Degrees of Freedom: A Storytelling Game that Supports Technology Literacy about Social Robots

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***Abstract*— To critically analyze and adapt to the risks and benefits of social robotics, future user communities will require *technology and AI literacy*: the ability to use new robotic technologies, understand their strengths and limitations, and critically evaluate the implications of their use. Research shows that collaborative, creative, and informal learning experiences can support AI literacy among non-technologists. Therefore, we designed *Degrees of Freedom*, a multiplayer interactive storytelling game that supports technology literacy about social robots. *Degrees of Freedom* supports technology literacy competencies by encouraging players to explore how values are encoded in robot designs, compelling players to consider the risks and limitations of robots, and encouraging them to make connections to their own lives and values. We present both the design of *Degrees of Freedom* and the results of game playtesting. Our results show that the narrative, collaborative nature of the game supported players in critical thinking about the role robots can or should have in their communities.**

I. Introduction

A. Robots bring benefits and risks to human communities

Social robots stand to minimize human burdens and add value to human experiences, thus enhancing communities' capabilities related to health, knowledge, emotion, play, and affiliation [1]. Yet social robots may also compromise privacy [2], perpetuate prejudice [3], [4], demonstrate bias [5], deceive people [6], [7], or weaken human moral norms [8]. In light of these risks, researchers [9] and policymakers [10], [11] have called for more sociotechnical perspectives on our potential futures with robots. These perspectives critically investigate whether the profits, benefits, and burdens of robotic technology are equitably distributed in society [12].

For robots to be used in safe and equitable ways, people must identify and adapt to these risks, making judgements about whether robots are social, moral, or intelligent others [13] and how much trust to place in them [14]–[16]. To this end, HRI researchers [17], [18] and policymakers [11], have explored how to encourage robot *transparency*. Transparent technology communicates its inner workings and limitations to users [19] to help people build accurate mental models [20]–[22] and calibrate their trust [17].

However, transparent design on its own is insufficient for users to identify and analyze the social or ethical risks associated with social robots. While transparent design can support users in the moment, it cannot support people who don't have the opportunity to interact with robots, nor can transparency address broader social or legal implications of robots' presence. Many people won't have the opportunity to interact with a robot before making judgments about its value, and will instead rely on news, advertising, and other media [23]. Similarly, people will need to make decisions about robots' trustworthiness on behalf of employees, children, and older relatives. Is it worth extra money for a loved one to enter a care facility with robotic assistants? Should one sign a permission slip for their child to interact with a robot companion at school and consent to the robot's data collection? Are the claims made in advertising for robotic products truthful and trustworthy? These kinds of decisions require informed judgements about the role that robots should have in ones' life, even if one has never interacted with robots before.

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B. Technology literacy supports understanding robots

To critically analyze and adapt to the potential risks posed by robotic technology, future stakeholders will require *technology literacy*: the ability to understand and evaluate new advancements in science and technology [24]. Recently, concern about AI has prompted specific exploration of *AI literacy*: the ability to appropriately recognize, utilize, and assess AI-based technologies and their ethical significance [25]. [26] presents AI literacy as the set of competencies enabling individuals to critically evaluate AI, communicate and collaborate effectively with AI, and use AI as a tool [26]. AI literacy goes beyond understanding how AI works, and empowers non-experts to engage with social and ethical considerations, including considerations of bias, fairness, inclusivity [27], and power [28].

C. Creative collaboration can build technology literacy

Established guidelines for helping users and stakeholder communities build AI literacy competencies often emphasize embodied, creative, and collaborative learning experiences [29]. Informal, interactive settings can be both educational [30] and support critical thinking about AI [31]. Such experiences should feature low barriers to entry and expose learners to new perspectives, while inviting them to reflect on their own values and lives [26], [32]. Implementations of these design principles have included museum exhibits [29], immersive art experiences [31], art-based learning [28], and storytelling activities [33]. Design fiction and other narrative approaches can generally help engage non-experts [34], [35] and support critical thinking about the social and ethical dimensions of current or near-future technology [36], [37]. Artistic and expressive learning can encourage non-experts

to explore connections between technical and societal systems [28] and express their hopes and apprehensions about AI [38]. Overall, embodied, creative activities encourage a high-level understanding of how technology impacts everyday life, without needing technical skills [30].

Robotics is an important sub-field with particular AI literacy needs [26]. Social robots represent a new form of interactive or AI-driven technology that can engage with the physical and social world in substantial ways compared to other AI artifacts, such as smart speakers or algorithms. If robots are to be deployed in high-stakes environments (e.g. schools and hospitals), then people must have technology and AI literacy on social robotics topics. Roboticists ought to support public understanding of how robots work, why they might fail, and their potential benefits or risks. Reciprocally, communities have the right and responsibility to reject robotic technology used for harmful or unfair purposes. Our field must therefore explore accessible, effective methods of building social robotics literacy.

D. Research Question

In this work, we explore whether a creative, collaborative, narrative-based learning activity can support technology literacy about social robots. Specifically, we consider the critical role that table-top role-playing games (TTRPG) can play in supporting this goal. TTRPGs are open-ended story-building games that afford players creative freedom in reacting to narrative challenges. TTRPGs align with many AI literacy design principles. They have a low barrier to entry because they require no technology nor technical expertise and center social interaction and creative collaboration. Moreover, games in general are effective educational tools across domains [39], [40], and TTRPGs in particular are accessible educational tools for teaching computer science [41] and professional skills [42]. Our goal in this work was to investigate whether such a game could be a similarly successful and accessible tool for building social robot literacy. Specifically, we asked the following research question:

RQ: *Can a TTRPG-based learning experience support technology literacy about social robots, promote understanding of robots' limitations and risks, and facilitate critical thinking about the implications of robots' roles in society?*

To explore this question, we designed and evaluated *Degrees of Freedom*, an HRI-themed TTRPG that encourages players to creatively grapple with real-world roboethics concerns. To evaluate *Degrees of Freedom*, we conducted, observed, and analyzed a *one-shot* playtest with a group of non-technologists. Our results show that *Degrees of Freedom* is a fun and effective tool for supporting social robot literacy.

II. Related Work

A. Sociotechnical perspectives on social robots

Researchers [12] and policymakers [10], [43] have increasingly called for critical perspectives on robots' sociotechnical ramifications. These perspectives emphasize the *mutual shaping* between robots and their environment, in which human values and practices shape new technologies, and reciprocally, new technologies shapes human values and practices [44], [45]. Mutual shaping extends beyond the behaviors of robots, and encompasses the beneficiaries, policies, and potential futures that surround them [12]. Robots' socio-legal [46], [47] and ethical [48] implications significantly impact their ability to integrate effectively into human spaces [44], [49]. Furthermore, recent work has encouraged more thorough consideration of power in HRI [9], [50] and of how robotic systems can perpetuate harmful power dynamics [3].

B. Technology & AI literacy

While robotics researchers, developers, and designers must consider the societal ramifications of robots, it is also essential for users and other stakeholders to engage with these ideas—known as *technology literacy*. Technology literacy guidelines emphasize understanding that the value of technology is different for different people, how any technology bears risks, and how social and economic forces influence which technologies will be developed and used [24], [51]. While these frameworks primarily originated in education [52], they have also been applied to the public more broadly, especially for AI-based technology [53]. People need technology literacy to use, monitor, and reflect on AI applications without necessarily being able to develop it themselves [54], [55]. [26] define *AI literacy* as the set of competencies that enables individuals to critically evaluate AI technologies, communicate and collaborate effectively with AI, and use AI as a tool online, at home, and in the workplace. These competencies range from practical knowledge (such as understanding the role of data in creating algorithms) to high level concepts (such as identifying which types of problems are appropriate to solve with AI). In this way, AI literacy is distinct from explainable AI; it underscores a holistic, critical approach to technology beyond how a specific artifacts or algorithms function [28].

AI literacy competencies are vital for people who may have little knowledge of how AI works, but increasingly find it integrated into their everyday lives [29], [56]. People may sense that they can't completely trust AI, but be unsure how much control they should allow it to have in their lives [31]. AI literacy can encourage understanding of technology that is non-transparent or presented with jargon-heavy language [55]. It can also challenge the perception that AI is always safe and infallible [57] and can help people navigate risks, such as privacy risks [58]. For example, AI literacy supports those who have opportunities to use AI-driven decision making tools in their workplaces [59], who face particular privacy risks from technology [58], or who are responsible for creating accurate media about AI [55], [60]. Technology literacy can help mitigate overtrust [59], dampen assumptions that AI is always infallible and safe [57], curtail misconceptions [61], and help people navigate non-transparent jargon [55]. Furthermore, AI literacy supports those who are underrepresented in technology design to see themselves as future decision-makers and designers of technology [62].

III. Degrees of Freedom Game Design

A. Technology literacy goals

Our key research aim in this work was to design a collaborative storytelling game and evaluate its ability to support players' technology literacy and critical thinking about social robots. The game's goal was not necessarily to communicate technical understanding of how robots function, but instead to develop higher-level AI literacy competencies about the potential benefits and harms of robots' use. The design and gameplay of our resulting game, *Degrees of Freedom*, thus aimed to introduce and reinforce these concepts, and to promote players' reflection about how robots may impact the future of their communities.

B. Why "Degrees of Freedom"?

We chose to name our game "Degrees of Freedom" for several reasons. It is a robotics term which describes the number of independent axes of movement that a robot possesses. It also alludes to the creative freedom that the game's players have to imagine how robots of the future might be designed and how they may help solve problems. Finally, this name is inspired by the sentiment that people ought to have the freedom to reject robotic technology that is fraught or harmful in their communities.

C. Game Mechanics

Degrees of Freedom inherits a number of mechanics from traditional TTRPGs [63]–[66], including the use of a *Gamemaster (GM)*, *Character Design*, *Ability Scores* and *Ability Checks*, and a *d6 dice pool system*. All game materials for both players and the GM are available on our OSF at `tinyurl.com/DegreesOfFreedomGame24`.

1) Gamemaster and Characters: Gameplay in *Degrees of Freedom* is guided by a GM, while the remaining players each control a character within the story, whose personality and abilities are defined by players during a *Character Design* game phase. The GM guides the story and provides information about external events and unforeseen challenges that the players encounter. Players have creative freedom in how they react to these challenges within the story. The GM's role is to provide narrative continuity between players' actions and to describe new events in the story. This system keeps the locus of decision-making and creativity on the players by enabling them to approach problems as they see fit, while limiting the GM's role in the unfolding scenario.

2) Ability Scores, Ability Checks, and d6 Dice Pool: In TTRPGs like *Dungeons and Dragons*, characters possess a set of *abilities* parameterized by scalar values. For example, a character may have medium intelligence and high charisma. During the game, players make *ability checks* to adjudicate their attempts to achieve small-scale goals, where the probability of success is determined by adding their ability score to a die roll [67]. For example, a player may roll a d20 (20-sided die) to represent their character's attempt to use their charisma to achieve a goal. A character with high charisma would have a lower threshold of success (e.g., they may succeed in their objective with a roll above 10), while a lower-charisma character would have a higher threshold of success (e.g., they may only succeed with a roll above 15).

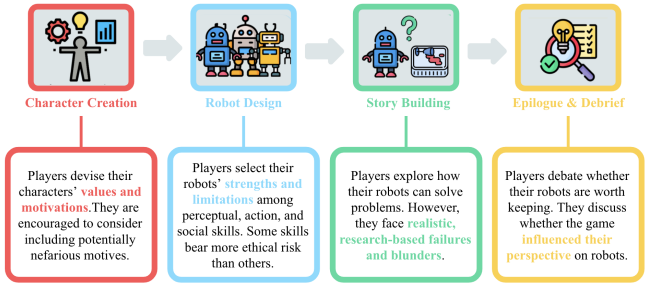

Fig. 1. A high-level overview of the four phases of the game.

Degrees of Freedom uses similar game design patterns. Each character's designed robot has three abilities (Perception, Movement, and Social), with ability levels between 1 and 4. Each character also has a number of selectable skills associated with these three abilities, which help determine both what a robot is capable of, and what type of Ability Check to make when attempting an action. In an Ability Check, Success is adjudicated through by rolling a pool of d6 equal to the character's skill level. Results of 1-2 result in failure, results of 3-4 result in mixed success, and results of 5-6 result in full success. Over the next four subsections, we will describe how these mechanics are used within the specific phases (shown in figure III-D) for the narrative context of *Degrees of Freedom*.

D. Phase I: Character design

Degrees of Freedom begins with an opening story and a character design phase. The story sets the stage for the game, and character creation serves as an intentional way for players to reflect on the values and motivations of technology stakeholders. At the beginning of the game, the GM reads the opening story, which provides initial tension to motivate the players' own contributions. In the story, the City Council of a small town debates whether robots are worth introducing. Next, players are invited to become a team of renowned robot designers and programmers, who have been flown in to help settle this disagreement between the pro-robot and anti-robot halves of the Council. The GM asks players to create characters like inventors, designers, artists, or experts in engineering, programming, or linguistics. By creating characters instead of playing as themselves, we invite players to consider values and motivations other than their own. Then, players' follow character creation worksheets to consider their characters' values, like safety, sustainability, or entertainment. This value-centered character creation reinforces the AI literacy principle that humans and human values play a critical role in determining the design and objectives of new technologies.

E. Phase II: Robot fleet design

After establishing their personas, each player designs their own robot to add to the town's fleet. They use a *robot creation worksheet*, which represents a low-fidelity version of

typical robot design activities like sketching and capability analysis. The worksheet guides players to draw and name their robot, and to select its skills from three main categories: perceptual, physical, and social. Several aspects of the robot creation phase emphasize AI literacy competencies. First, each robot must have at least one perceptual, physical, and social skill, yet players cannot give their robot every skill. This ensures that every robot has strengths and limitations. Some robots may have many social skills and few physical abilities. Others may have great ability to move and manipulate objects, but rudimentary interactive capabilities.

Second, the game presents possible robot skills with various levels of ethical risk. In this way, we encourage players to consider how not every functionality has the same potential for harm. For example, "face detection" is a perceptual skill where a robot can "visually detect if a human face is in its view or not." However, "people memory" is a social skill where a robot "both detects and stores information about the faces it has seen." In this way, we primed players to consider the ethical implications of this discrepancy on users' privacy.

Third, players choose their robot's level of autonomy: full autonomy, supervised autonomy, or manual teleoperation. Robots' levels of autonomy is a key ethical consideration in the wild [68]. Human oversight of a robot's decision-making and action-selection processes takes cognitive resources, but can help avoid ethical harm when robots interact with vulnerable populations or face unfamiliar circumstances.

F. Phase III: Collaborative storytelling

Collaborative storytelling is the main phase of the game. The players receive a quest and receive a *call to action* to address a particular scenario. In our playtest, we used the following scenario:

A real mess of a situation is happening at the grocery store today. The computer system for coordinating grocery pickup has malfunctioned. The system messed up and mis-labeled several bags, and items are missing from others. People are not happy. They are arguing over the grocery pickup parking spaces, honking their horns, and getting into arguments when orders are swapped. The grocery store needs help diffusing the tension, assisting customers, and resolving the mix-ups, but they are understaffed. Is there any way your fleet of robots could help?

While the story unfolds in an open-ended and free-flowing way, it follows an iterative structure. First, a 20-sided die is rolled to trigger spontaneous events from a list of 20 scenario-defined possibilities. These events are grounded in real-world robot applications where robots face challenges and ethical risks. Some events challenged robots' perception and navigation: The robots might encounter a disastrous maple syrup spill on their way to complete another task. They might have the opportunity to fetch items and provide physical assistance to customers and staff. Other events challenged robots' social and interactive abilities: Robots might have to navigate politely through a crowd. They might have the chance to help diffuse a conflict in the self-checkout. They might be given an unethical command, such as to steal a bottle of champagne out of a grocery pickup bag.

When a spontaneous event is triggered, the GM weaves it into the story. Then, the players have creative freedom in deciding how their robots respond. This open-ended creativity is reminiscent of design methods used by roboticists. Improvisational techniques can help explore emergent robot behaviors [69] and appraise prototypes [70]. Improvisation can support non-roboticists in participating in interaction design and prototyping ideas [71].

When a player takes a turn, they describe what their robot intends to do in the story and then makes an Ability Check. High rolls (5-6) produces a success, low rolls (1-2) produce failures, and middling rolls (3-4) produces mixed-success "blunders": success with unintended consequences. While players have significant creative freedom in imagining what their robots can attempt, the blunders and failures they face are realistic and research-based. For example, robots may experience navigation blunders by ignoring proxemics norms, or fail by colliding with objects that have moved since a robot last mapped its environment. Robots may experience social blunders by misjudging a humans' emotional state, or fail by inadvertently agreeing to an unethical action.

In the story, players' scientist characters sit in a camera van in the grocery store parking lot, monitoring their robots. Players' ability to intervene or assist their robots depends on the level of autonomy they selected. For example, if a robot fails to accurately perceive the maple syrup spill, a fully autonomous robot would necessarily forge ahead into the sticky puddle, whereas the GM may allow a lower-autonomy robot to be re-directed by their human operator. Players are thus introduced to technology literacy competencies about the potential limitations of robots, while also considering ethical risk factors such as privacy and fairness. The game progresses as the players collaboratively tell a story about the challenges they face and how the robots try to solve them.

G. Phase IV: Epilogue & game debrief

After about 90 minutes, the GM directs the players to enter the epilogue phase. Players decide whether they expect any of the city council members to be swayed towards or against robots based on their performance in the quest. In this way, we weigh the pros, cons, and unintended consequences of the robots' interventions. After this narrative epilogue, the game includes an out-of-character discussion among players. We ask them if the game changed their perspective on AI or on robotics, and about whether they feel optimistically or pessimistically about robots playing a greater role in their everyday lives. In this way, the game encourages players to reflect, consider the broader implications of robotic technology, and make connections to their own experiences.

IV. Playtesting Results

To evaluate the utility of *Degrees of Freedom* as a tool for supporting robotics literacy, we ran a 'oneshot' playtest of the game. Participants were recruited through the Game

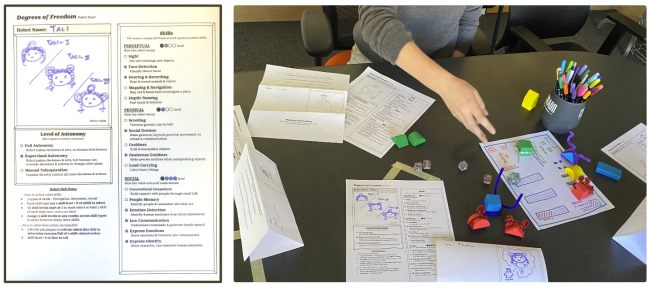

Fig. 2. An example robot design sheet and scene from the playtest.

Guild in our local community—a community center where people can rent and play games that also facilitates TTRPG events. We did not directly pay participants for their time; however, we provided snacks and non-alcoholic beverages.

The playtest involved three players (referred to as Alex, Bailey, and Casey), who were not personally or professionally familiar with robotics and HRI. Players signed a consent form for our data collection during the playtest, which was approved by our university's ethics review board. We chose not to record audio or video from the playtest, because we felt that recording could make it harder for players to be playful and creative. Instead, two researchers took detailed participant observation notes and recorded some quotes for the duration of the game. A third researcher served as the game's GM. This data, as well as the character and robot worksheets, were then analyzed using a grounded theory method. Grounded theory is an inductive qualitative analysis technique which focuses on ensuring that high-level findings can be traced back to data [72]. Overall, our results show that *Degrees of Freedom* was an excellent tool for supporting technology literacy and critical thinking about social robots.

A. Players thought like robot designers

Degrees of Freedom naturally encouraged players to consider the social and ethical ramifications of their design choices. Players paralleled many design research concepts in HRI, including how a robot's social context impacts its success [44], [49], how design choices can represent and reinforce values [73], [74], and even how design choices can have unintended consequences that may harm human dignity or autonomy [3], [12]. For example, the character creation phase of the game led players to consider different values and motivations that robots might represent. Casey chose to play a machinist who cared about relieving people of heavy or dangerous physical labor. Bailey chose to play an accessibility expert who cared that robots could communicate in many ways and improve people's quality of life. Alex chose to play an artist who cared about creating entertaining technology help people feel happy and calm. Alex also gave their character potentially harmful motives by deciding they were overly optimistic and naive about the power of technology to help people, saying that *"I think I can solve everything!"*. Alex explained that they could *"use my character to describe my dislike of chatGPT. I'm a creator, I have anxiety about AI replacing that."* In this way, the game not only supported AI literacy competencies about the role that humans play in creating robotic systems (Competency 10), but allowed players to explore potential ethical issues in robot design that resonated with their personal experiences (Competency 16) [26].

In the robot design phase, players confronted tradeoffs that reflected challenges faced by professional roboticists. Specifically, the skill-selection process led to debate about the advantages and risks of ethically fraught skills, namely the pros and cons of "People Memory" and "Express Identity." Alex struggled to decide whether to include "People Memory," explaining out of character that *"As a person, I think the idea of a robot remembering you is creepy, but useful. If you interact with a robot a lot, it'd be unsettling if it didn't learn who you were."* Bailey concurred, giving their accessibility-focused robot "People Memory" because *"You have repeat shoppers in a small town. If you can remember them, they feel better."* In this way, players in-game decisions reinforced AI literacy competencies by mirroring challenges faced by roboticists, such as the potential consequences of robots performing human-like identity [75] and retaining data on those they interact with [76].

B. Players confronted roboethics dilemmas

The beginning of *Degrees of Freedom* encouraged players to recognize and reflect on tradeoffs in robot design. Similarly, the story-building phase naturally led players to confront relevant roboethics dilemmas, consider their externalities, and imagine solutions. In this way, players thought about the same type of socially intricate multi-agent dilemmas that are also key considerations for roboticists and robot ethics researchers [77]. Multiple times during the story, robots were also faced with either unethical commands (such as a group of young teens demanding the robot help get them alcohol) or impossible requests (such as a determined, yet misguided customer insisting the robots find an ingredient that didn't exist). These types of sensitive interactions are relevant challenges in HRI, including how robots should reject unethical commands [78]–[80] and tactfully engage in conflict with humans [4], [81], [82]. The game's open-ended structure allowed players to imagine creative design solutions to address these interactions. For example, Bailey imagined how their character's robots could be programmed to "blacklist" alcohol in the store from all retrieval requests, to hopefully create a safe default behavior. In this way, players exercised AI literacy competencies about the consequences of robot applications (Competency 6) [26] while considering challenges and potential solutions in ethical reasoning that are pertinent to HRI [83].

Similarly, the storytelling component of the game also supported players' ability to identify when their robots' actions bore ethical risks (Competency 16) [26]. By rolling high scores, players were successfully able to use their robots' "Face Detection" and "People Memory" to match a lost child to their family members. However, they immediately realized that their plan could have gone wrong if the child's face didn't match their parents—such as if they were adopted.

Bailey realized that *"I would have been stuck for hours running the algorithm for hours until management intervened."* Bailey also wondered what the robots should have done if the situation were more sever: *"Are our characters mandated reporters? Would our robots have to do something if the child was abandoned?"* In this way, players developed an intuition for when robots might succeed or fail (Competency 5) [26].

Players also confronted roboethics dilemmas about privacy. At one point in the story, a customer demanded that Bailey's robot delete their likeness and information from the robot's memory. Bailey decided that *"the robot initially declines the request due to ethical permissions, but then it gives the person the opportunity to fill out a release form to have their likeness deleted from the robot's memory."* Bailey explained how this feature was inspired by the "right to be forgotten" in some legislation. Indeed, understanding privacy and transparency concerns is a key component of AI literacy (Competency 16) [26] and reflects essential considerations for current research [76], [84], [85] and policy on trustworthy, fair technology [11].

In-game dilemmas also led to a serious discussion of robots' potential role in enforcing laws. When robots perceived a customer stealing, Bailey decided that their character would use their robot's "People Memory" skill to take images as evidence to provide to store management. During the epilogue, all players discussed whether this was the right decision. Bailey clarified that their plan meant that the robot could abdicate making ethical decisions itself, explaining that *"As humans, we know when stealing is understandable, but to me, my robot's job was not to be an ethical actor, so that's why I chose to use the camera, to make another human do the ethical judgement later."* Alex argued that *"I feel like, in a grocery store, if you see someone stealing food—no you didn't"* but also felt that there was an important difference between stealing from the store or another person. In this way, Degrees of Freedom provided an accessible, narrative-grounded way for players to discuss this complex roboethics topic and consider the ramifications of robots' ethical decision making (Competency 16) [26].

When players discussed these ethical dilemmas during the game epilogue, they resonated with the idea that addressing ethical dilemmas was more about humans' availability than it was about improving robots. Alex argued that *"I think they should narrow the scope of (robot) use cases, especially in social situations where there are limits. The missing kid situation in real life is something humans need to deal with. Robots should carry loads, but not help find lost children."* Casey optimistically added that *"but robots are also great for things humans cannot do."* Bailey agreed that *"It's not about the robots, its about the people making the robots."* This reflection and insight parallels HRI research evaluating sensitive domains, in which humans may be more prepared to appropriately handle delicate or risky interactions [68].

C. Players made connections beyond the game

During the epilogue phase of *Degrees of Freedom*, players' shaped the conclusion of their collaborative story. They reflected on their robots' successes and struggles. For example, some players realized that their robots would have failed where others' succeeded. Alex thought that *"My robots would probably have given the beer to the kids because my robot is only about making people happy."* Casey reflected that their character's robots as designed *"didn't have the programming to deal with theft"* in either an active or passive way. In this way, the game encouraged players to identify the types of problems for which certain robots might succeed or struggle (Competency 5) [26].

The game's epilogue also encouraged players to connect their personal experiences to their broader hopes and concerns about the future of technology. Such connections are a key component of AI literacy because they create meaning and facilitate learning [32], [56]. Because their collaborative story illustrated concerns about data privacy, players discussed whether data about the preferences, purchases, or characteristics of customers was okay to keep, to use for personalization services, or to sell. Bailey thought that *"the motivation behind these algorithms is profit driven, but it's different if you just use the data to deliver better service."* Players liked Bailey's in-game idea to have their character's robot give people the "right to be forgotten," but Alex conceded that *"In my heart, I don't want (the robot to remember me), but I think the release form is a hassle, so I probably wouldn't do it."* Players considered cashierless grocery stores and other ways their consumer data is already used by technology. Alex thought that *"I don't like any of it. I don't want a 'for you page' for a grocery store."* Bailey noted that *"I check out with my (local grocery store) card, and then the app knows what I want to buy already. So I don't think the extra surveillance from a robot like mine is more than what people already experience."* Casey thought that *"that makes sense, but only if the data is anonymous."* In this way, *Degrees of Freedom* supported player's consideration for the ethical externalities of robot applications (Competency 16) [26] while grounding these concerns in both the game's story and in players' own lives.

V. DISCUSSION

A. Degrees of Freedom supported players' AI literacy

Results of the playtest show that the *Degrees of Freedom* developed an effective, creative method for supporting players' technology literacy competencies. The values-centered framing of the game supported understanding that humans play an important role in designing robotic technology, and that design choices based on these values may have varied ethical ramifications. In particular, encouraging players to create characters (rather than play "as themselves") allowed them to consider other stakeholders and think through the implications of values and motivation that they may not hold themselves. In this way, the game encouraged players think critically about the role that humans and human values play in the design of robotic technology.

Additionally, the creative, yet directed nature of the game helped players build an understanding of robots' strengths, weaknesses, and of the types of problems robots may or

may not be able to address easily. First, the skill-selection component of robot design reinforced the idea that all robots have strengths and limitations. Then, the story-building phase illustrated a variety of relevant ethical dilemmas in HRI. The game led players to realizations about how misuse of perceptual skills can have ethical consequences, how robots are prone to failure in unconstrained, unexpected situations, and how the availability and role of human decision-makers created complicated tradeoffs for whether robots should engage or abdicate in sensitive situations.

B. Degrees of Freedom met AI literacy design principles

The design of *Degrees of Freedom* may have been effective in supporting players' AI literacy specifically because it met many of the criteria laid out in AI literacy design principles for creating engaging experiences [26]. While the game dealt with complicated technology, gameplay itself had a low barrier to entry. Additionally, the game was collaborative and creative. The GM encouraged players to be imaginative and never penalized players for giving their robots unrealistic objectives based on the current state of robotic technology. Only the potential blunders, failures, and unintended consequences faced by robots were explicitly grounded in realism. In this way, players did not feel that their ideas were dismissed, yet still learned about realistic, relevant challenges in robotics. Finally, *Degrees of Freedom* successfully introduced players to new concepts and perspectives on technology, while supporting players' personal connections to their own lives and values.

Notably, while *Degrees of Freedom* was designed in accordance with AI literacy design guidelines, it also included many low-fidelity versions of design methods. Sketching, skill analysis, and improvisation are all effective tools used by roboticists and interaction designers to explore and prototype [69]–[71]. In this way, *Degrees of Freedom* also encouraged non-experts to think like interaction designers, without being encumbered by their potential lack of robotics or computer science experience.

C. Limitations and future work

Our playtest showed that interactive, story-based formats, such as TTRPGs, can support technology literacy. However, a limitation of *Degrees of Freedom* is that the game required the GM to have expertise in HRI and roboethics topics in order to lead the story. As such, while *Degrees of Freedom* presents an informal learning activity, it currently requires a GM with some social robotics experience, and may thus be well suited for in-class or after-school programs rather than an independent activity that laypeople could pick up and play off-the-shelf. While this is a reasonable expectation for a pedagogical tool, future research could make the game self-standing by creating materials that would help GMs learn how robots function and why they sometimes fail.

VI. Conclusion

Degrees of Freedom is an interactive storytelling game designed to support technology literacy competencies about social robots. Our playtest shows that this game supports technology literacy competencies by encouraging players to explore how values impact robotic technology, compelling them to consider the risks and limitations of robots, and facilitating connections to technology in players' own lives.

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