each supplier of materials?"
"Have I represented the true necessary effort required to complete the proposed task?"
"Am I accurately reporting the hours worked?"
"Do my values align with my client?"
"Have I retained a diverse team?"

Table 2. Example questions that transcend purely technical concerns

Ethical decision making goes beyond what is legal, acceptable or common. Something may well be legal but still be unethical depending on a particular viewpoint (for example the interaction of aquifers and agriculture, etc). An ethical ***professional decision*** is not merely based on what is allowed and/or technically valid, but also what is judged to be right and fair. The modern problems of humanity that call for engineering solutions are increasingly complex and multifaceted involving conflicting demands. Hence, there needs to be ***trade-offs*** in the decision-making process.

Examples of conflicting demands includes: the conflict between alleviation of poverty through development versus the harm caused to the environment as a result of that development; the conflict between the short-term and long-term gains/ losses; the conflict between the needs of current generation versus that of the future generation, or the needs of individuals versus those of the organisation, broader community or economy. Ethical decision-making calls for careful consideration of all options, weighing up expected gains, losses and risks, and

5 Beard, M. and Longstaff, S. (2018) Ethical by Design: Principles for Good Technology. ethics.org.au/ethical-by-design/

then holistic thinking about what brings best overall value within defensible constraints: a decision that in hindsight is most likely to be considered right and fair.

Domain specialisation becomes critical because the process of appropriately considering trade-offs necessitates quantification and nuance particularly since many trade-offs have interacting impacts as well as unintended consequences. To begin considering domain considerations within the still broad specialisation of general Engineering we can rely on the definition of The Institution of Engineers, Australia[6]: "Engineering is a creative activity of synthesising and implementing the knowledge and experience of humanity, to enhance the welfare, health and safety of all members of the community, with due regard to the environment in which they live and to the sustainability of the resources employed." At the more specialised level, ***Civil and Environmental Engineering***, specifically, often involves the expenditure of resources via an infrastructure solution towards a societal aim within an environmental context. The expenditure generally consists of resources (e.g., time, labour, natural) both on a systematic level as well as personal investment and numerous impacts (e.g., environmental, health, equitable access).

As noted, civil infrastructure and the natural environment represent systems that are characterised by an inherent component which requires the sharing of space and resources. One relevant view is that the ethics of ***Sharing Systems*** can benefit from three core concepts to be well understood by those who design and practice within the system[7]: (i) ***virtues*** – traits/dispositions that relate to fundamentals of right/wrong but do not relate to specific rules (ii) ***principles*** – duties, obligations and requirements (not necessarily rules but can lead to specific rules) and (iii) ***ethical expertise*** – while potentially debated, this relates to the skill of discerning the proper course of action. Defining an ideal set of virtues and principles is not an aim of this paper. But, the broad concept of how we view and impart skills that can lead to an increase in ***ethical expertise*** (or a domain-specialised version thereof) is of keen interest. ***Specifically, we want to advocate that skills related to reflecting and communicating on ethical considerations while utilising domain-specific technical skills is vitally important.*** Such a view requires that we move past an emphasis on purely domain-central technical skills alone.

6 The Institution of Engineers, Australia. (2000) Code of Ethics

7 Chan J.K.H., Zhang Y. (2020) Sharing Ethics. In: Sharing by Design. Springer Briefs in Applied Sciences and Technology. Springer, Cham. doi.org/10.1007/978-3-030-43569-1_5

Transcending Technical Mastery[8]

In engineering practice, we commonly face considerations and dilemmas on aspects such as: the individual's standard of care vs what is expected of the individual by their employer or the client; the trade-off between economy, speed and quality in projects; personal/family obligations vs obligation to the employer and the client; difficult decisions about working on projects that are not aligned with personal or societal values (eg. projects in the gambling industry, tobacco industry, fossil fuel industry, etc; the industries that conduct legal businesses and have engineering needs that need to be met by competent engineers).

Recent problems arising in the building and construction industry are evoking regulatory responses from various governments in Australia. Legislative responses are commonly introduced when ethical practices have eroded or failed. Some are asking if we would have had building quality issues if engineering ethics were upheld at every link in the supply chain? However, it is also critical to ensure that engineers have a scope that appropriately aligns to their ethical duty. ***Market fragmentation,*** in search of productivity, can be a complication for ethical assurances. Ultimately, when ethics must be relied upon for any market to function appropriately, an accredited professional should have a duty and scope which are in alignment to consider the many competing trade-offs that may exist.

"Technical mastery divorced from ethical restraint is at the root of all tyranny"

– The Ethics Centre

Moreover, while considering trade-offs within the context of professional decisions, the Engineer should be consistently cognizant of ***diverse groups*** that must be considered. Each group may have distinct as well as overlapping concerns that will relate to the decision. One general set of high-level groups that an Engineer should have in mind (Society, Client, Employer and Self) is noted below with two examples of the sort of considerations relevant to each group is noted below:

Society	Client	Employer	Self
Impact	Informed Consent	Economic	Health/Care
Justice, equity	Liability	Liability	Reputation

Trade-offs will appear between groups and considerations. Appropriately deciding each trade-off is complex and cannot fully be prescribed. In fact, if the outcome could be fully prescribed and scripted, one could argue that society would have no need of professional Engineers! *Therefore, the goal of an Engineering education is not to teach the script of trade-off decisions nor is it simply to teach technical knowledge. Rather, the most significant portion of an Engineer's responsibility is the act of making technically informed conscious decisions that deliberately and comprehensively consider the trade-offs of resources and impacts across diverse stakeholder groups.* To emphasise, an Engineer who intentionally neglects or turns a blind eye to an impact is one who is failing their professional obligation.

Further, being unaware of an impact that should have been known is not a strong justification for failure. Engineers often work in consideration of extreme conditions so must be equipped to deal with events beyond the realm of historical experiences. Further, being unaware of an impact could be akin to possessing an insufficient education to be practising as an Engineer. It is true that the domain-knowledge of Engineers is growing year to year and if an impact has not been historically commonly known then it is understandable if it had not been incorporated onto trade-off decisions. However, this stresses the importance of life-long education for all practising Engineers with a focus on the development of judgement as opposed to precise technical recipes that focus on straightforward calculable answers.

8 Beard, M. and Longstaff, S. (2018) Ethical by Design: Principles for Good Technology. ethics.org.au/ethical-by-design/

Education

There are three critical engineering educational goals related to ethics:

- **Skills/Expertise** – the underlying intellectual basis for discerning between what is ethical and what is not. It is important to note that the relevant expertise significantly transcends codes of conduct or any prescriptive formulaic approach.
- **Practice** – Practical know-how in terms of ethical solutions that can be utilised in an engineer's daily professional activity.
- **Mindset** – Having an individual and group culture that encourages a constant attention towards doing what is ethical.

First, it is critical to explicitly note that ***ethical expertise*** should be viewed as a technical subject with related skills and knowledge of a depth at least on par with other fundamental domains. As noted in Table 2, there are more papers with a title containing ethics (4.66M) than artificial intelligence (3.26M) and nearly as many papers as those containing the keyword mathematics (5.06M). Given the broad complexities of technological and infrastructure impact on society, engineering educational experiences must embrace the technical depth of ethics in a broader more systematic manner.

Given the broad knowledge of the ethics literature, educational experiences must be re-evaluated to integrate the most critical lessons. Practising and future engineers will be influenced by both their formal and informal exposure to ethical thinking throughout their education, training, and practise. Universities have a responsibility to shape the Engineering profession by fostering an ethical culture throughout an Engineer's academic training, that can then follow through their progression in the profession.

Many universities promote ethical training through formal academic teaching (e.g. direct inclusion in class curricula). It is clear that the use of different approaches in the classroom (including case studies, role-playing exercises, quizzes, scenarios) throughout a student's academic career will promote student engagement with ethical considerations. The presentation of these concepts alongside technical teaching will also nurture a student's interpretation and appreciation for ethical reasoning and behaviour.

Google Scholar Papers by Keyword:
5.06M: Mathematics
4.66M: Ethics
3.26M: Artificial Intelligence

Table 3 – Paper Number Comparison by Domains

However, Engineering students are influenced by both their academic and social experiences during higher education. The focus on formal instruction may miss opportunities to increase students' understanding of the social implications of engineering via their engagement in broader extracurricular programs (internships, student societies, or formalised mentoring) or informal engagements (including interactions with peers or faculty/staff in and outside the classroom).

There have been formal examinations of the impact of educational curriculum on ethical appreciation by students. While ethics is increasingly present within engineering programs, one assessment of 4,000 students concluded "We suggest that institutions integrate ethics instruction throughout the formal curriculum, support use of varied approaches that foster high-quality experiences, and leverage both influences of co-curricular experiences and students' desires to engage in positive ethical behaviours."[9]

Ultimately, we assert that future engineers will need to navigate complex ethical landscapes, utilise deep empathy for diverse groups, reflect on ambiguous problems which will not necessarily have a single correct solution, listen carefully and be capable of communicating respectfully with those whom they may not agree. This requires new approaches to incorporating the treatment of ethical considerations into curricula both in method but also as a matter of frequency across numerous courses. At the highest level, the educational innovations should support a cultural change that (i) begins to highly value ethical expertise rather than solely technical expertise and (iii) shift from finding the one correct answer to emphasising a skillset that enables conversations about a range of ethical answers.

9 C.J. Finelli, M.A. Holsapple, E. Ra, R.M. Bielby, B.A. Burt, D.D. Carpenter, T.S. Harding, and J.A. Sutkus (2012) "An Assessment of Engineering Students' Curricular and Co-Curricular Experiences and Their Ethical Development" The Research Journal for Engineering Education, Vol 101, Issue 3 doi.org/10.1002/j.2168-9830.2012.tb00058.x

A Note on Incomplete Solutions

It may be useful to note some examples of well-intended, even valuable, solutions which will not be sufficient to remedy the situation:

- Solutions which focus solely on creating a culture of ethical practice (such as codes of conduct) are highly valuable but not sufficient because Engineers must develop deep ethical skills to solve novel problems which may have never been encountered previously. Ideally, we must teach them how to think, not what to think.
- Simply requiring engineers to take ethics courses would be valuable but not sufficient because, like mathematics, ethics must be placed within the specific questions being faced by an engineer given the highly specialised technical knowledge of domain-based engineers.

As a result, a diverse range of coordinated solutions is needed both within the classroom as well as the broader educational experience. These solutions must equip engineers with new (i) fundamental knowledge related to ethical expertise, (ii) practical guidance on how to apply knowledge within an engineer's highly specialised domain, and (iii) efforts to create a culture that requires constant mindfulness on behaving ethically.

Summary and Next Steps

No specific value system has been prescribed. Rather, it is asserted that we must develop new educational experiences that impart fundamental ethical expertise, impart practical domain-oriented guidance and ensure a culture of mindfulness.

Further, the practices of civil and environmental engineering are intrinsically linked to a ***sharing system*** which must be explicitly acknowledged in all of our decisions. Then, our practice must be made with significant deliberation where all viewpoints are carefully considered and our professional judgement requires a readiness to provide an intellectually consistent narrative to justify all decisions. The individual engineer (or firm or agency) can employ a vast array of ethical frameworks to provide their respective intellectual narrative but the rigor of the narrative justification is paramount. Most critically, the deliberation must be conducted at the onset where it can influence decisions not after the fact to simply provide excuses.

A key component of achieving the desired educational and professional outcome is an ongoing cultural shift which requires everyone's participation. The first steps towards achieving the aforementioned cultural shift relate to:

1. **Increase Frequency** – As noted in table 1, there is a societally perceived distinction between the time given to ethical concerns by professional sectors. By simply discussing ethical concepts (and asking if something is ethical or to provide an ethical approach) more frequently, cultural shift and societal perception of our activity is encouraged.

2. **Acknowledge Ethical Expertise** – There should be the explicit acknowledgement of the topic of ethical expertise as a required body of knowledge to be approached similarly to other fundamental subjects such as mathematics given the depth of work in the ethical research literature as noted in table 2.

3. **Make Space for Deliberation** – Ensuring that time is provided for deep reflection and deliberation is vital. As noted, ethical decision-making is not characterised by following a recipe or a single formulaic approach. The most central concept is that deliberate conscious choices are made while nuance is deeply explored. Rather than dictating the "right way", always stress that we deliberate in an attempt to achieve intellectually consistent decisions.

4. **Expand on Detailed Examples** – With an increased frequency and greater time for deliberation, continually developing additional case study examples become important which can diversify the range of potential aspects that an engineer can consider. Ideally, case studies should highlight that, generally, no single solution is clear but multiple complex solutions must be explored.

5. **Be Open about Trade-offs** – Win-win outcomes are ideal. But, we should be direct that trade-offs exist and we should manage them explicitly with care and fairness.

6. **Acknowledge the Sharing System** – Infrastructure and the Environment are both characterised by the inescapable reality of being *sharing systems*. This gives additional nuance to the ethical consideration that come into play.

7. **Continually Grow Understanding** – The practicalities of engineering must meet external time constraints to deliver needed outcomes. However, we must ensure that society progresses in positive directions over time (i.e., each project should be better). Therefore, over the life of an engineer and organisation, we must continually expand our understanding of the sharing system and the potential impacts of our work.

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