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Integrating Design Futuring into Engineering Education

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Abstract

As transformations across societal, technological, and environmental systems continue to accelerate, engineers must be prepared to anticipate, analyze, and respond to uncertain futures. Design futuring, a practice that integrates methods from futures studies and design, offers a valuable framework for developing these critical competencies. This paper explores strategies for embedding design futuring into engineering education, emphasizing its potential to engage students in envisioning alternative futures while fostering critical reflection, ethical awareness, and systems-level thinking.

The paper adopts a hybrid methodology that combines a review of relevant literature with reflective analysis based on extensive experience teaching design thinking and product development to engineering students, as well as facilitating futuring activities in community-based workshops and participatory design events. Key recommendations include leveraging makerspaces as sites for exploratory learning, incorporating futuring tools into instructional practices, cultivating institutional support through communities of practice, and building interdisciplinary partnerships.

To evaluate the effectiveness of these approaches, the paper proposes preliminary assessment strategies including pre- and post-course surveys, guided reflection, and analysis of student-created artifacts to capture shifts in identity, creativity, and anticipatory competence. These strategies collectively aim to promote a forward-looking culture within engineering education.

By advancing discussion on pedagogical methods, institutional conditions, and evaluation frameworks, this paper contributes to an emerging discourse on the role of futures literacy in preparing engineers to shape more inclusive, just, and resilient futures.

Introduction

Since early descriptive accounts of how expert designers navigate uncertainty and address complex, ill-defined problems [1, 2, 3, 4], design thinking has emerged as a valuable problem-solving paradigm with growing relevance to engineering education. Its early adoption coincided with increasing concerns about the limitations of traditional engineering curricula, which have been criticized for being overly conservative, outdated, and narrowly focused on present-day problems and constraints [5, 6, 7]. In response, design thinking introduced more innovative pedagogical methods that promote creativity, iterative development, and human-centered problem solving.

Over the past two decades, design thinking has been widely integrated into first-year engineering design courses, product design curricula, and senior capstone projects [8]. A 2023 systematic review by Deng and Liu [8] highlights how the integration of design thinking in higher education fosters interdisciplinary collaboration, engages students in real-world challenges, and cultivates empathy and user-centered mindsets.

Despite this widespread adoption, however, questions remain regarding the development of future-oriented competencies within these pedagogical models. A recent systematic review by Brosens et al. [9], *How Future-Proof Is Design Education?*, analyzed 95 studies and found that many design education programs still lack clear 21st-century learning objectives—particularly those that cultivate transferable skills, systems thinking, and anticipatory capacity. While design thinking has introduced important innovations, much of its current use remains focused on solving present-day problems, often framed as latent needs or existing constraints. This focus can limit students' ability to imagine alternative futures, anticipate disruption, and contribute proactively to long-term societal transformation.

This paper addresses these gaps by exploring strategies for integrating futuring practices into engineering education. Futuring, understood as a set of methodologies that support critical reflection on possible, probable, and preferred futures, offers a distinct yet complementary approach to design thinking. Drawing on existing literature and reflective insights from implementing experimental instructional approaches in teaching design thinking and futuring exercises, this paper proposes a series of teaching modules aimed at embedding anticipatory thinking into engineering curricula. These modules are designed to function either as stand-alone activities or as entry points for sustained engagement with future-oriented design practices.

The research questions guiding this study are:

- What are the key methodologies of futuring, and how do they complement or enhance existing approaches like design thinking in engineering education?
- What specific pedagogical tools can effectively be used to integrate futuring into engineering education?

The Study of Futures

Future-focused education, a term often found in educational policy, centers on preparing students with adaptable, future-ready skills to tackle complex societal challenges. In engineering education, this means helping students navigate and shape a rapidly changing world by integrating emerging technologies, fostering interdisciplinary learning, and emphasizing real-world problem solving [10].

A key component of future-focused education is futures literacy, defined as the capacity to imagine, critically reflect on, and use the future to inform present-day decisions. This conceptual framework, advanced by UNESCO, is recognized as a vital 21st-century competency [11, 12]. Rather than treating the future as a fixed destination to be predicted, futures literacy encourages viewing it as a space of possibility. It invites exploration and reflection on how assumptions about the future influence present choices. Integrating this mindset in engineering education bridges the gap between technical expertise and societal needs, preparing graduates to contribute meaningfully to a dynamic and interconnected world [10].

Closely related, futures studies as an academic field moves beyond conventional planning tools like forecasting and risk assessment. It embraces uncertainty and explores multiple plausible futures to spark imagination and address complex challenges [13, 14]. As James Dator famously stated, "The future cannot be predicted because the future does not exist" [15].

In engineering education, the use of futures literacy has primarily focused on planning and risk management. While these approaches are valuable, they tend to constrain the broader, exploratory potential of futures thinking. Relying on past data and predictive accuracy can overlook transformative shifts and obscure less probable yet desirable outcomes [16]. This narrowing of possibilities may hinder strategic decision-making by limiting innovative pathways. In contrast, adopting non-predictive, imaginative approaches encourages value-driven exploration and embraces uncertainty as a source of creativity.

In educational settings, futures studies offer a range of methods that engage individuals in the disciplined use of imagination to address complex, wicked problems that resist simple solutions. Among its diverse qualitative and quantitative approaches, several are particularly relevant to design practice [17]. Horizon scanning, for instance, involves identifying emerging trends and signals of change by systematically reviewing both broad external sources and domain-specific information. Backcasting begins with a vision of a desirable future and works backward to explore the steps necessary to reach that future, encouraging long-term thinking. Scenarios, another central method, use narrative constructs to imagine different futures. Rather than functioning as concrete plans, scenarios serve as tools for critical discussion, allowing diverse perspectives to surface and promoting strategic thinking without the pressure of immediate decision-making.

Unlike probabilistic approaches like risk assessment and statistical modeling, which focus on predicting likely outcomes based on known variables, futuring methods prioritize possibility, uncertainty, and values. They create space for imaginative exploration, helping individuals navigate complexity by combining creative thinking with real-world context. By doing so, futures studies promote holistic, integrative thinking that connects emerging ideas to broader societal change.

While these methods are centered on imagining what could or should happen, they have practical implications for the present. As our visions of the future shape our current actions, they in turn influence the future that materializes [18]. This dynamic relationship underscores the power of proactive imagination in reorienting our strategies and decisions toward preferred futures.

Integrating Science Fiction into Engineering Education

Science fiction has demonstrated significant potential as a tool for illustrating complex concepts, fostering interdisciplinary dialogue, and preparing students to address emerging technological challenges. Early calls to leverage science fiction in this context date back to Segall [19], who emphasized its value in enhancing engineering education and attracting students to the field. By incorporating science fiction films and literature into his teaching, Segall sought to illustrate fundamental engineering principles and help students navigate abstract concepts in physics and mechanics. He argued that science fiction could create "lasting mental images" tied to underlying theories, thereby making abstract material more accessible and engaging.

The use of science fiction in engineering education has predominantly focused on ethical and societal considerations. Berne [20], for instance, highlighted the pedagogical value of using the film *The Matrix* to introduce complex ideas in engineering ethics. Through this approach, students were encouraged to engage in constructive thinking, writing, and discussion about challenging ethical dilemmas. Similarly, Summet and Bates [21] demonstrated how short science fiction stories, combined with structured assignments, could effectively engage students in ethical reasoning and critical analysis, rendering abstract ethical challenges more tangible and relatable.

A key theme in the literature is the potential of science fiction to encourage interdisciplinary exploration and critical thinking about technology's broader implications. VanderLeest [22] described science fiction as a "mental laboratory" where students can explore the societal impacts of technology and engage in thought experiments. His courses utilized a variety of media, including novels, short stories, and films, to provide opportunities for students to examine ethical dilemmas, understand cultural contexts, and explore imaginative possibilities. This approach also fostered collaboration between engineering students and peers from non-technical disciplines, broadening their perspectives on engineering challenges. Additionally, Bates [23] and Sleezer and Bates [24] explored the use of science fiction in reflective assignments. These assignments enabled students to connect ethical frameworks to real-world engineering projects, explore societal impacts, and engage with creativity in problem-solving.

Although there is growing interest in the pedagogical potential of science fiction, its use in engineering education remains limited. One reason may be that existing efforts often feel disconnected from the core of engineering practice. Many approaches draw on methods from the humanities, such as analyzing films or short stories to spark discussion, but they often fail to connect these explorations to the hands-on, design-oriented activities that better engage engineering students. Aligning science fiction with practical, project-based work could better embed it into the engineering curriculum and make its value more apparent.

Future-Oriented Approached in Human-Computer Interaction

Human–Computer Interaction (HCI) is a multidisciplinary field focused on the design, evaluation, and implementation of interactive computing systems aimed at enhancing human activities and experiences. While user-centered design has been the dominant paradigm, emerging theories increasingly challenge the centrality of the individual user, shifting the focus toward broader, interconnected systems. Advances in technologies such as the Internet of Things, artificial intelligence, and big data have further redefined interaction, extending it to include complex systems, environments, and multifaceted exchanges between humans, objects, and intelligent systems. These developments have prompted the incorporation of novel methods and epistemological frameworks into HCI, broadening the field's scope and deepening its engagement with the complexities of socio-technical systems.

Since the early 2000s, HCI has integrated an expanding array of design approaches that intentionally orient toward the future. These include speculative design [25], design fiction [26], experiential futures [27], critical design [28], material speculation [29], discursive design [30], and speculative enactments [31]. Unlike conventional design artifacts that prioritize immediate functionality, these approaches serve as tools for reflection on the ethical, social, and cultural implications of emerging technologies. As Dunne and Raby emphasize, "The idea is not to show how things will be but to open up a space for discussion" [25].

While these methodologies share a forward-looking perspective, each employs unique strategies to engage audiences. Speculative design seeks to provoke reflection through evocative and open-ended material expressions, encouraging consideration of emerging and uncertain worlds. Design fiction, one the other hand, employs materiality strategically to create believable and relatable representations, situating the viewer in prospective futures and fostering engagement through familiar narratives [26, 32]. More recently, experiential futures have focused on offering embodied experiences through diverse media, deepening engagement and stimulating discussion by making alternative futures tangible and immersive [27]. Such approaches play a crucial role in assessing the plausibility of speculative narratives while fostering critical thought about the implications of future technologies.

Efforts to define and unify the methods and frameworks that explore alternative futures under a single term have led to various interpretations. Zhu et. al. [33], in a literature review of 53 artifacts serving as tangible representations of alternative futures, collectively refers to these as *speculative artifacts*, emphasizing their role in fostering reflection on emerging and uncertain technological landscapes. In an earlier effort, Kozubaev et. al. [34] introduces the term *design futuring* to describe these practices. In a broader context, the term *design futures* has been used to encompass designerly approaches that articulate alternative possibilities through material artifacts [35]. However, within the ASEE community, discussions surrounding these methods remain relatively underdeveloped and distinct from traditional future-oriented engineering education. To address this gap and maintain conceptual clarity, this paper adopts the term *design futuring*, specifically referring to the use of design practices to explore and express alternative futures.

Examples of Design Futuring in HCI

A recent review of futuring artifacts in HCI highlights how these artifacts leverage familiar, tangible elements to embed future contexts into everyday life, enhancing their relevance. They critically examine potential technological futures, challenge existing assumptions, and reimagine the societal role of technology [33]. The following three examples of design futuring artifacts illustrate how material properties can be used to immerse participants in alternative futures, prompting thoughtful reflection on the dynamic relationship between technology, individuals, and society.

According to Dunne & Raby, *Designs for an Overpopulated Planet* [36] envisions a speculative future in which overpopulation forces marginalized communities to adapt by using prosthetic devices to extract nutrients from otherwise indigestible food sources. The project explores a world where individuals take control of their evolution to confront food scarcity. At the Museum of Modern Art (MoMA), the project was displayed through meticulously crafted artifacts, along with props, photos, and accompanying text, to create a fictional narrative. This setup invites audiences to imagine different interpretations and engage in reflection on the societal and ethical implications of such a future.

Figure 1: Designs for an Overpopulated Planet. Source: [36]

The *Open Forest Project* [37] challenges traditional views of forests as merely resources for human exploitation by highlighting their dynamic role within ecological systems. Presented at the CreaTures 2022 Festival in Seville, the project combines research infrastructure and sensors to collect data on forest-atmosphere interactions, including growth rates, wind speed, and aerosol exchange. This data serves as a foundation to explore how both humans and nonhumans perceive forests, sparking playful yet meaningful discussions. Running across four countries from 2020 to 2022, the project culminated in an interactive catalogue that brings together stories, data, and insights, reframing the forest's role from a resource for human benefit to a protective force against ecological disasters. The project highlights the continuous transformation of ideas and processes, rejecting simplistic dichotomies between old and new perspectives.

Figure 2: The Open Forest Project. Source: [37]

Cyano Automaton [38] is a critical project featuring an interactive bioreactor that cultivates Spirulina, a photosynthetic bacterium traditionally consumed in South America and tested by NASA as a potential food source for astronauts. Artist Agnieszka Pokrywka addresses how environmental crises stem from colonialism, an ongoing legacy that the project critiques. Through live data, Spirulina itself narrates its story, while the bioreactor, equipped with Arduino and Raspberry Pi, collects and analyzes environmental data. It integrates images from NASA and other open-source archives, producing tweets, visualizations, and publications. By juxtaposing the futuristic potential of space food with the historical exploitation of natural resources, *Cyano Automaton* challenges dominant narratives of space exploration, prompting critical reflection on its ethical and ecological implications.


Figure 3: Cyano Automaton. Source: [38]

These examples demonstrate how design futuring artifacts can serve as powerful tools for fostering critical thinking and expanding our imagination of what is possible. By making the future tangible, such artifacts not only invite reflection on ethical and societal implications but also help individuals connect present actions to their long-term impacts. This approach cultivates a sense of responsibility toward future generations and encourages more intentional, values-driven decision-making in the present.

Drawing on futuring design within HCI, this paper proceeds to explore two critical questions: first, does it make sense for engineering education to incorporate design futuring? And second, how can design futuring methods be integrated into existing engineering curricula, especially considering potential challenges such as the limited depth of thinking, reflection, and criticality often observed among engineering students?

Critics of Design Futuring

The review of design futuring practices would be incomplete without addressing critical perspectives. Futuring artifacts aim to critically examine socio-technical systems and explore potential futures, fostering deeper understanding and discourse around emerging technologies. However, evaluating their impact on design practice and society presents ongoing challenges. A recent literature review of 53 HCI artifacts [33] addresses two key questions: what are the impacts of these artifacts on HCI, and how do they engage participants in conversations about alternative futures? The study's findings reveal that these artifacts play a vital role in sparking meaningful conversations around emerging technologies, encouraging participants to envision alternative futures. These tangible artifacts serve as powerful tools within HCI, enhancing human-technology interaction by challenging traditional paradigms and prompting users to rethink their relationships with technology. Additionally, the findings underscore the potential of speculative design to address pressing social and technological challenges, providing both tangible and intangible experiences that provoke reflection among participants.

Despite these contributions, design futuring practices have faced criticism, particularly for resembling patterns of colonial ventures [30], and neglecting cultural differences [40]. Future-making in design is inherently political, as different social groups have unequal access to resources, varying levels of proximity to sources of power, and differing opportunities to realize their visions. There is a growing call for speculative designers to be more accountable for their political and social positions [40, 41, 42]; they must recognize their own privilege and understand that the ways in which they represent future possibilities have world-making consequences.

Integration of Makerspaces and Hands-On Learning in Engineering Education

This section examines the challenge of integrating futures literacy into the engineering curriculum. One key obstacle, as outlined in the National Academy of Engineering's *The Engineer of 2020*, is that engineering programs are already overloaded. The report notes that adding new content—such as communication skills, social sciences, business knowledge, cross-cultural awareness, and emerging technologies—is often impractical, given that engineering undergraduates already face heavier course loads than students in many other disciplines [43]. Similarly, efforts to embed ethics into engineering courses have often struggled due to time constraints and uncertainty among instructors about how to teach these topics within technically intensive curricula [44, 45]. Futures literacy presents a similar challenge. Developing visions of the future requires time, skilled facilitation, and research support, making it a resource-intensive endeavor [46].

These constraints, however, open up opportunities to explore new ways to incorporate futures thinking into engineering education without adding to the existing curricular load. This section highlights the untapped potential of school-based makerspaces and the diverse forms of making and tinkering they support, positioning them as promising environments for engaging students in design futuring practices.

Rooted in the maker movement—a technology-driven extension of DIY culture—makerspaces originated as hubs for hands-on creativity, community learning, and open-ended exploration.

Milestones such as the launch of *Make* magazine in 2005 and the first Maker Faire in 2006 galvanized a growing culture of invention and collaboration [47]. In educational contexts, makerspaces have evolved into university-wide facilities open to students across disciplines and equipped with digital fabrication tools like 3D printers, laser cutters, and coding platforms, in addition to traditional hand tools. These spaces not only support the development of technical proficiencies but also cultivate habits of inquiry and experimentation that are essential for navigating complex and evolving design challenges.

Educators and researchers have increasingly recognized makerspaces as valuable learning environments that scaffold intellectual growth, foster student agency, and build pathways into STEM careers [48]. In the context of engineering education, the act of making reinforces adaptive and creative thinking, encourages iterative problem-solving, and supports the translation of abstract concepts into tangible forms. For example, as students construct physical prototypes, they often identify new design needs and constraints that were not apparent in theoretical planning, deepening their understanding of both materials and systems [49, 50].

Despite these strengths, critiques have emerged. Scholars argue that many educational makerspaces have yet to fulfill their promise as transformative, future-focused spaces. Gilbert [51], for instance, contends that they often mirror rather than disrupt traditional pedagogical norms. Furthermore, research points to ongoing inequities within makerspace participation, with underrepresented students frequently marginalized or discouraged by the cultural dynamics that replicate existing hierarchies in STEM [48, 52, 53]. These issues underscore the importance of intentional design and facilitation to ensure makerspaces are inclusive, critically engaged, and oriented toward broader societal futures.

Within engineering education, makerspaces also offer fertile ground for integrating entrepreneurial mindsets and project-based learning. When designed to support interdisciplinary collaboration and creative risk-taking, they can nurture the skills necessary for innovation, resilience, and leadership in complex environments [54, 55]. However, the full potential of these spaces remains constrained when activities focus solely on technical execution without incorporating critical reflection or long-term thinking.

To unlock the future-making potential of makerspaces, it is necessary to move beyond surface-level tinkering and create learning experiences that connect making with imagination, ethics, and systems thinking. By doing so, makerspaces can become dynamic environments where students not only build physical prototypes but also prototype alternative futures. This shift requires a pedagogical reorientation—one that integrates futures literacy with hands-on practice to help students imagine, explore, and critically engage with the social and ethical dimensions of technology and design.
The following section introduces Critical Making as a pedagogical approach that aligns with this vision. By combining material experimentation with critical inquiry, Critical Making enhances the educational value of makerspaces, turning them into spaces for thoughtful, inclusive, and transformative engagement with the future.

Critical Making: Material Practice as Reflective Inquiry

Critical making, a term coined by Matt Ratto, refers to "using material forms of engagement with technologies to supplement and extend critical reflection, reconnecting lived experiences with technologies to social and conceptual critique" [56]. Rooted in the intellectual legacy of the Frankfurt School and shaped by the activist spirit of the 1960s, this approach blends theoretical inquiry with making—not to build functional products for future deployment, but to provoke reflection on the values, assumptions, and consequences embedded in existing technologies.

Emerging from early 2000s speculative design practices, critical making incorporates material creation as a parallel and complementary mode of knowledge production alongside traditional scholarship. In educational contexts, it engages students in prototyping, testing, and iterative processes where reflection emerges as a core component, not a secondary outcome. Unlike conventional engineering approaches that prioritize outcomes, efficiency, or usability, critical making shifts attention to the process itself. Through the act of making, students are invited to explore ambiguity, surface assumptions, and generate new questions about the social, cultural, and ethical dimensions of technology.

Critical making has found institutional homes in programs such as the Critical Making Lab at the University of Toronto and the Studio for Critical Making at Emily Carr University. These initiatives challenge dominant engineering narratives by framing making as a method of critique rather than production [57]. They emphasize the development of technologies that are culturally situated, socially responsive, and personally meaningful. For example, the Studio at Emily Carr draws from humanities-based perspectives to question traditional design priorities, encouraging work that is more aligned with social justice and inclusivity than with technical performance alone.

In engineering education, the integration of critical making is still emerging. As early as 2016, the ASEE community began exploring how practices from the digital humanities could inform engineering pedagogy. Nieusma and Malazita [58] highlighted the value of making as a form of inquiry—particularly in its capacity to reflexively interrogate design choices, question problem definitions, and examine how technologies shape and are shaped by society. In product design and innovation courses, for instance, students who engage in critical making are encouraged to wrestle with socio-technical entanglements rather than simply designing solutions. This helps cultivate a deeper awareness of the ethical and political dimensions of engineering work.

Critical making lacks an intentional orientation toward the future. Even when the artifacts produced take conceptual or speculative forms, the process remains rooted in present-tense reflection and critique. This absence of a future-oriented lens may limit its potential to foster the kind of anticipatory thinking needed for developing futures literacy within engineering.

Additionally, a review of critical making projects[1] suggests that successful integration into curricula often depends on the presence of artist-activist communities, supportive institutional cultures, or instructors with training in critical theory. This presents a challenge for engineering

[1] A collection of critical making projects are available online. Accessed: Jan. 10, 2025. [Online]. Available: http://conceptlab.com/criticalmaking/

educators: without intentional scaffolding or professional development, the tools and techniques of critical making may remain underutilized or misaligned with engineering's goals.

An Outline for Integrating Design Futuring into Engineering Education

As previously discussed, integrating design futuring into engineering education presents several challenges. One major concern is the risk of overloading an already content-heavy curriculum [59]. Engineering students are expected to master a wide array of technical and professional competencies, leaving limited space for additional material. Another barrier lies in the practical demands of implementation. Instructors often lack the time, resources, and facilitation skills needed to effectively incorporate design futuring into their teaching. Similar to the integration of ethics into engineering education, introducing futures literacy can require significant planning, specialized knowledge, and pedagogical support [21, 24].

A further challenge involves cultural and intellectual barriers to embracing the speculative and critical orientation that futuring entails. A review of critical making projects suggests that many engineering educators may not feel equipped to critique technology or explore alternative futures. These efforts often rely on collaborations with artists, activists, or institutions that already value critical perspectives, highlighting a gap in current faculty expertise and training [46].

To overcome these challenges, one promising strategy is to restructure existing courses to embed design futuring principles, rather than introducing additional content. This approach mirrors successful models from ethics education, where ethical considerations are integrated into technical instruction. Embedding futuring in this way allows students to engage with forward-thinking concepts without increasing their overall workload.

The following section outlines four key strategies for enabling this integration: positioning makerspaces as centers for future-making, incorporating design futuring into current instructional models, and fostering institutional cultures that support critical inquiry.

Establishing a New Approach to Makerspaces: Hubs of Future Making

Positioning makerspaces as hubs of future making offers a powerful, practice-based framework for embedding futures literacy into engineering education. Traditionally focused on technical skill-building, these spaces must evolve into environments for futures-oriented inquiry—where the act of building not only solves problems but also shapes possibilities. By integrating design futuring practices, makerspaces can support students in imagining and materializing alternative socio-technical futures. This approach leverages students' natural affinity for hands-on problem-solving while expanding their capacity for critical, long-term thinking, enabling educators to reimagine making as both technically rigorous and intellectually provocative.

What changes are needed? This shift requires intentional changes. First, educators should embed speculative design and scenario-based challenges into makerspace programming—asking students to prototype for long-term, ethical, and societal implications, not just functional outcomes. Second, instructional support must be expanded to include interdisciplinary facilitation, drawing from design studies and STS (science and technology studies) to guide critical reflection alongside making. *Table 1* presents a proposed evaluation rubric for prototypes aligned with design futuring principles. Third, makerspace culture should embrace ambiguity and exploration, valuing speculative prototypes that raise questions over those that offer immediate solutions.

Table 1: Proposed Evaluation Rubric for Design Futuring-Aligned Prototypes

Dimension	**Description**	**Evaluation Criteria**
Critical Imagination	Evaluates the extent to which the concept challenges dominant assumptions and explores alternative futures.	Does the prototype envision a future that diverges from the status quo? Does it engage creatively with what *could* be, rather than what *should* be built next?
Societal & Ethical Reflection	Assesses how well the project considers long-term societal, cultural, and ethical impacts.	Has the student identified possible unintended consequences? Does the concept reflect awareness of equity, justice, and environmental responsibility?
Narrative Coherence & Framing	Examines the clarity and depth of the future scenario the concept addresses.	Is the prototype accompanied by a compelling narrative or context? Does it clearly articulate the future world it imagines or intervenes in?
Interdisciplinary Integration	Measures the use of insights from humanities, social sciences, or speculative methods in the design process.	Has the student drawn from fields like STS, sociology, or speculative fiction to inform their design? Is there evidence of systems thinking?
Provocation & Inquiry	Values concepts that raise meaningful questions rather than offering finalized solutions.	Does the prototype prompt discussion, debate, or reconsideration of current trajectories? Does it serve as a thought experiment rather than a finished product?
Making-as-Reflection	Recognizes making as a process of thinking and reflection, not just production.	Is there evidence that the student used iteration and prototyping to refine ethical or conceptual questions? Were materials or forms used intentionally to provoke reflection?

How can we measure effectiveness? Effectiveness can be measured through reflective assessments, design journals, and evaluation rubrics that consider critical engagement, not only technical execution. Studies could also examine whether such integration increases diverse participation or shifts student perspectives on the role of engineering in society.

What is the impact on existing uses? This future-focused use of makerspaces does not displace existing functions but enriches them—equipping students with both the practical and conceptual tools needed to address complex challenges. As such, makerspaces can serve as a critical bridge between technical education and futures literacy, positioning engineers as agents of societal transformation, not just problem solvers.

Instructional Models

Design thinking and design futuring share a foundational ethos: both embrace ambiguity, encourage divergent thinking, prioritize iterative, hands-on making, and rely on systems thinking to address complex challenges. They also emphasize communication with stakeholders, often using visual tools such as storyboarding. These shared principles create a natural alignment, allowing design futuring to enrich design thinking with a critical, future-oriented perspective. However, design futuring introduces a distinct shift in purpose, scope, and temporal orientation. While design thinking focuses on addressing present-day user needs through functional solutions, design futuring asks: *What could exist, for whom, and under what conditions?* It treats time as a design material, employing speculative tools—such as futures wheels and provocative prototyping—to explore how today's decisions shape long-term, systemic outcomes.

Beyond problem-solving and optimization, design futuring engages students in worldbuilding and cultural critique. It encourages them to envision entire socio-technical systems—economies, infrastructures, and values—while interrogating who benefits from imagined futures and who may be excluded. In this context, prototypes are not solutions but provocations designed to question assumptions and inspire critical dialogue.

Ultimately, design futuring cultivates futures literacy in engineering students: the capacity to engage with uncertainty, anticipate change, and act with ethical and imaginative awareness. It redefines the engineer's role—not only as a problem-solver but as a shaper of more inclusive, just, and sustainable futures. Table 2 summarizes the key distinctions between design thinking and design futuring.

Table 2: Comparison of Design Thinking and Design Futuring

Aspect	**Design Thinking**	**Design Futuring**
Focus	Solving current problems	Exploring possible futures
Time Orientation	Lifecycle, long-term impact	Temporal speculation, scenario building
Prototype Function	Usable, testable solutions	Provocative, reflective artifacts
Design Goal	Optimize, improve, sustain	Question, reimagine, provoke
Learning Outcome	Technical and user-centered skills	Futures literacy, critical systems awareness

Effectively integrating design futuring into education requires structured methods that support students in envisioning and shaping alternative futures. Jim Dator's futures visioning framework provides a foundational approach for this work, outlining key components essential to engaging students and communities in critical, long-term thinking [60]:

- Appreciating the past: Begin by understanding the community's history, recognizing its rationale for existence and past events.
- Understanding the present: Discuss current problems and possibilities, allowing individuals to voice concerns and see the present as a steppingstone to future solutions.
- Forecasting aspects of the futures: Identify likely challenges and opportunities for the next 20-50 years, focusing on emerging trends and past/present continuities.

- Experiencing alternative futures: Engage in at least four distinct future scenarios, recognizing that many possible futures exist based on different combinations of trends and ideas.
- Envisioning the futures: Prepare to create a preferred future, drawing from past, present, and alternative futures.
- Creating the futures: Decide on actions to take now to move toward the envisioned future.
- Institutionalizing futures research: Establish a continuous process for future scanning, ensuring the community remains informed about upcoming challenges and opportunities.

Building on a table developed by Evans et al. [61], which mapped futuring methods and techniques relevant to design, the following tables propose discussion prompts and group activities aligned with each of Dator's components. These are intended to support instructors and facilitators in embedding futures literacy within project-based or participatory design settings.

This guidance is grounded in over a decade of teaching design thinking to engineering students, primarily within product development contexts. It also draws from practical experience in organizing community-centered design events and participatory workshops. The instructional techniques and toolkits presented here have been tested, adapted, and refined over time. Rather than offering a prescriptive or one-size-fits-all model for teaching futures thinking, this work contributes to the evolving conversation on how to develop thoughtful, context-responsive pedagogy in engineering and design education.

Table 3: Understanding the present context

Technique	**Format of Delivery**
Headline Clustering: Exploring signals of the future Participants are provided with a selection of printed newspaper articles that explore the emergence of technology and its potential, specifically selected for their provocative claims. The task is to review the headlines, identify recurring themes, and cluster them into insightful categories. In small groups, discuss the emerging trends and reflect on their probability and significance.	Group discussion
Critique the Ideal Vision Participants are given a document that outlines an ideal vision for the future (e.g., Google's proposal for a walkable city, NYC's vision for 2050, etc.). The task is to critically engage with this vision by considering the ways it might fail. Reflect on which groups (human or nonhuman) are excluded or overlooked in this vision. In small groups, identify potential shortcomings, marginalized perspectives, and alternative scenarios that challenge the idealized vision.	Group discussion

Table 4: Appreciating the past

Technique	**Format of Delivery**
Historical Immersion Day Students participate in a visit to a local historical site, museum, or archives where students can explore artifacts. The goal is to immerse them in the history of a specific era or event. The task is to envision how their community present might be different if one or more facets of the past changes.	Field-trip Journaling

Table 5: Envisioning the future

Technique	Format of Delivery
Envisioning the Future of Local Manufacturing (temporal distancing from the present) In this exercise, envision your local city in the year 2050—transformed into a thriving hub of local manufacturing. Using a map of your city, work in small teams to identify three to five key sites that symbolize the heart of this prosperous manufacturing landscape. For each chosen site, - Briefly describe what makes it unique, - Reflect on how these sites have evolved from their current state to become hubs of local production and making by 2050, and - Discuss how these sites contribute to the city's sustainability and economic resilience. Use this information to craft your acceptance speech as you accept the prize of the century!	Narrative writing
Envisioning the Future of Local Manufacturing (spatial distancing from the present) Imagine living on a newly discovered planet facing rapid economic and cultural change. Using a design toolkit, your team will respond to waves of transformation—such as globalization, automation, and immigration—while incorporating robots, social media, and superhuman powers like time-traveling. Capture your evolving story through a visual storyboard, showing how your team's choices shape this new world.	Storyboards

Table 6: Experiencing alternative futures

Technique	Format of Delivery
Creating A Newspaper of the Future Reflect on current trends in energy technology and its impact on society. Working in small groups, use mixed media. such as drawings, headlines, articles, and advertisements, to create a newspaper from the future. Your task is to imagine: - What will the headlines of this future newspaper say about energy breakthroughs and consumption? - What types of advertisements will appear, and what do they reveal about societal values around energy use? - What significant changes do you envision in the way energy is produced, distributed, and consumed in the coming decades?	Mixed media
Crafting Material Artifacts: Responses to Climate Futures Identify early signals of change, map out the potential consequences, and visualize their imagined futures as everyday streetscapes in their neighborhoods. Envision social and technological inventions that respond to climate change. Create life-size models to bring their ideas to life.	Materialized artifacts (high fidelity productions)

In these activities, students typically move through a range of experiences—starting with confusion or discomfort in response to the ambiguity inherent in futures thinking. However, by the end of the exercises, many express enthusiasm for their insights and demonstrate increased confidence, particularly in group discussions. Tables 3–6 outline specific tasks that can be integrated into existing engineering education curricula. These activities offer a promising foundation for future pilot studies that could evaluate both student deliverables and the learning mechanisms at play, paving the way for more rigorous research in this area.

Figure 4: Left – A newspaper from the future created by a participating team. Right – A newspaper from the future under development. Source: [35].

Figure 5: Example of a toolkit designed and utilized during the workshops. Source: [35]

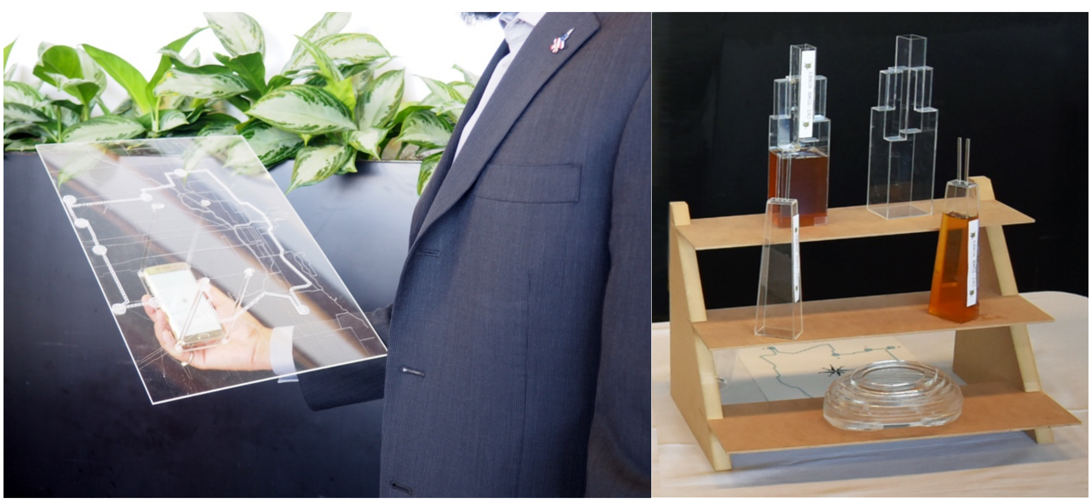

Figure 6: Left – Prototype of a hologram map, created as part of the Bee Hiveway student project. Right – Materialized artifacts envisioning the city as a leading exporter of urban honey through the advent of Bee Hiveway. Source: Author's personal archive.

Establishing Support Networks Beyond the Classroom

This paper proposes two key strategies for supporting the integration of design futuring into engineering education: cultivating communities of practice and fostering an institutional culture that embraces futuring and interdisciplinary collaboration.

One promising model, highlighted by Rover [62], involves the formation of communities of practice to support educational innovation in engineering. Drawing on Bess's framework of teaching domains—such as pedagogy, research, mentoring, curriculum integration, and assessment—communities of practice encourage collaborative engagement across roles. This model distributes instructional responsibilities across faculty, teaching assistants, industry professionals, and context experts, creating a sustainable and supportive learning environment for new teaching approaches.

A second strategy focuses on shaping institutional culture to value critical inquiry and diverse perspectives. Lessons from critical making and speculative design show that incorporating voices from the arts, activism, and other disciplines can enrich engineering education. Institutional initiatives such as interdisciplinary speaker series, field trips, and hands-on workshops can create space for these perspectives. For this to succeed, institutions must provide resources and training for educators, equipping them to lead discussions on alternative futures and embed futuring practices into their teaching.

Together, these approaches establish the structural and cultural foundations necessary to advance futures-oriented pedagogy in engineering education.

Evaluating Outcomes and Tracking Progress

To assess the effectiveness of embedding design futuring in engineering education, I draw on Borrego and Henderson's framework [63], which classifies educational change strategies based on two dimensions: the target of change (individuals or structures/environments) and the nature of the change (prescribed or emergent). This framework helps guide both the design and evaluation of interventions by considering the systemic layers in which educational change occurs.

Evaluation Methods

To evaluate individual-level outcomes, pre- and post-course surveys will measure shifts in students' engineering identity, beliefs, and perceived competencies. These surveys will explore how students' perceptions evolve from viewing engineering as rooted in technical expertise to seeing it as a practice centered on collaboration, problem-solving, systems thinking, and ethical responsibility. Complementary self-reflection surveys during futuring activities will offer insight into behavioral changes and emerging skills, helping track progress across identity development and technical confidence.

Additionally, we propose analyzing student-generated artifacts—such as speculative prototypes, future scenarios, and visual narratives—as evidence of futures literacy. Evaluating these materials will help assess students' ability to integrate long-term thinking, anticipate complex implications, and communicate future-oriented ideas effectively. Faculty evaluations of these artifacts can also provide insight into how futuring impacts perceptions of student learning and engagement.

Broader Participation and Makerspace Engagement

Design futuring's inclusive nature—requiring no prior technical expertise—presents an opportunity to broaden participation. Drawing on classroom experience, students often drawn to hands-on tools but less familiar with digital fabrication or electronics find these activities approachable. Therefore, one aspect of evaluation will track increased engagement in makerspaces and shifts in students' technical skill acquisition over time.

Indicators of Impact

Potential outcomes of integrating futuring practices in engineering education include:

- Divergent thinking, demonstrated by the range and originality of solutions in student design work.
- Systems thinking, assessed through students' ability to articulate interdependencies, unintended consequences, and long-term system dynamics.
- Anticipatory competence, reflected in the development of plausible future scenarios and the flexibility of corresponding design responses.
- Ethical awareness, evident in reflective assignments and design justifications that consider social and environmental equity.
- Career orientation, measurable through post-graduation tracking of students' participation in socially responsible or sustainability-focused work.

Future Research Directions

This evaluation also points toward several areas for further investigation. Key among them is identifying institutional and cultural barriers that may limit the adoption of futuring pedagogies. Addressing these requires institutional commitment through curriculum redesign, faculty development, and dedicated resources.

Educator preparation is another critical focus. Determining effective methods for training instructors to lead futuring activities—particularly around ethical foresight and interdisciplinary integration—will be essential to scaling this approach.

Finally, future studies should explore how futuring can redefine the role of engineers—not just as problem solvers but as anticipatory leaders shaping inclusive and sustainable futures. Research should further examine how futuring fosters interdisciplinary collaboration, helping engineers partner with fields like the humanities, social sciences, and business to address complex societal issues such as climate change, equity, and technological ethics.

Conclusion

This paper has proposed various strategies for embedding design futuring into pedagogy, emphasizing the need to build upon existing frameworks rather than disrupt traditional norms. Key among these strategies is the incorporation of makerspaces as centers for future-making, where design futuring merges with the existing culture of hands-on, collaborative learning. These spaces serve as hubs for what could be described as a new modality of tinkering, where the emphasis shifts from the creation of artifacts to the process of exploration, experimentation, and the development of critical thinking. Additionally, parallels are drawn between the open-ended design challenges often practiced in engineering schools and the design futuring process, offering familiar contexts to embed these new methodologies. The goal is to combine futures literacy with current practices and move beyond just predicting the future. It encourages students to see themselves as engineers who can shape the future—by imagining new possibilities, questioning existing ideas, and exploring different solutions. Additionally, this paper outlines several prompts and activities designed to engage engineering students in the practice of design futuring. The success of this integration depends on thoughtful implementation, continuous evaluation, and the cultivation of an institutional culture that values futures thinking as a core component of engineering education.

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