Teaching Case

Design Fiction as a Novel Approach to Cultivate Awareness of Social Responsibilities: An Explorative Study in a Technical Writing Course for Engineering Students

—Yunye Yu, Yiying Wu, and Sibo Pan

***Abstract*—Introduction:** *It has long been advocated that engineers should enhance their social and ethical responsibilities. With the rapid advancement of science and technology, this imperative becomes increasingly pressing.* **About the case:** *This teaching case took place in a public research university in China. The primary objective is to enhance engineering students' understanding of their social responsibilities.* **Situating the case:** *This study is an exploration of the application of design fiction, a commonly utilized practice in interaction design, within the context of a technical writing course.* **Methods/approach:** *Within the study, participants were tasked to engage in creating speculative scenarios of future food in 2040. This scenario revolved around an imaginary technology related to food, envisioning its impact on people's lives and society. Through a structured process of guided speculation and critical reflection, participants wove together fragments of these future scenarios to craft complete fictional narratives.* **Results/discussion:** *The result of this investigation revealed that the fictions generated by participants encompass a diverse array of elements that manifest the writers' heightened awareness of social responsibilities.* **Conclusion:** *We contend that this study introduces an innovative and engaging approach to the teaching of technical writing, one that holds promise as a valuable complement to the existing curriculum. Moreover, within the sphere of engineering education, this research underscores the potential of design fiction in nurturing a deeper understanding of social responsibilities among engineers, particularly on a "macroethical" scale.*

Index Terms*—Design fiction, food, future, social responsibility, technical and professional communication.*

Engineering plays a significant part in shaping our society by designing and implementing technologies, infrastructure, and systems that have far-reaching impacts on people's lives, the economy, and the environment. With this influence, there comes a moral and often legal obligation for engineers to consider the broader implications of their work beyond technical aspects and economic considerations. In *Rethinking Engineering Education*, Crawley et al. [1] argue that higher education needs to educate students to become modern engineers with technical expertise, social awareness, and innovation preference. Zandvoort et al. [2] argue that science and engineering education should "empower students to fulfil this (social) responsibility" because science and engineering's functioning in the world relate to many formidable current and future problems that are threatening the prospect of our society, including justice and peace, sustainability, and the well-being of humanity.

Lately, the rapid and unprecedented advancement in scientific and technological progress, particularly within the realm of artificial intelligence, has accentuated the necessity to enhance the social and ethical responsibilities of engineers [3], [4]. Consequently, it is imperative that upcoming engineers acquire a comprehensive understanding and a reinforced awareness of the significance of sociotechnical considerations in the practice and design of engineering throughout the entirety of their engineering education [5].

Echoing their call, we explored a novel writing practice—design fiction—in a technical writing course, aiming at cultivating awareness of social responsibility in engineering students. In this article, we respond to the call for cultivating awareness of social responsibilities in engineering students. We believe that design fiction, as a methodology and theoretical framework that was first developed in the field of human–computer interaction and interaction design, is able to bring

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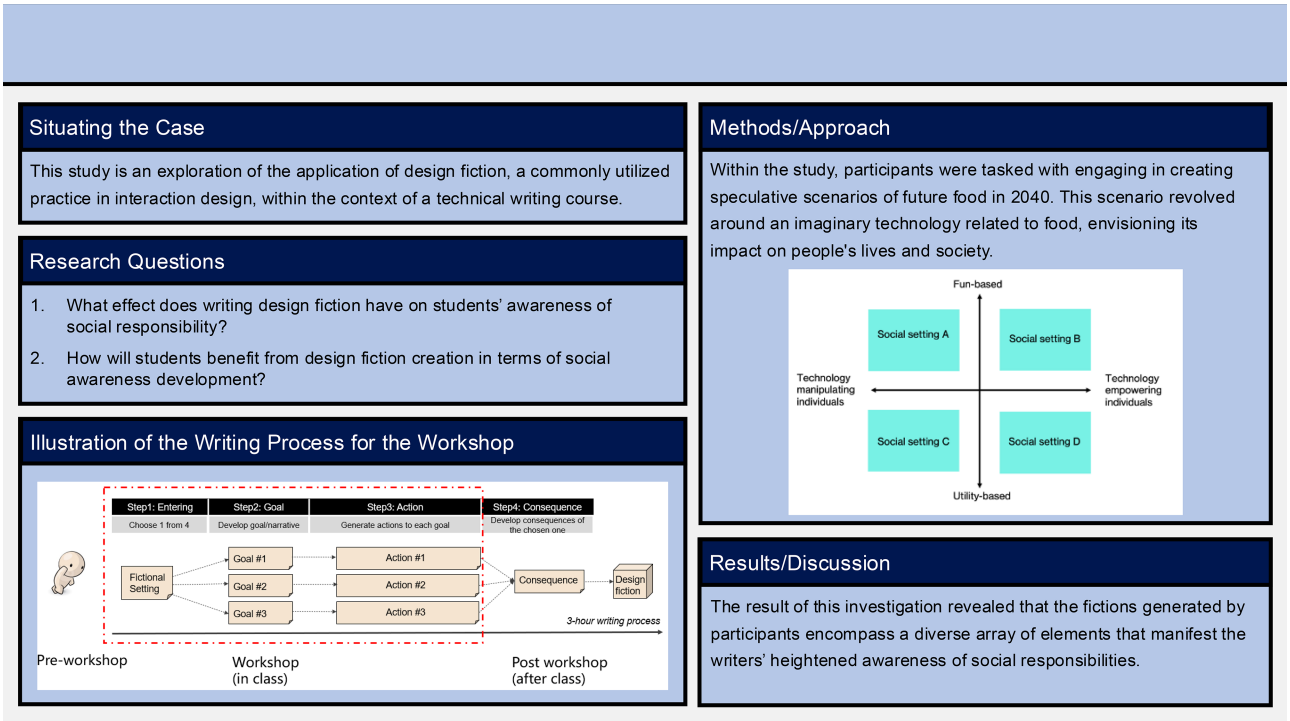

innovative approaches to engineering education, especially in cultivating awareness of social responsibilities in engineering students. In the following sections, we describe in detail our design fiction writing workshop and provide an in-depth analysis of the awareness of social responsibilities demonstrated in our students' writing. The results suggest that design fiction can be a useful approach in bringing about and developing awareness of social responsibilities. We further discuss the implications of how to incorporate this genre in technical communication courses.

The key concepts of this article are *design fiction* and *social responsibilities*. *Design fiction* refers to a writing genre that creates speculative and provocative worlds in which a technology or design artifact is narrated. A comprehensive review of design fiction can be found in the Situating the Case section. *Social responsibility*, as an indispensable code of conduct in the engineering and business world, has drawn an increasing share of attention in recent decades. To operationalize this concept in our study, we adopt a framework to categorize social awareness into six subcategories, which can be found in the Results/Discussion section.

We have chosen the Chinese context for our study due to its unique characteristics. Since the founding of the People's Republic of China in 1949, there has been an emphasis on developing science and technical education to meet industrialization and national production needs, to "rebuild the country," as the rhetoric of the times has often used the phrase to describe the process. As a result, engineering education has become crucial to achieve industrialization. However, it has primarily focused on transmitting knowledge rather than fostering critical thinking or understanding of social responsibilities.

Teaching about social responsibilities does form a part of the curriculum, but it is often limited to case studies and conventional teaching methods, which can be inflexible and result in low student engagement and a superficial understanding of these responsibilities. Our goal is to introduce innovative teaching approaches that emphasize social responsibility, integrating them within technical writing courses without focusing solely on explicit content. The assignment includes creating a food label, which is a typical genre of technical writing, for hypothetical future food in 2040.

This teaching case was an attempt to explore the value and contribution of design fiction in technical writing courses within Chinese engineering education. This study intended to explore the following research questions.

RQ1. What effect does writing design fiction have on students' awareness of social responsibility?

Practitioner Takeaway

- This study demonstrates design fiction as a creative tool in technical writing courses, enabling students to explore societal and ethical implications of future technologies.
- By crafting speculative narratives, students developed a deeper understanding of their broader social responsibilities as engineers, shifting focus from individual ethics to societal impacts.
- Design fiction provides educators with a flexible method to incorporate ethics and social responsibility into technical courses, making it a valuable complement to traditional engineering education.

RQ2. How will students benefit from design fiction creation in terms of social awareness development?

In subsequent sections, we will outline the case context, including the teaching environment, course curriculum, and student background. We will describe the integration of a design fiction workshop into the English Technical Writing class aimed at enhancing students' social responsibility awareness. We will further discuss the promising outcomes of students' writing, which reflects a broad spectrum of social responsibilities, and demonstrate how design fiction, a writing activity rich in critical and speculative thinking, effectively cultivates social awareness among engineering students.

About the Case

As mentioned in the introduction, fostering social responsibility among engineers is crucial in engineering education. There is an urgent need for innovative teaching methods in China, as traditional case-based approaches often fail to engage and motivate students. The institutional site of this study was a public research university in China. According to *U.S. News & World Report*, the school was ranked in the top 15 "Best Global Universities for Engineering" [6]. The total number of students enrolled is 38,419, including 1689 international students [7]. The undergraduate student population is 16,785, and the postgraduate population is 21,634. The students are mainly Chinese, with only approximately 4.5% being international students.

Undergraduate students need to take three semesters of *College English* to fulfil the institution's requirement. Under the umbrella term of *College English*, there are diverse elective courses with distinctive focuses that provide students with options to meet their individual needs and interests. For instance, *Academic Writing* focuses on helping students acquire basic knowledge and writing skills essential in the academic setting. The *IELTS Course* is an exam-prep course for students who plan to apply for study-abroad programs. The course in this study, *English Technical Writing,* is designed to provide students, especially engineering majors, with basic principles of professional communication as well as basic knowledge of technical writing.

In the context of our course, the choice to have students write design fictions in Chinese emerges from practical considerations and pedagogical principles. Initially, we were inclined to conduct the writing tasks in English. However, a pilot study conducted with second-year students revealed challenges in effectively conveying their intended ideas and expressions in a non-native language. The feedback from this pilot study supported our hypothesis that asking students to write design fictions in English could hinder their ability to fully articulate their concepts and insights. The "intricate and intimate connection" between thought and language supports our decision to let students write design fiction in Chinese.

The technical writing course bears the responsibility to use subject matter to advance critical reasoning procedures [8], [9]. Technical writing is not just about "accurately" transmitting reality [8, p. 99]; it needs a deeper, humanistic approach [10]. Critical thinking skills, such as "advanced concept formation," "hypothetical reasoning," and "empathic thinking," should be valued [8, p. 101]. As Yancey [11] put it, writing is the medium for critical thinking, also a form that influences and expresses the content of critical thinking.

The goal of the design fiction workshop is to promote critical reflection on technology, irrespective of the language used. Ensuring

effective communication of ideas is paramount in fostering deeper thinking and comprehension of technology's societal implications. Therefore, we believe that by allowing students to write in Chinese, their native language, we provide a more conducive environment for them to express their thoughts with clarity and precision.

Another constraint in this study was a tight schedule. The duration of a design fiction workshop can vary depending on its objective, complexity, and the depth of speculation desired. Typically, a design fiction workshop can range from a few hours to several days, allowing participants to engage deeply in the reflective and creative process. However, due to the limitations of our course, which includes weekly 90-minute class meetings and the need to address other curriculum requirements, conducting a multisession, in-class workshop was not feasible. As a solution, we opted to organize the workshop into three phases: the preworkshop preparation phase, the in-class workshop, and the postworkshop phase. This approach allowed us to accommodate time constraints while still providing students with a meaningful design fiction experience. This activity aligns with the course objectives approved by the university that emphasize teaching critical thinking and problem-solving skills. It is important to recognize that social responsibilities are multifaceted, and it may be unrealistic to expect students to fully develop all the social responsibilities through a single writing assignment.

In the next two sections, we will elaborate on the dimensions of social responsibilities that are used to evaluate students' writing and outline the procedures of the design fiction workshop.

Situating the Case

Concept of Design Fiction Design fiction is a specific genre of creation that is attentive to narrating speculative worlds. This method was originally developed in the fields of human–computer interaction and interaction design. The term *design fiction* was first coined by science fiction novelist Bruce Sterling [12] in 2005, who later elaborated with the definition of "the deliberate use of diegetic prototypes to suspend disbelief about change" [13]. Later, this method gained more theoretical legitimacy after Julian Bleecker's book *Design Fiction: A Short Essay on Design, Science, Fact and Fiction*. In that book, he elaborated on the key concept "diegetic prototype" developed from theater studies.

Meanwhile, design fiction practice is often associated with another well-established design program called speculative and critical design that argues interaction design should provoke debate about technological applications rather than serving commercial use [14]. Albeit working with diverse definitions, roots of origin, purposes, and tools [15], to put it simply, design fiction means the composition of a fictional world in which a yet-to-exist technology is implemented and used.

Design fiction has been used as a valuable tool for the critical investigation of technological innovation by designers. For instance, it is used to challenge the status quo [16], problematize upstreaming technology [17], and foster political engagement [18]. It means that in the exploration of possible futures, this method has neither interest in predicting futures, such as "how the future should be," nor in glorifying futures by positioning the described technology as the solution to problems. Rather, with its discursive orientation [19], it is attentive to exploring possible ethical, social, and political implications of the new technology for the society and people's everyday living. The future scenarios often appear provocative, aiming to elicit discussion and debate on matters concerning a new technology.

Therefore, more than the speculative technology itself, social values embedded in the technology have been an important part of the inquiry in design fiction practice, such as issues of privacy and surveillance in drones [20], domestic robots [21], and urban technologies [22]. Thus, design fiction serves as a tool of critical thinking that asks questions rather than providing technological solutions. Also, design fiction can be collaboratively created or used for collaborative design [23]. Thus, design fiction takes various formats, such as a multimedia package of storytelling [24]; well-crafted exhibit objects [14]; fully functional prototypes [25], [26]; artifacts and videos used in co-design workshops [27], [28]; and performative events [29], [30].

Designing Social Responsibility in Engineering Education Despite the advocacy of both researchers and educators regarding the significance of integrating social responsibility into engineering education [2], it appears that these efforts have not been fully sufficient. Notably, when compared to health professionals and scientists,

engineers exhibit less inclination to regard social responsibility as "important" [3, p. 4]. Consequently, there has been growing emphasis on the exigency of fostering social responsibilities of engineers [5], but no consensus has been reached on what social responsibilities consist of [14]. This study does not attempt to make a clear-cut definition; instead, it positions the problem in a broader social context and considers "social responsibility" a multidimensional construct. The dimensions examined include

1. Concern for human welfare and safety
2. Concern for environmental sustainability
3. Consideration of societal risks and consequences
4. Consideration of societal needs and demands
5. Pursuit of the common good
6. Civic engagement and services
7. Communication with the public
8. Participation in policy decision making [31, p. 291]

Incorporating Design Fiction in a Technical Writing Course Seeing the inherent nature of its provocativeness and reflectiveness, we applied design fiction in a technical writing course to cultivate students' awareness of social responsibility. Our attempt also contributed to the trend of social justice turn in technical and professional communication as it sought to encourage engineering students' critical reflection on technology and its impact on human activity as well as society.

This study was part of a larger explorative project in which we explored the value and contribution of technical writing courses in engineering education in the Chinese context. This article examines samples of design fiction on the theme of "futures of food" and further articulates how a creative approach could be applied in technical writing courses to cultivate engineering students' awareness of social responsibilities.

The design fiction workshop was closely related to this English Technical Writing course as it developed students' critical thinking, a key component listed in the course syllabus. It integrates design fiction into technical writing through assignments like food label writing. This method aligns with Miller's concept of "context[ualized] logic" [10]. Logistically, to fit into a 90-minute session, the workshop includes preworkshop readings, in-class activities, and postworkshop assignments, ensuring comprehensive engagement within tight time constraints.

Methods/Approach

To answer our research questions, we decided to structure a design fiction workshop in the English Technical Writing class. We conducted the design fiction workshop in three parts. We assigned preworkshop tasks to orient students to design and speculation, we conducted a 90-minute workshop with 176 students, and we finished with a postworkshop survey. We collected the design fictions and data through a Tencent Questionaire and analyzed the data using content analysis.

Participants A total of 176 students were recruited, most of whom were second-year engineering majors. Eight participants were excluded due to incomplete fictional stories (i.e., final draft missing a specific explanation of desired technology and design concept). As a result, 168 participants were included in this study (60.7% male and 39.3% female). All of the participants were engineering majors, including civil, mechanical, transportation, electrical, software, and computer engineering. The study was supervised by the first author's institution to ensure its compliance with university regulations and human rights requirements.

Procedure of the Design Fiction Workshop The design fiction workshop had dual objectives. First, because the workshop is aligned with university-approved course objectives, including critical thinking, engineering ethics, and problem-solving skills, it functioned as an integral component within the course framework, providing students with intellectually stimulating learning resources and an inspiring pedagogical encounter. Second, the design fiction workshop was oriented toward eliciting and cultivating an awareness of the impending challenges confronting society. All of the workshop's materials, directives, and students' written outputs were in Chinese.

The study required each participant to generate a speculative narrative pertaining to the landscape of future food in 2040, elucidating the impact of emerging technologies, including automation and Big Data. The research was executed through a structured progression with three distinct phases.

Phase I: Preworkshop Empirical studies have suggested that prior knowledge of social issues shapes student perceptions [32]. We arranged

Fig. 1. Two examples (of 10 speculative design concepts) of food provided to students: Insect banquet and "is eating still the only way?".

two preworkshop tasks to help students dive into imagination and design thinking. First, we carefully selected 10 speculative design concepts of future foods that had been created by other designers in the field of human–food interaction. We presented them in 10 cards, each with a brief introduction (see Fig. 1). We asked students to choose one design concept that they liked the most and one that they disliked the most, and to elaborate on their choices. One aim of this commentary exercise was to get students, who had no design background, familiar with the speculative and futuristic nature of design fiction, and to widen their imaginative horizon.

The second task was an analysis of a technological product. We asked students to choose a product related to cooking, food production, or food delivery that they used in their daily lives. We provided them with a design analytic framework with which to tell about the main user group, function features, the most typical use context, value proposition, and potential risk. This framework was used as a small exercise for students to think like a designer.

Phase II Workshop The design fiction workshop was themed "futures of food in the year 2040" and lasted 90 minutes. Before guiding the students to fiction creation, the teacher introduced the new concept of design fiction as akin to science fiction in its portrayal of future technologies but with a keen focus on daily life. More specifically, the discursive nature of design fiction was empathized [33]: the future story is created to remind, inform, inspire, provoke, or persuade. Thus, students were reminded to avoid creating utopia or dystopia to develop more nuanced and enriched reflections.

The creation process had four steps:

I. Entering the fictional setting
II. Setting a goal
III. Taking action
IV. Developing consequences (see Fig. 2)

We first presented the predeveloped four social settings in 2040 (see Fig. 3 and Table I) by using the method "scenario planning" derived from future studies [34]. Scenario planning is a strategic approach to envision various possible futures by examining identified trends and events in the present. Instead of predicting a single outcome, this approach anticipates a wide spectrum of future scenarios, typically four, to enhance the strategic thinking and planning of organizations and individuals in the environment of uncertainty.

We adopted this approach to provide backdrops as a guiding structure for students to further imagine future narratives of food. Two design experts from the teaching team (experts in human–food interaction) conducted a scanning study of trends related to lifestyles and eating habits, the food industry and business, and emerging technology. Based on these varieties, they developed two sets of variables (see Fig. 3). The first dimension referred to the human–technology relationship, differentiating between "technology manipulating individuals" and "technology empowering individuals." The other dimension pertained to the value and experiences associated with eating, which is "fun-based" and "utility-based." Drawing upon the two sets, four distinctive categories of social contexts were established (see Table I).

As shown in Fig. 1 and Table I, the four zones, respectively, described four types of scenarios on food culture, food production, and consumption in the future world. The four settings served as

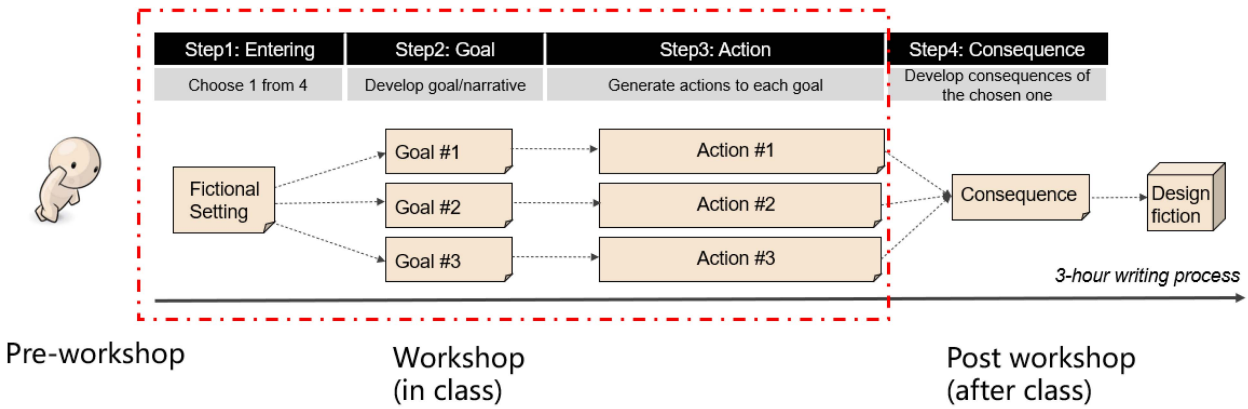

Fig. 2. Illustration of the writing process.

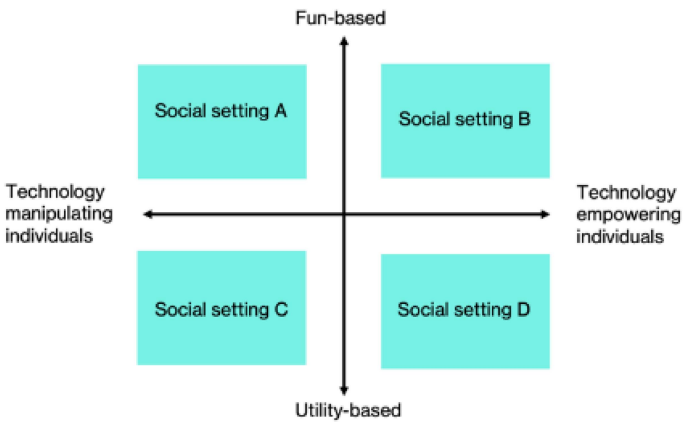

Fig. 3. Four social settings.

inspiration and direction for students' imagination to depart, including food production, food supply, and logistics of food. After reading four different types of future worlds, participants then chose one that they found the most interesting or inspiring to "enter" to start their journey of speculation.

Participants were randomly paired and discussed, inspiring each other to develop fictional elements, such as characters, activities, and experiences based on the chosen setting. In the process of Setting a goal, Taking action, and Developing consequences, we provided participants with semistructured, semiopen sentence patterns so they could develop stories. The story structure was suggested regarding *When* (set in 2040), *Why* (background setting and speculation of future eating), *Where* (set in a specific context), *Who* (build up a persona/a normal person), and *What* (describe a design concept/dietary technology of future eating).

Postworkshop Participants were given one week to revise and finish the draft of fictions about the futures of food. They were also required to develop a food label for the future food that they created in the design fiction, applying technical writing principles taught in the course. A postworkshop survey was conducted to collect participants' reflective feedback on the method and the topic. The following five questions were posed in the survey.

1. What did you like the most about the design fiction workshop?
2. Which part/point of the workshop did you find the most challenging?
3. Compared with before, what changes can you find in yourself?
4. What sets design fiction apart most significantly from other forms of writing practiced in this course, such as rhetorical precis, job application materials, and instructions?
5. Is there anything else you would like to share regarding the design fiction workshop or the topic of "futures of food?"

Data Collection and Analysis We collected students' fiction stories in digital format through a *Tencent Questionnaire* and conducted content analysis to identify elements of social responsibilities in design fiction. Specifically, we recruited two readers to read and code the design fictions using a 6-D coding scheme (see Table II), which was adapted from the Views of Social

TABLE I
DETAILED DESCRIPTION OF THE FOUR SOCIAL SETTINGS

	Original Texts (Provided to Students)	Literal English translation
Scenario A	食物娱乐业： 2040 年，对于很多人，吃、食物本身已经不再重要。人们更加渴望感官的体验和刺激。于是，衍生出了“食物娱乐业”这个新的消费类型。商家纷纷推出以打造愉悦和猎奇体验为主的餐饮服务。纯数据化产生的感官模拟技术和全息影像技术可以带给人们从味觉、嗅觉和视觉上体验的无限可能性。	Food Entertainment Industry: By 2040, for many people, eating and food itself are no longer important. People are even more eager for sensory experiences and stimulation. As a result, a new type of consumption called the “food entertainment industry” has emerged. Businesses are introducing dining services that primarily focus on creating pleasurable and adventurous experiences. Sensory simulation technologies generated purely through data and holographic imaging technologies can bring limitless possibilities for people to experience from taste, smell, and visual perspectives.
Scenario B	2040 年，人造食物的技术（比如 3D 打印，食物修改液等）日趋成熟，开始走近社区和千家万户。“万物皆可吃”和“变变变”等主题，给日常的烹饪带来了无穷无尽的 DIY 乐趣。尤其当进食场景变得多元化之后，进食不再受到时间和地点限制。人们玩出了花。	In 2040, the technology of artificial food (such as 3D printing, food modification liquids, etc.) is becoming increasingly mature, stepping closer to communities and households. Themes like “everything is edible” and “change, change, change” have brought endless DIY fun to daily cooking. Especially as eating scenarios become more diverse, eating is no longer constrained by time and location. People have become so creative in their play.
Scenario C	2040 年，人们的日常烹饪大量依赖自动化机器人。饮食变得十分高效，以精细化营养管理为核心价值。天然食物作为植物，或者用明火烹饪的古老概念早已淡化。取而代之的是由人工智能给出的各种数字、测量和计算。但同时，人的咀嚼能力、消化能力也随之退化，并且越来越容易过敏。	In 2040, people’s everyday cooking heavily relies on automated robots. Diet has become highly efficient, with fine management of nutrition as the core value. The traditional concept of natural food, whether from plants or cooked over an open flame, has faded away. Instead, various numbers, measurements, and calculations provided by artificial intelligence have taken its place. However, at the same time, people’s chewing and digestion abilities are deteriorating, and allergies are becoming more common.
Scenario D	2040 年，生态环境极度恶劣，大量土地被破坏，新鲜食物极度稀缺和昂贵。而长期食用廉价的工业化人造食物，容易造成营养不良。为了增加和拓宽可用作制作食物的资源，越来越多的人开始开发食物生产系统，人类迎来了“没有什么是不能吃的”繁荣时代。	In 2040, the ecological environment is extremely harsh. A large amount of land is destroyed. Fresh food is extremely scarce and expensive. Long-term consumption of cheap, industrialized artificial food can easily lead to malnutrition. In order to increase and expand the resources available for food production, more and more people are starting to develop food production systems, and humanity has entered a prosperous era of “there is nothing that cannot be eaten.”

Responsibility of Scientists and Engineers [31] scale. Originally developed to assess engineers’ and scientists’ social responsibility perspectives, the scale’s categories offer a validated framework for our study. We streamlined it from eight to six dimensions, merging “participation in policymaking” with “services and community engagement,” and blending “societal needs” into “effort to minimize risks.”

We also collected and transcribed participants’ critical reflections and feedback on the creation of design fiction.

RESULTS/DISCUSSION

Content Analysis Results: Coding Results The content analysis based on coding showed interesting results. The results answered the two

TABLE II
CODING SCHEMES FOR SOCIAL RESPONSIBILITIES IN DESIGN FICTION

Code #	Name of Element	Descriptions
1	Consideration of societal consequences (CONSEQ)	• Having a good understanding of potential benefits and risks that arise from the implementation of science and technology [35] • Being attuned to the broader implications for society, such as the disparities in wealth and access to natural resources, as well as the need for equitable social justice [36], [2]
2	Protection of human welfare and safety (HUMAN)	• Believing that the purpose of scientific and engineering practices should promote human welfare, health, and safety [36], [37], [2]
3	Promotion of environmental sustainability (ENVIR)	• Commitment to protect the environment for sustainable development, such as caring for Earth's ecosystem, underscoring the readiness and capability of scientists and engineers to actively preserve and restore our planet [36], [38]
4	Efforts to minimize risks (RISK)	• Encompassing the provocative stance of scientists and engineers in anticipating potential risks and actively taking actions to minimize the risks [34], [3] • Being aware of the uncertainty and possibility of errors in science, technology, and engineering, and critically examining the context, the methodology, and the responsiveness to societal needs and demands [40]
5	Communication with the public (COMMU)	• Being responsible to explain their work and findings to the public, openly address potential issues (both positive and negative) that may arise from these findings • Being responsive to and considerate of diverse perspectives during practice [37], [35], [3] • Being able to communicate and engage with a broad spectrum of stakeholders, including marginalized groups and less privileged communities, to reconcile potential conflicting interests or values [41], [40]
6	Services and community engagement (CIVIC)	• Offering technical expertise to benefit others • Examples are pro bono endeavors such as volunteering to provide free engineering services to communities, participating in voting or advocating for engineering-related concerns, and contributing to advisory boards for policy making [36], [42], [43]

research questions that we proposed earlier in this article. In fact, 97.6% of the design fictions included an element of social responsibility, directly answering, at least in part, RQ1—What effect does writing design fiction have on engineering students' awareness of social responsibility. Frequently mentioned words, such as "imagine/imagination," "creative/creativity," and participants' responses to the survey, revealed that design fiction helped students to notice and critically reflect on the influence of technology on our society through a futuristic lens, which answers RQ2—How will students benefit from design fiction creation in terms of social awareness development?

Brief Overview of the Coding: Coding results showed that among the 168 valid design fictions, 164 (97.6%) showed some social responsibility element. Among the six dimensions, dimensions "1 Consideration of societal consequences (CONSEQ)," "2 Protection of human welfare and safety (HUMAN)," and "4 Efforts to minimize risks (RISK)" are the three most presented dimensions (see Table III).

Detailed Analysis of Each Dimension: Dimension 1 (CONSEQ) was the most prevalent category and can be further subdivided into three distinct groups. The first was the consideration of societal consequences, especially the benefits that future food technology may bring to society. The design fictions with this concern showed an evident optimistic stance towards technological advancement, believing that technology would be able to enhance convenience, efficiency, and overall quality of life. For instance, individuals facing dietary challenges, such as diabetes or weight management, might have their daily life quality improved through future foods.

The second was the consideration of risks. In this category, design fictions had a more pessimistic view regarding technological progress, highlighting concerns related to social issues, such as wealth disparity, social equity, and environmental pollution.

The third group acknowledged both positive and negative outcomes of technology use or perceived technological progress as devoid of value

TABLE III
CODING RESULTS OF DESIGN FICTIONS

Code # and Name of Element	Frequency	Percentage	High Frequency Words (Original)	High Frequency Words (Literal English Translation)
1 CONSEQ	133	79.17%	带来、导致、造成、影响、垄断、穷人、富人，社会精英、平民百姓、贫富差距、公平	Bring, lead to, cause, affect, monopoly, the poor, the rich, the elite, the common people, the wealth gap, fairness
2 HUMAN	120	71.43%	健康、营养、安全、精细化管控、根据人体需要	Health, nutrition, safety (safe), refined control, according to the needs of the human body
3 ENVIR	37	22.02%	环境、可持续	Environment, sustainable (suitability)
4 RISK	83	49.40%	威胁、风险、饮食文化、food culture、家庭团聚、失业	Threats, risks, food culture, food culture, family reunification, unemployment
5 COMMU	4	2.38%	推广	Promote (promotion)
6 CIVIC	5	2.98%	制定、法律	Make or formulate, law

judgments. For instance, a "condensed food pill" could supply all the nutrients that the human body needs; however, producing these pills would require a 3-D printer and raw components. While the process would be quick and simple, potential issues such as allergies and food safety concerns would raise questions about liability.

Discussions of Dimension 4 (RISK) gravitated towards two main focal points: the potential impact of technology on culinary culture and considerations of social (in)equity. These design fictions implied that technological advancements might be accountable for the decline of culinary culture in some areas. They believed that food served not only as sustenance but also carried significant cultural meanings, encompassing familial bonding, leisure enjoyment, reverence for sustenance, and the intrinsic vitality of food. The emergence, prevalence, pricing, and scarcity of future foods could potentially exacerbate socioeconomic disparities.

Another noticeable finding was that Dimensions 5 (COMMU) and Dimension 6 (CIVIC) were manifested comparatively infrequently, appearing in fewer than 10 instances with our collection. The collected design fictions rarely engaged with the proactive engagement of citizens in policy formulation, citizen's involvement and service within society, or communication with the public. The majority of the futuristic food concepts depicted in the design fictions were largely "novel concepts," primarily stemming from the research and innovation of highly skilled technological experts. However, the dissemination and promotion of these novel food concepts garnered limited attention, at least from the participants.

A small portion of design fictions delved into ethical quandaries arising from technological advancement, advocating for the formulation of regulatory policies. However, these appeals for "policy formulation" primarily arose from the standpoint of the "ordinary citizen" rather than from that of an engineer, imploring governmental entities to establish regulations (for example, see Figs. 4 and 5), rather than originating from the researchers' active involvement. A possible explanation for this result is the oversight of communication issues. For instance, the university's technical writing syllabus did not mention public communication, a common shortfall in Chinese writing courses, which typically prioritize form and delivery over audience engagement.

A single design fiction often encompasses multiple dimensions. For instance, a design fiction might incorporate three dimensions, namely: 1 CONSEQ, 2 HUMAN, and 3 ENVIR. Alternatively, another design fiction could involve two dimensions, specifically: 1 CONSEQ and 2 HUMAN. In the datasets, a total of 19 combinations of dimensions

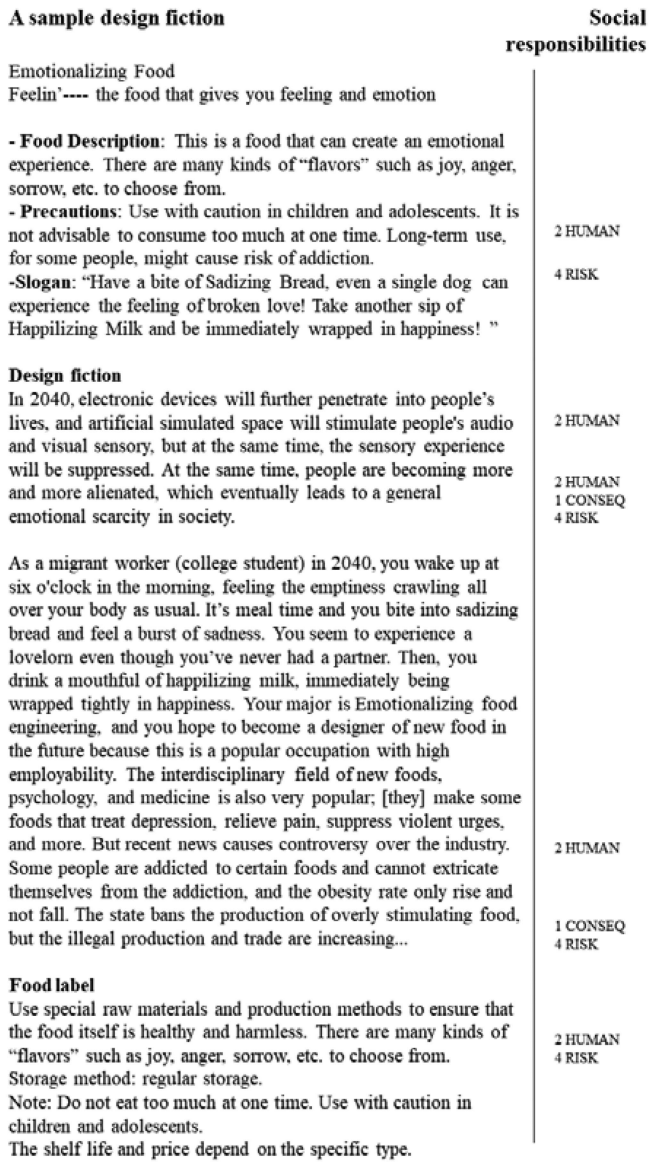

Fig. 4. Sample design fiction themed "emotionalizing food."

were identified (see Table IV). Dimensions 1, 2, and 4 (1 CONSEQ, 2 HUMAN, and 4 RISK) as well as Dimensions 1 and 2 (1 CONSEQ and 2 HUMAN) were notably present, showcasing a discernible disparity in comparison to the other dimensions of social responsibility. This trend underscores that the collected design fictions predominantly gravitate towards social responsibility domains closely intertwined with the human condition. Prominent recurring terms include "convenience in daily life," "efficiency," "health and nutrition," and "social equity."

Sample Design Fiction Here, we use one sample (see Fig. 4) from the study to illustrate what design fictions look like and how they can showcase the awareness of social responsibilities. All of the design fictions, as well as the food labels, were originally written in Chinese. The English version presented in this article is a shortened literal translation.

The example shows how the fiction relates to our instruction. This design fiction relates to the preworkshop materials, as it is inspired by the speculative design concept of future food, "enlarging your sensual experience" (see Fig. 5), even if it does not exactly mirror the one from the #7th food concept. The author adapted this concept to develop and speculate on its function, purpose, etc. It is worth noting how students interpreted the same instructions yet provided different structures relating to different scenarios. In this sample, the student speculated on emotions, suggesting how food can stimulate emotions and be commercialized for this function. The student also speculated on the potential positive and negative consequences for society, showing his or her awareness of the technology's impact on people's lives and society. This idea is innovative, creative, and thought-provoking for readers in 2024.

Participants' Feedback: Postworkshop Survey
The postworkshop survey consisted of five open-ended questions.

What Did You Like the Most About the Design Fiction Workshop?: Participants expressed appreciation for various aspects, including "the creative elements within the process," "the opportunity for open and inventive paired discussions," "the introduction of daring speculative future scenarios," "the blend of practicality and critical thinking in the speculation," and "the chance to let my imagination and creativity boom." Words that were frequently mentioned by participants included "imagine/imagination," "interesting," "possible/possibility," "create/creativity," "thinking, diverge/divergence," "society," and "discuss/discussion" (see Fig. 6).

Which Part/Point of the Workshop Did You Find the Most Challenging?: Regarding question 2, participants identified challenges in areas, such as "how to speculate on a future scenario," "how to establish connections between technology and societal impact," and "how to articulate the notion of social impact, which is such a vague and obscure concept." Words that were frequently mentioned by participants included "imagine/imagination," "scenario," "society," "story," and "food" (see Fig. 7).

Fig. 5. Seventh speculative design concept of future food, “enlarge your sensual experience.”

Fig. 6. Two word-clouds showing the high-frequency words from participants’ response to survey question 1; on the left, the original Chinese words, and on the right, the literal English translation.

TABLE IV
FREQUENCY OF CO-OCCURRENCE AMONG DIMENSIONS

Code # and Name of Element	Frequency	Percentage
124 : 1 CONSEQ 2 HUMAN 4 RISK	39	23.22%
12 : 1 CONSEQ 2 HUMAN	38	22.62%
1234 : 1 CONSEQ 2 HUMAN 3 ENVIR 4 RISK	11	6.55%
14 : 1 CONSEQ 4 RISK	10	5.96%
24 : 2 HUMAN 4 RISK	8	4.77%
123 : 1 CONSEQ 2 HUMAN 3 ENVIR	7	4.17%
13 : 1 CONSEQ 3 ENVIR	6	3.57%
134 : 1 CONSEQ 3 ENVIR 4 RISK	3	1.78%
23 : 2 HUMAN 3 ENVIR	2	1.19%
234 : 2 HUMAN 3 ENVIR 4 RISK	2	1.19%
25 : 2 HUMAN 5 COMMU	1	0.59%
34 : 3 ENVIR 4 RISK	1	0.59%
125 : 1 CONSEQ 2 HUMAN 5 COMMU	1	0.59%
126 : 1 CONSEQ 2 HUMAN 6 CIVIC	1	0.59%
146 : 1 CONSEQ 4 RISK 6 CIVIC	1	0.59%
1356 : 1 CONSEQ 3 ENVIR 5 COMMU 6 CIVIC	1	0.59%
12345 : 1 CONSEQ 2 HUMAN 3 ENVIR 4 RISK 5 COMMU	1	0.59%
12346 : 1 CONSEQ 2 HUMAN 3 ENVIR 4 RISK 6 CIVIC	1	0.59%

Fig. 7. Two word-clouds showing the high-frequency words from participants' response to survey question 2; on the left, the original Chinese words, and on the right, the literal English translation.

Compared With Before, What Changes Can You Find in Yourself?: These could be the enhancement or diminishment of specific skills, the affirmation or deformation of an existing idea or concept, and the acquisition of new experience.

Regarding question 3, participants reported changes that encompassed various aspects, such as "for the first time I begin to think about how the future would look like with this technology," "how to think outside the box," "[to] use my own thoughts to think and create," "start to see the ugliness behind the wonder of technologies," "start to rethink the relationship between artificial intelligence and the future of human society," and "development in logical thinking and storytelling."

Many students recognized a fundamental difference in thinking and reasoning when comparing traditional technical and professional writing genres, such as resumes and instructions, with the process of design fiction. As they noted, the traditional genres are typically characterized by deductive and convergent thinking, while design fiction is marked by its inductive and divergent nature. We need to emphasize that in this study, we integrated elements of traditional professional writing, such as creating slogans and food labels for future food products. This integration allowed students to engage in various modes of thinking, reasoning, and writing, providing a valuable opportunity to exercise and broaden their cognitive skills.

What Sets Design Fiction Apart Most Significantly From Other Forms of Writing Practiced in This course, Such as Rhetorical Precis, Job Application materials, and Instructions?: Concerning question 4, participants noted disparities that encompassed aspects, such as "having no rules, no format, no templates," "applying divergent thinking in writing," "giving me the freedom to develop my thoughts," "workshop being enjoyable, playful, and engaging," "[required to] take a lot of time to present my thoughts in writing," "making the classroom more active," "showing broader and deeper scope of thoughts," and "requiring a higher level of literary skills."

Is There Anything Else You'd Like to Share Regarding the Design Fiction Workshop or the Topic of "Futures of Food?": In response to question 5, participants offered a wide range of insights, including comments like "[this is a] new format and novel experience," "students in need of more writing time," and " [I think that] group collaboration might be a better form of organization."

Conclusion

This study was an exploratory attempt to integrate design fiction into a technical writing course, aiming to foster an enhanced comprehension of social responsibilities among engineering students. We distinguished two main questions that seek answers. Drawing upon speculative design theories and the realm of engineering education, we illustrated how design fiction can be used to revitalize prevailing pedagogical approaches and to provoke students' awareness of social responsibilities. The findings of this study showed that under the guidance of researchers, students engaged in the formulation of design fictions centered on the theme of "futures of food" through a structured workshop. Notably, design fiction emerged as a potent instrument for imbuing engineering students with a deeper understanding of the diverse dimensions of social responsibilities as seen through a 97.6% rate of connection between design fictions and social responsibilities and our student feedback showing they had grown in terms of understanding technology and society.

The contribution of this study is twofold. First, for the teaching of technical writing, it introduces a novel and engaging approach that resonates with Miller's argument from 45 years ago. Miller contended that technical writing is not superfluous but contextual, and not merely positivist but grounded in a "communal rationality" [10]. Although design fiction's speculative characteristics set it apart from conventional technical and professional writing practices, the positive reception from participants underscores the potential of design fiction to serve as a valuable supplement to the existing curriculum.

Second, in the context of engineering education, this study underscores the capacity of design fiction to foster a broader understanding of social responsibilities among engineers, operating at a "macroethical" level. This level delves into the ethical and societal ramifications of engineering projects as holistic entities, in contrast to the "microethical" approach where ethics courses primarily concentrate on engineers' individual decisions and actions [16].

Design Fiction as an Innovative Teaching Approach Social factors have been an integral

part of engineering education. The ABET Engineering Criteria for 2022–2023 set up a series of programmatic expectations related to the cultivation of ethics among students, such as that the program should demonstrate that students have

> an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

and

> an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts. [44]

Within the current educational landscape, colleges and universities employ two primary approaches to the instruction of engineering ethics: a dedicated course on engineering ethics and the introduction of ethical issues into other courses—the so-called "ethics across-the-curriculum" approach (see, for example, Steneck [45]). Our study could be regarded as an "ethics across-the-curriculum" course, a nontechnical course that is also impactful in students' acquisition of engineering ethics [46].

Despite the consensus about its importance, the teaching of social responsibility in engineering education has been monotonous with regard to teaching methods. In many engineering ethics courses, the main pedagogical approach has been to apply moral philosophy to case studies on engineering practice. For example, the course often includes some historical context, although the social aspects of engineering are less frequently addressed. Case studies typically focus on individual actions, analyzing what an engineer should do in specific situations. This approach appears to be influenced by methods used in legal and business education. Many cases involve hypothetical ethical dilemmas or examine accidents and disasters [47].

The justification for the efficacy of this innovative approach as a complementary addition to the prevailing curriculum extends beyond the generation of enthusiasm—a consequence attributed to its novel organizational framework and the selected subject matter. Beyond infusing excitement, the design fiction methodology also cultivates critical thinking, as evidenced by prior work [48]. Within the design fiction process, authors engage in the construction of a fictional future realm, complete with its distinct operational principles and worldviews, seamlessly interwoven with technological elements within the human experience. This creative exercise empowers authors to engage in imaginative speculation and critical reflection concerning the intersections of technology and human society. It is worth noting that although speculation should not be deemed inherently superior to ethical case discussions, it does provide authors with a heightened degree of freedom and openness that is less practiced in discussions.

Engaging with these case studies enables students to acquire insights into safety concerns within engineering design. Furthermore, it provides them with a nuanced understanding of the intricate interplay among stakeholders, including design engineers, subcontractors, governmental regulatory entities, the courts, and journalists in the practice of engineering. However, a drawback associated with this pedagogical approach arises as certain students may perceive that although the content is intriguing, the likelihood of their involvement in a high-profile incident akin to the Challenger accident is minimal, thus leading to a perception that discussions surrounding ethics may have limited relevance to their individual experience.

We argue that design fiction offers a remedy to this limitation by affording students the role of "agent" or "creator" within the engineering context. This role endows them with autonomy, authority, and incentive to engage in introspection regarding social, societal, and interpersonal matters. There has been empirical evidence that students are more likely to value social justice concepts when they are "**presented within the context** of—and as highly relevant to—solving engineering problems" [32, p. 741]. Hence, the design fiction methodology not only furnishes students with a contextual framework but, more significantly, offers them the pivotal opportunity to construct this framework and cultivate a comprehensive socioenvironmental landscape. This endeavor entails ensuring coherence, plausibility, accountability, and critical reflection, encompassing not only the existing scenario but also a prospective vision of the future.

Another major pedagogical implication for educators is using design fiction to bring about innovation, excitement, and fun to current coursework. Empirical surveys suggest that

engineering as a profession is becoming inaccessible or uninteresting to potential future professionals in the US [49], [50], [51], and China is currently witnessing a decelerating growth in the enrollment of engineering majors at the undergraduate level [52]. Our postworkshop survey shows that students were very excited about the new approach, and their critical reflection, engagement, and motivation were significantly enhanced.

Moving From Microethics to Macroethics The problem with the traditional individualistic approach to engineering ethics is that it is overly simplistic given modern collaborative engineering practices [53]. Engineers mostly work in teams, and independent decision making is rare [54]. Examining engineers' accountability reveals that individual conditions rarely apply in today's engineering landscape [55]. Comparatively, institutional contexts curtail engineers' autonomy, shaping their choices. This dichotomy is termed microethics versus macroethics.

The concepts of microethics and macroethics introduced by Ladd [56] and further explored in the area of engineering ethics [57], [58], [59], distinguish between individual engineer interactions and broader societal responsibilities. Herkert [58], [59] advocates for a comprehensive ethics education that integrates micro and macro perspectives achieved through multidisciplinary collaboration among ethicists; science, technology, and society scholars; and educators to develop case studies aligning public policy, professional organizations, and engineering codes of ethics.

Therefore, the concepts of microethics and macroethics provide educators a framework to help students understand that ethical considerations extend beyond individual actions and decisions. This dichotomy promotes a holistic understanding of ethical responsibilities, urging engineers to act ethically, not only in their immediate professional interactions but also to consider the broader societal implications of their work.

Design fiction, as our response to Herkert's [59] call to integrate engineering ethics and science, technology, and society, encourages students to explore and envision the broader societal and ethical implications of technologies and innovations. By engaging in the creative process of crafting speculative future scenarios, students are prompted to consider how technology may shape human life, and how their engineering work could impact society, the environment, and various stakeholders on a larger scale. Based on the analysis of students' writing and feedback, we argue that by integrating design fiction into engineering education, such as a technical writing course, educators can provide students with a unique platform to explore the ethical challenges and responsibilities associated with future technology. It encourages a forward-thinking perspective that aligns with the macroethical considerations required in the increasingly complex and interconnected world of engineering.

One notable limitation pertains to the skewed distribution observed in the dimensions of social responsibilities. As depicted in Table III, the analysis underscores a discernible inclination within design fictions towards dimensions closely aligned with human and human body-related considerations, namely: "1 CONSEQ," "2 HUMAN," and "4 RISK," with comparably less prominence attributed to the remaining three dimensions. This apparent imbalance may find its rationale in the choice of workshop theme ("futures of food"), which inherently encompasses human physiological factors. Nevertheless, the way that this thematic context exerted influence over the focal points within diverse facets of social responsibility requires further investigation.

Future Research Finally, we would like to discuss three points regarding future research.

The first prospective line of study pertains to investigate the transformation of awareness to subsequent decision-making processes and eventually translate these decisions into actionable outcomes. This area remains relatively unexplored, thus warranting additional scrutiny in future inquiries. We believe that delving into this aspect of research holds substantial importance for validating the effectiveness of design fiction's contribution to the teaching of technical writing and engineering education.

Second, prior investigation has examined the nexus between preexisting knowledge and social responsibility. For instance, scholarly inquiry has indicated that engineering students tend to agree on fundamental obligations, such as safety and the enhancement of social well-being, yet display a diminishing focus on marginalized and underprivileged groups [45]. The inclinations of students towards social responsibility are a fusion of their inherent perspectives on social responsibility and their preconceptions regarding

the domain of engineering, aligning with the conceptual framework of the Professional Social Responsibility Development Model [60]. Influences from precollege experiences, such as familial values inclined towards volunteerism or engagements in high school engineering endeavors, have been identified as pivotal factors [46]. Subsequent investigations along this line of research could explore the specific ways in which prior knowledge shapes the construction of design fiction.

Finally, it would be valuable to inquire into strategies for effectively integrating prior knowledge into the design fiction process, particularly during the preparatory stages preceding the workshop. Further empirical inquiries are warranted to address these nuances.

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