



Thinking Critically and Conscientiously with Design

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ABSTRACT

BACKGROUND & CONTEXT

Both engineering and education practices are influenced by technological advances. However, while engineering is commonly defined as the driver of innovation, education practices are commonly rooted in tradition and stability. This dichotomy is increasingly challenged by the rapid pace of technological change such as AI-driven platforms and virtual labs. These advances introduce changes in practice, compelling educators to re-design curriculum and learning experiences.

PURPOSE OR GOAL

The conscientious design framework had been found to be effective in guiding engineering design education. The purpose of this paper is to illustrate the applications of the reasoning framework to curriculum design.

APPROACH OR METHODOLOGY

This conceptual paper argues that a conscientious framework designed for engineering can help guide curriculum design. The conscientious design framework emphasizes reasoning fluency and agency through the intentional negotiation of design risks and benefits. In this framework four reasoning quadrants are connected and engaged through the core practice of conscientious negotiation. Additionally, there are two catalysis of reasoning fluency: multicultural ingenuity and ethical integrity.

OUTCOMES

The paper presents the conscientious engineering design approach and strategies to facilitate and elicit reasoning for conscientious design of engineering curriculum.

CURRICULUM

The reasoning necessary for conscientious engineering design can help navigate curriculum reform efforts that are necessary when incorporating AI tools to be effectively used in the classroom.

KEYWORDS

Conscientious reasoning; AI; decision-making.

The Intersection of Engineering and Education

As engineering educators, we regularly engage with two types of design activities: engineering design and curriculum design. In engineering design, design requirements along with criteria and constraint are essential to meet while in curriculum design our efforts are assessed against program outcomes and learning objectives. In both cases, design takes place in the context of diverse stakeholders and those who are effectiveness directly and indirectly. One key distinction is that in education humans guide humans with the support of technological tools, while in engineering, technology plays a more prominent, though dynamic role.

The technological advances influence both engineering and curriculum design practices in unexpected ways, although engineering is often associated with innovation education is often associated with tradition. For example, the education communities have reacted to the emergence of Large Language Models as mainstream tools with a reaction to ban them for their inappropriate use of AI and lost opportunities if AI were used in beneficial ways. However, engineering communities had long been integrating them into products in various forms such as image recognition and computer vision. And the time-and-time used pedagogies are no longer effective with the mainstream use of large language models and plethora of emerging AI tools, where students can easily find answers to homework problems, run AI to analyse data, and create personalized study guides. How might we approach this paradox if we approached the challenge with a conscientious design perspective (See Figure 1)?

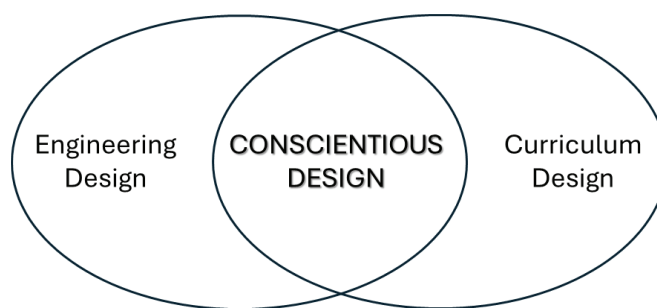


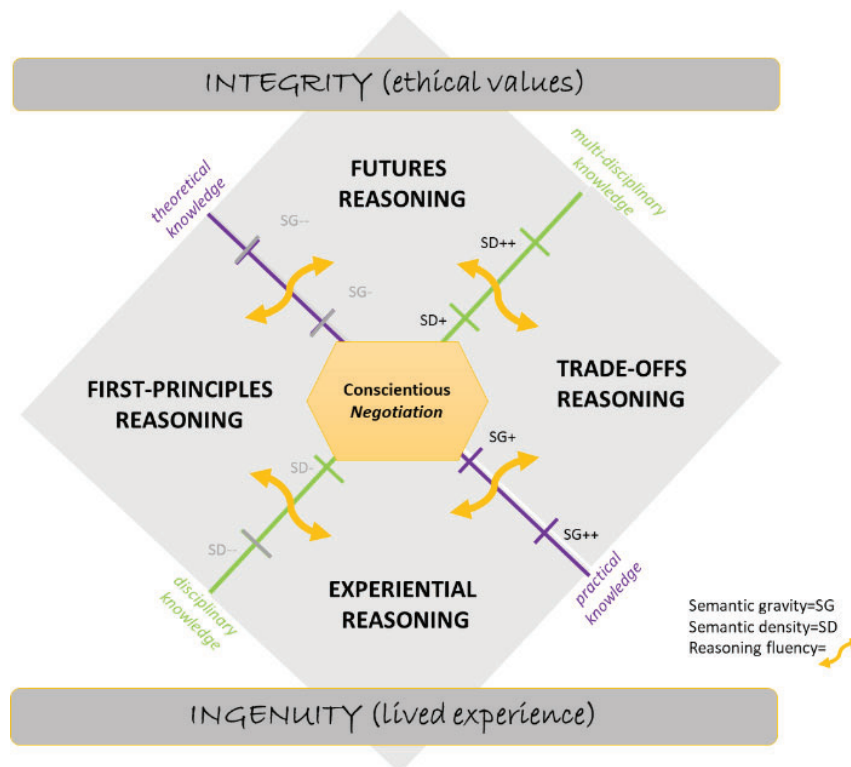
Figure 1: The intersection

Engineering educators have outlined ways to position AI in education (Schleiss, Johri, & Stober, 2024). These approaches range from cautious integration to disruptive transformation but all with a focus on pedagogy. AI literacy has also been defined as a standalone concept (e.g., OECD, 2025). Some of these conceptualizations are closely aligned with other competencies such as computational literacy, information literacy, and data literacy (Mills et al, 2024) while highlighting human decision-making (Pomerol, 1997). Given these developments, engineering educators can create AI-specific policies specific to engineering. However, this conceptual paper takes an alternative approach with the aim to explore how existing reasoning frameworks can guide engineering education, especially during this transformative period influenced by AI.

According to Dede et al, (2021, p.1), “AI is becoming increasingly proficient at calculation, computation, and prediction (“reckoning”) skills. As such, we will see increased demand for human judgment skills such as decision-making under conditions of uncertainty, deliberation, ethics, and practical knowing.” As engineers and engineering educators, this has always been the situation we work in. Given that we need to re-imagine engineering education, can the key principles of conscientious design reasoning be used as an overarching framework to inform our curriculum decisions?

Engineering education with a focus on conscientious and critical reasoning can promote a diverse range of outcomes such as technical acumen, conscientious decision-making, sustainable and ethical design, and purposeful utilization of students' cultural assets.

As illustrated in Figure 2, four reasoning quadrants are facilitated through negotiation, more specifically a conscientious negotiation of design risk and benefits. The reasoning quadrants rest on two knowledge axes. One represents the practical-theoretical knowledge axis, called semantic gravity. The other represents the axis for disciplinary depth and multidisciplinary breath, called semantic density. Both social negotiation (communicative practice) and internal negotiation (reflective practice) are essential for conscientious decision-making.



The four quadrants of conscientious design reasoning can help guide instructors when designing courses and support students as they reason fluently while solving problems. To achieve successful curriculum design, we need reasoning beyond the application of data but effectively integrate lived experiences, qualitative understanding, weigh trade-offs including values and carefully examine moral dilemmas (Purzer & Arigye, 2024). It is important that reasoning fluency is practiced across four quadrants of reasoning: experiential, first-principles, trade-offs, and futures reasoning. Table 1 provides definitions as well as examples of ways such reasoning can be elicited, whether the design objective is curriculum, or a design objects.

Table 1: Conscientious Engineering Reasoning Quadrants

Reasoning Quadrant	Description	Engineering Design Reasoning	Curriculum Design Reasoning
Experiential Reasoning (EX)	Reasoning informed by past lived experiences and through experiments and experiential learning	What are the everyday experiences of people impacted by [this problem]? Use analogies or stories that provide human connection to the problem.	What are the prior experiences of learners? What experiences can be created to facilitate learning?
First-Principles Reasoning (FP)	Reasoning from disciplinary principles, technical core concepts, and abstracted knowledge	Breakdown the key scientific principles that make [this solution] work. Describe the fundamental scientific principles. Provide a summary of relevant equations.	What are core disciplinary concepts in this course? Which motivation and learning theories could be consulted?
Trade-offs Reasoning (TO)	Reasoning from weighing competing requirements including values and the conscientious negotiation of risks and benefits	List the main trade-offs involved in [this problem]. Provide a list of decisions based on weighing of these trade-offs.	What resources are available? What are my constraints (time, large class size, etc.)
Futures Reasoning (FU)	Reasoning into novel contexts and future situations through the examination of intended and unintended consequences of today's decisions	What are the preferred, probable, and unintended outcomes that may emerge when we implement this solution in location X? Provide potential blind spots.	What is the vision for student learning at the end of this course? What do hope students will remember 5 years from today? What are unintended applications of this content in different contexts?

Conclusions

As engineering educators, we routinely navigate two distinct yet interconnected domains of design: the creation of engineering solutions and the structuring of educational experiences. It is essential that the designers maintain their agency and decision-making responsibility, and a guiding tool is helpful to achieve this. In other words, if we promote the important of conscientious negotiation in the practice of engineering, we have the opportunity to effectively create curriculum that is up-to-date, student-centred, and designed to most effectively use or teach new technologies.

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