Teaching Human-Robot Interaction: Using Speculation and Fiction to Make Spaces for Possible Robotic Futures

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***Abstract*— We explore *speculation* ("wondering about how things could be") as a pedagogical tool for teaching HRI. We focus on the potential of speculation to create spaces for discussion and debate on future HRI scenarios. Drawing particularly on dystopian fiction, students are encouraged to imagine human-robot interactions that offer alternative, "possible futures" in response to the negative consequences of technology. This approach challenges traditional user-centered design by guiding students to prototype complex HRI systems. To illustrate this, we introduce the motivations for and the process of our approach and present case studies from our own course delivery. While our case study centers on designing robotic environments–an emerging subfield of HRI–we see the approach as broadly applicable to the design of social robots and other embodied forms of robotics.**

I. Introduction

Design educators and researchers continuously strive to provide students with the necessary tools to navigate and shape the future of our evolving world. In Human-Robot Interaction (HRI) pedagogy, this often involves fostering methods that address societal needs while anticipating future technological trajectories. Traditional user-centered design emphasizes short-term usability, often overlooking long-term impacts. This results in a 'time lag' between recognizing societal needs and delivering effective, future-focused solutions. Digital fabrication accelerates prototyping but does not resolve the challenge of designing under uncertainty.

Conceptualizing design as a time-lagged, prophetic endeavor reveals that traditional user-centered methods often prioritize immediate, localized concerns, focusing on meeting specific needs within current technological and cultural contexts. Although such approaches provide value in addressing existing challenges, they often limit students' ability to engage actively with potential speculative futures. One crucial insight emerging from the field critiques the assumption that present user needs are sufficient grounds for innovation. For instance, Bannon, Bardzell, and Bødker [1] argue usability-centered approaches can't anticipate future technological and societal shifts.

To address this gap, this paper explores the role of *speculation* – "wondering about how things could be" [2] [3] [4] – in HRI education as a core principle. The objective is to foster a mindset geared toward envisioning comprehensive, multidimensional robotic environments through speculation.

But where do students begin? To inspire "speculating through design," Dunne and Raby (2013) suggest looking "beyond design to the methodological playgrounds of cinema, literature, science, ethics, politics, and art," which provide "fictional worlds, cautionary tales, what-if scenarios, (and) thought experiments" [3]. In our pedagogical approach, we focus on using speculative design to help students engage with potential futures, particularly through dystopian fiction. This approach encourages students to prototype environments where interactions unfold, offering possible futures for human-technology relationships as a recourse to dystopian fiction's "cautionary tales."

This paradigm shift in HRI design pedagogy is informed by a growing body of research and practice, including the foundational work from three ACM workshops co-convened by one of the authors of this paper: *Archibots: Intelligent and Adaptable Built Environments* (Ubicomp'09), *Ar-CHI-Tecture: Architecture and Interaction* (CHI'12) [5] and *Interaction and Architectural Space* (CHI'14) [6] which, collectively, emphasized the importance of considering not only the objects of interaction but also the architectural and contextual spaces in which they reside. These workshops underscored the value of integrating architectural thinking into HRI, highlighting how physical and social spaces shape and are shaped by technological interactions as time unfolds.

Like architecture, fiction captures the unfolding of time and lived experience, making it a generative medium for design speculation. Fiction provides a rich space for students to envision diverse future scenarios, fostering design practices that reflect the present while anticipating and exploring unforeseen, multidimensional outcomes. Speculation inspired by fiction encourages students to challenge, extend, and/or disrupt technological paradigms and traditional user-centered approaches. By speculating through fiction, students experiment with designing systems, interfaces, and spaces that anticipate future societies' challenges and possibilities, opening uncharted territories for possible, future human-robot interactions.

A. Designing the Future

Our pedagogy of speculation is inspired by *Speculative Design* and *Future Studies* [7]. Kozubaev emphasizes Future Studies as "critique coupled with actionable insight" [7]. This dual focus supports a pedagogical approach that helps students both critique existing systems and envision alternatives.

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Our approach also draws from Design Futures [8] and Design Fiction [9] [10] [11], which use storytelling conventions to prototype experiences and social systems. Design Fiction, as Blythe notes, emphasizes the "diegetic" nature of objects – placing them within functioning, imagined worlds. While one form of Design Fiction, science fiction, may provide valuable speculative tools, it may also reproduce dominant cultural assumptions. A form of Design Futures, Afrofuturism [12] [13], addresses this by centering marginalized perspectives and imagining inclusive, justice-oriented futures. While not focused on Afrofuturism, our HRI pedagogy shares its emphasis on equity and diversity [13].

Our pedagogy also emphasizes the pedagogical value of making and learning through artifact creation. As Blythe and others argue, *Research through Design* [14] [15] is valuable both for its outcomes and process [14] [15]. Students engage with speculative futures by creating complete yet adaptable artifacts that respond to new insights and contexts. By drawing on dystopian fiction, our approach helps students navigate "negative" use cases, addressing problems and contradictions in speculative futures. In doing so, it encourages students to consider broader implications of robotic design.

B. Exploring and Navigating the Entanglements

Our pedagogy of speculation is moreover inspired by Jennifer Golbeck's film-based HCI pedagogy [16], in which students design technologies for characters from *Ghostbusters*. While Golbeck's approach introduces HCI through imaginative contexts, our course expands this model by engaging students in speculative ecosystems involving multiple timelines, characters, and entangled systems. Through techniques like user enactment [17] [18], students critically explore complex, environmental-scale interactions and envision alternative futures.

In our pedagogy for an HRI course, we harness the potential of integrating fiction, particularly dystopian narratives, as a critical tool to engage students in confronting the unpredictable and challenging "wicked problems" of the future [3]. Rather than selecting a single technology from a movie scene as design inspiration, we encouraged students to explore the broader complexities of interactions across multiple artifacts, protagonists, and environments over extended time and space [19]. We positioned fiction not just as a backdrop for technology design, but as a vibrant, evolving field of interactions. Through our pedagogical approach, students learn to think about HRI design as dynamic ecosystems involving diverse artifacts and their integration into a larger socio-cultural and technological landscape. The focus is on the negotiations between individuals and their environments, seen through the lens of fiction, where the world is dynamic and multifaceted. Thus, in contrast to traditional HCI and HRI assignments emphasizing user research and problem-solving based on immediate user needs, our approach, based on speculation, challenges students to think critically about the systems they create and the broader implications of their designs in contexts. The focus is not on solving specific, predefined problems but exploring and navigating the entanglements of social, technological, and environmental dynamics. This fosters students' understanding of the complexity of creating interactive systems for future worlds. In short, while Golbeck's course focuses on a singular device, ours encourages broader, systematic thinking about unpredictable human-technology interactions.

II. A Pedagogical Approach for HRI Design

Our pedagogical approach involves five steps, each aimed at fostering a student's ability to develop human-robot environments that respond to complex and dynamic futures. The five steps of our approach are described here.

A. Mapping the Work of Fiction

The first step is to map the chosen speculative fiction's world, focusing on its protagonists, environments, and systems of interaction—social, psychological, political, economic, and technological. Students explore the entire ecosystem, including human, non-human, and environmental relationships. Through still images, video, text, and found artifacts, students discern the complex web of connections defining how characters, spaces, and technologies interrelate. This mapping process allows students to position themselves within future-oriented systems and better understand how design choices can shape these environments.

B. Generating Plausible Backstories

We employ "method acting" techniques to develop rich backstories for protagonists, similar to the Stanislavski method [20], encouraging students to construct the character's attributes like motivations, desires, intentions, relationships, and societal contexts. Rather than assigning superficial attributes, students delve into questions that define how these protagonists would interact with and be shaped by their environment, such as "Who am I?", "What do I want?", and "What challenges must I overcome?" By answering these questions, students generate more relatable characters and understand how these fictional users will interact with imagined future technologies. This process informs the design of interactive robotic environments, where understanding the full narrative context of the characters is essential to imagining how interactive systems evolve in response to social challenges.

C. Scenario-in-the-Text

We encourage students to write new scenarios *directly into the text* of the work of fiction, particularly at critical junctures where the protagonists' outcomes could shift due to interactions with the latest technologies. These reimagined scenarios act as "turns in the tale," offering an opportunity to explore how alternative futures might unfold when the characters engage with prototypes of interactive robotic environments. Students are invited to envision these interventions as intentional "correctives" in fiction, empowering students to move beyond their initial understandings of technological

constraints and reconsider the impact of design decisions on large-scale environmental dynamics. Students engage in speculation by reworking the narrative, critically analyzing, and reshaping their design process.

D. Configuring the Artifact

In contrast to Design Fiction's focus on technological artifacts, our pedagogical approach positions the artifact not as a singular object but as part of an ecosystem of distributed components. Students move beyond designing isolated technologies, learning to develop responsive, mutable environments shaped by interactions between human and non-human actors. As in the work of Lucy Suchman on "configuration" [21], we conceptualize these interactive robotic environments as dynamic, evolving systems that respond to various external forces over time. Students work with rapid prototyping techniques to explore how multiple artifacts (software, devices, spaces) can intersect in these speculative environments. Rather than simply aiming for feasibility, students are encouraged to consider how their designed artifacts might evolve and adapt through ongoing, unpredictable interactions, preparing them to think beyond current technological limitations and toward systems that anticipate future frictions and possibilities.

E. Evaluation, Defined by Enactments in Social Settings

Evaluation involves "user enactments" where the designer steps into the protagonists' shoes, engaging with their designs in a scale model of the future environment. This experiential learning process lets students assess how their designed systems might behave in practice directly. This approach draws inspiration from Lofland's "social setting framework" [22], where each social setting involves a web of interactions between human and non-human actors. Evaluation becomes a dynamic process, incorporating enacted scenarios that reflect potential real-world interactions in envisioned futures. Students may scale down these environments, using scale models and figures to test prototypes and ensure their artifacts are responsive to diverse future contexts. This form of evaluation highlights technology's complexity and social impact at the environmental scale, encouraging students to think holistically about how their designs influence and are influenced by technological and social systems.

III. Case Studies with Ballard's "Stellavista"

Our pedagogy was implemented from 2018 to 2025 in an upper-level course with graduate and advanced undergraduate students from mechanical engineering, computer science, HCI, and design. The course, fulfilling robotics minor and graduate program requirements at Cornell University (in Ithaca, New York), guided students in exploring relationships between people and environments through dystopian fiction. Drawing from Ballard's "The Thousand Dreams of Stellavista" [23], students designed robotic environments responding to narrative moments where technology threatens human relationships. Using tools such as 3D printers, CNC routers, microcontrollers, and a woodshop, students fabricated functioning, intricately crafted prototypes for possible futures.

In Ballard's narrative, a young couple, Howard and Fay, move into one of many robotic houses in a desert community near Los Angeles. These "psychotropic" homes sense inhabitants' emotions and physically – and atmospherically – "morph" in response. As Ballard relates, many of these homes had malfunctioned over time, leading some of them to be decommissioned or reprogrammed to limit their functionality. When Howard and Fay's marital difficulties are sensed by their robotic house, it becomes a threat to not only their relationship but also to their physcial well-being. Ballard's story was selected for its striking portrayal of what can go wrong when technology, originally intended to improve our lives, spirals out of control.

In our course, students worked in teams of (mostly) three to create preferred futures for the protagonists, remaining mindful of real-world applications for future societies – anticipated, plausible, likely, or inevitable. Student teams created projects that ranged from highly speculative and imaginative systems to those that more concretely suggest a technical pathway forward (e.g.,, *Axis* in Fig. 1E, and *Ripple* in Fig. 1F). Notably, these two projects informed the instructor's ongoing Robot-Room project (Fig. 2), an US NSF-funded research initiative that frames HRI not just as a robot acting in a space, but as the space itself becoming a robot, inhabited.

To ground these speculative explorations in practical and technical outcomes, students were required to produce a fully functional working prototype, a video that clearly demonstrated system operation and user interaction, and a comprehensive written report. The report was expected to include a use-case scenario, a design narrative, technical descriptions of input and output components, labeled diagrams of electronic systems, reflections on the design and fabrication process, and the system code. These structured deliverables enabled a more robust engagement with HRI, not only encouraging speculative thinking but also anchoring it in tangible, testable systems that meet a high standard of technical and professional rigor.

The following subsections trace the unfolding process of using speculation as a pedagogical approach for teaching HRI – a brief report on the outcomes. While this paper includes only a few selected student outcomes (Fig. 1), our supplemental video (https://vimeo.com/1070653869) offers a visually rich overview of some student outcomes guided by our pedagogical approach.

A. Mapping the Work of Fiction

After reading Ballard's story, student teams mapped it, identifing its protagonists, places, and processes, particularly emphasizing human-machine relations. The students accomplished much of this activity through discussion and note-taking while working through the text. This mapping captured a complex entanglement of people, technology,

place, and culture: the social relationships of the characters, the interactive technology of the house, the network of spaces within the house, and the notorious and mysterious history of the house marked by its high-profile, previous owners. Of particular interest was Howard and Fay's relationship as it evolved through the story, and the impact particular technological systems of the robotic house had on this relationship.

B. Generating Plausible Backstories

To "paint portraits" of the protagonists—termed "augmented personas"—students used Stanislavski's seven questions to develop backstories for Howard and Fay. While doing so, each group created or sourced images reflecting their vision. Fay (30 years old, freelance writer) emerged as a stronger character: opinionated, introspective, curious, yet acquiescent. Howard (34 years old, lawyer) was career-driven, social climbing, dismissive, and purposeful in his smiles. Through mood boards and sketches, teams elaborated these characters' complexities and dynamics, which are further revealed in the subsequent scenarios.

C. Scenario-in-the-Text

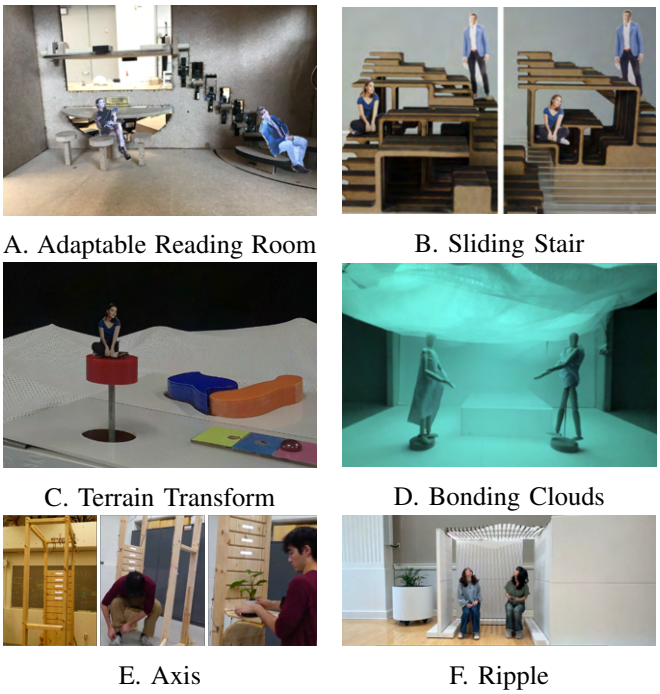
At this juncture in designing better futures for Howard and Fay, the student teams composed scenarios to be inserted directly into the published text of Ballard's dystopian story. After the traumatic incident within the story, the inserted scenarios acted as a corrective measure—a turn in the tale—for a possible preferred state that the team strives to achieve through the artifact design. Each team focused on one area of the house and the technology there, seeking to conceive an improved state of affairs from the malfunctioning technological system afflicting the couple. The scenarios of each team, embedded into the original text, promised a better prospect—for technology, the two people, and us as the designers and inhabitants of a yet-known future.

One team project, the *Adaptable Reading Room* (Fig. 1A) was an idealized workspace that connected the indoors and the outside and, meanwhile, Howard and Fay. Another project, the *Sliding Stair* (Fig. 1B) offered two features responsive to Howard and Fay's problems: the dynamic opening of a kitchen space made accessible to both parties, and the dynamic creation of a stair connecting two levels of the home and, at the same time, two people.

D. Configuring the Artifact

In configuring the artifact, students used various tools, including mood boards, sketches, and charts, to make visible the fictional work's people, processes, and places. Prototyping varied from low- to high-fidelity, with some mechanisms becoming quite complex to achieve functional prototypes.

Projects ranged from kinetic floor forms like *Terrain Transform* (Fig. 1C), to mood-responsive ceilings like *Bonding Clouds* (Fig. 1D), and gesture-reactive walls like *The Axis* (Fig. 1E). These projects involved rapid prototyping using 3D-printed elements, servo motors, gesture and sound sensors, and modular frames, allowing students to engage in HRI work grounded in sensing and actuation at the environmental scale.



A. Adaptable Reading Room B. Sliding Stair

C. Terrain Transform D. Bonding Clouds

E. Axis F. Ripple

Fig. 1: Some student outcomes from our course delivery following our pedagogic approach.

E. Evaluation Defined by Enactments in Social Settings

In "user enactments," the teams of students evaluated their designs formatively and summatively by having team members assume the role of Howard and Fay, tracing the unfolding text and embedded scenarios, constructed (to the fullest extent possible) in the "physical form and the social context of simulated futures" [18]. This process of user-enactment to scale, which follows the CoDAS method [24] of our lab, advanced the developing designs from low to high-fidelity prototypes, permitting a qualitative assessment of the outcomes and a basis for reflection on each. Essentially, the prototypes, all designed around a single house for a single "real" site that we identified in class, served as the stage for various events to transpire over time, representing an extended, rather complex day-in-the-life of interactions between people, processes, and places.

Among the projects evaluated through user enactment, *Ripple* (Fig. 1F) stood out for its focus on emergent social interaction. The team built a sculptural canopy with two side-by-side stools, using ultrasonic and sound sensors to drive movement and lighting based on proximity and conversation. In its idle state, the canopy blinked softly and remained still. With one person seated, the canopy began a slow, wave-like motion. When a second person joined, the movement accelerated. And with conversation, it rippled at full intensity. Enacted fictions – where students played the roles of the characters found in the fictional work – served to evaluate how well the system scaffolded social connection through

subtle environmental cues, showing how speculative robotic artifacts shape social dynamics, grounding in lived scenarios.

IV. Discussion

Using speculation and fiction, our HRI pedagogy promises a broader approach than traditional methods, emphasizing socio-material artifacts that span human-technology interactions across time and space. By leveraging fiction, especially dystopian narratives, students can explore complex societal issues and imagine future technological contexts [1] [7].

With speculation at its core, our pedagogical approach fosters a generative, exploration-driven process where students envision interactive environments and long-term social-technological dynamics. It encourages critical thinking about future societal needs rather than focusing solely on current product iteration. Our pedagogy of speculation allows students to design not just for present-day, market demands but for speculative future scenarios, challenging the status quo and pushing boundaries [15] [16]. Unlike traditional human-centered design focused on known users and environments [25], our approach helps students develop skills to speculate and design for complex, possible future environments. Through the inspiration of fiction, students investigate the societal impact of technology and strive to design with more thoughtful, long-term perspectives [26] [27]. Ultimately, a pedagogy of speculation equips students with the skills to conceptualize future interactive systems, thereby expanding their understanding of how technology and human behavior may evolve together [3] [4].

An important aspect of this course was balancing students' creative freedom with the structured learning objectives. Each student team chose its own focus and crafted unique narrative test-insertions to explore speculative human-robot interactions. Still, all projects were expected to adhere to three central HRI criteria: (1) to design and clearly communicate the human-robot interaction using established HRI methods such as written scenarios, storyboards, and video storytelling; (2) to incorporate physical movement of mass in response to inputs, grounding the designs in foundational robotic principles; and (3) to engage with socio-environmental contexts.

While our course delivery focused on student teams creating robotic domestic systems (e.g., furniture, stairs, walls), the pedagogy of speculative design presented here holds broad relevance to HRI education more generally. So, if the aim were to develop a social robot for a child, our speculative approach would foster rich exploration drawing, for instance, from Ishiguro's novel, K*lara and the Sun*, encouraging students to imagine a robot responsive to the nuanced social dynamics, ethical dilemmas, and future interactions of the fictional work rather than only the constraints of immediate usability and practical efficacy. By prioritizing speculation, students develop skills to critically engage with the future implications of robotics, regardless of the form.

It is worth noting that the explorations undertaken in the delivery of our course not only served as valuable pedagogical experiments in speculative design and HRI but also contributed directly to shaping the instructor's ongoing Robot-Room project. Student projects (i.e., *Axis* in Fig. 1E and *Ripple* in Fig. 1F) demonstrated how responsive environments can meaningfully adapt to human presence and behavior through embedded sensing and actuation. These speculative yet functional prototypes foregrounded the idea of the inhabited robot, in which interaction is embedded in spatial, physical elements such as walls, ceilings, and furnishings. Inspired by this work, the Robot-Room (some early rendering of it in Fig. 2) extends some aspects of the student work into a fully reconfigurable, robotic living environment, where ceiling and furniture components physically transform in response to voice commands, touch panels, or mobile inputs. Here, the pedagogical process led to course delivery serving as both a site of learning and a catalyst for robotic laboratory research.

Fig. 2: Two views of a robot-room under development by the authors: Left–a configuration of furniture; Right–the room's morphing ceiling.

V. Conclusion

In a *New Yorker* article [27], Adam Gopnik reflects on the intertwined nature of dystopia and utopia, citing the words of John Stuart Mill: "Dystopia is how utopianism turns back upon itself" [27]. This paper similarly asks: *What might student HRI designers speculate from dystopian fiction?* Specifically, drawing on Ballard, *what value lies in designing rooms inspired by the single, detached home portrayed in such works?* Gopnik offers an apt response: "If it seems callous to suggest that making...beautiful rooms can make for a better world, it's immensely moving to see how powerful that idea was for the utopian thinkers of the later nineteenth century" [27]. Gopnik sees the wallpaper of William Morris, for one, as the threshold from the domestic interior to a better world outside – a physical token of Morris's courageous vision for the future.

Our pedagogy of speculation guides students in exploring human-robot relationships through fiction to envision robotic futures. As early validation, students reimagined a dystopian psychotropic house wreaking havoc on a couple, redesigning parts of it to foster a more harmonious home. As Gopnik observes, "We always want to get past the room we're in, to break out and change the universe," yet "the lesson that life tends to teach...is that change begins at home and that we can't escape rooms on our way to worlds. The world is

made of rooms" [27].

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