"Give it Time:" Longitudinal Panels Scaffold Older Adults' Learning and Robot Co-Design

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ABSTRACT

Participatory robot design projects with older adults often use multiple sessions to encourage design feedback and active participation from users. Prior projects have, however, not analyzed the learning outcomes for older adults across co-design sessions and how they support constructive design feedback and meaningful participation. To bridge this gap, we examined the learning outcomes within a "longitudinal panel." This panel comprised seven co-design sessions with 11 older adults of varying cognitive abilities over six months, aimed at designing a robot to guide a photograph-based conversational activity. Using Nelson and Stolterman's framework of the hierarchy of design-learning, we demonstrate how older adult panelists achieved multiple design-learning outcomes — capacity, confidence, capability, competence, courage, and connection — which allowed them to provide actionable design suggestions. We provide guidelines for conducting longitudinal panels that can enhance user design-learning and participation in robot design.

CCS CONCEPTS

• **Human-centered computing** → **Participatory design**; *User centered design*; • **Computer systems organization** → *Robotics*; • **General and reference** → *Design.*

KEYWORDS

Co-design, participatory design, older adults, social robots, design-learning, photograph

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1 INTRODUCTION

Human-Robot Interaction (HRI) researchers use participatory design to ensure robotic technology meets the needs of older adult users [40, 52, 53]. Such research can involve multiple co-design workshops [3, 26, 31, 34, 36, 48, 50] or even long-term community-based research [35, 43, 44]. One of the benefits of longer interactions between researchers and users is that it enhances users' *learning* about robots [48] and design that can, in turn, enable more informed and constructive user feedback.

Long-term co-design participation promotes users' learning in multiple ways, similar to how designers develop design-learning skills. These skills, as categorized by

While multiple co-design sessions have been conducted in previous research, most studies have not closely analyzed how the abovementioned learning outcomes enhance user participation. To address this gap, we investigate the learning process within a "*longitudinal panel*," which consisted of multiple co-design sessions focused on the design of an HRI activity involving the same group of older adult panelists. Our research aims to answer the question: *How can learning about robots and design in a longitudinal panel enable older adult panelists to provide valuable, constructive feedback on the design?*

The longitudinal panels we describe were carried out as part of a research project centered on enhancing the well-being of older adults [26–28, 31, 31, 32, 49]. This project draws inspiration from the Japanese concept of "ikigai" or meaning and purpose in life [19] that can be derived from personal, interpersonal, and community sources, such as hobbies, family, and volunteering [49]. Specifically, the project aims to develop a social robot that can help older adults address the challenges they face in navigating life after retirement, including issues such as the loss of social ties, changes in supportive social structures, and declining health [37]. The panels focused on developing the robot's capabilities to guide an ikigai-related activity with older adults — prompting them to discuss people, events, places, activities, and objects important to them through sharing a personal photograph. We wanted the interaction to be natural and engaging for older adults, and for the robot's conversation and behaviors to fit their values. We iteratively designed the robot's interactive behaviors in this activity with 11 older adult panelists in seven panels (Fig. 1). Here, we present an analysis of the panelists' process of sense-making about the robot, reflecting on their diverse personal experiences, and building their design-learning. The knowledge they produced significantly contributed to the ikigai robot design.

2 RELATED WORK

2.1 Longitudinal Panels and Design Feedback

We use the term "longitudinal panel" to describe a co-design approach involving the same group of users coming together repeatedly over an extended period to engage in iterative robot design. In contrast to focus groups, which treat the group as an aggregate of individuals with occasional voting to gather data on group opinions quickly [25], the concept of a longitudinal panel draws inspiration from "longitudinal research methods" in which researchers collect data with the same participants over time [7, 16] and "expert panels" in which individuals with relevant forms of experience collaborate to make decisions [51]. While the term co-design 'cohort' could also suggest working repeatedly with the same group of participants [2], we prefer 'longitudinal panel' for its emphasis on the evolving learning outcomes and the iterative co-design process experienced by both panelists and researchers.

Longitudinal panels in various forms in past studies have demonstrated the benefits of user feedback in the design process. For example, in a series of "workshops," Antony et al. developed personas and activities for inclusive robot design, leading to the identification of various motivators for physical activities [3]. Similarly, "long-term co-design" [48] and "situated participatory design" [54] involved placing robots in users' homes for extended periods, ranging from a summer to a year. During these collaborations, participants actively engaged with the robots, programmed them, provided valuable guidelines, reflected on design aspects, and suggested improvements to existing robotic systems [48, 54]. "Community-based research" also incorporates multiple workshops with participants acting as equal partners in the design process [5, 42]. The participants go beyond design ideas and contribute to research tasks including designing interviews, creating workshop tools, collecting materials, and offering feedback on design [35, 38, 44]. In short, these various forms of longitudinal panels demonstrated active participation and important design outcomes, with a key factor to this success being continuous exposure and learning in the process.

Figure 1: The longitudinal panel in action (one participant chose not to sign a media release, so we blurred their face).

2.2 The Hierarchy of Design-Learning

The learning of the panel participants over time can be seen from the perspective of how a designer comes to possess knowledge relevant to the design process, the ability to create new designs, and a particular design style [45]. Nelson and Stolterman suggest there are seven elements in the design-learning process [45]: 1) **Capacity** involves internalizing facts, skills, and understanding [10, 20, 47]; 2) **Confidence** entails trusting one's ability to perform or take action [30, 41]; 3) **Capability** is linked to being able to create or produce [33, 55]; 4) **Competence** refers to learning and recognizing what needs further learning and what doesn't [21]; 5) **Courage** involves the ability to be creative and innovative [60]; 6) **Connection** relates to interrelating with the overall design and the global system and external world [6]; and 7) **Character** represents personal wholeness, personality, and unique design that distinguish one designer from another [10]. These hierarchical design-learning categories scaffold one another: individuals must develop basic routine and adaptive expertise before advancing to value and design expertise [45]. However, one can specialize in a particular skill, becoming more proficient in a specific category over others, and a team can comprise designers with various types of expertise and roles in the design process. Building these design-learning elements with the participants enhances the design feedback from co-design.

2.3 Learning to Support Older Adult Co-design

Learning is essential when designing robots with older adults, particularly since the adults may perceive robots as challenging [61] or too complicated to use [18] due to their limited exposure to such technology. To facilitate older adults' learning, dedicating more time and implementing a structured learning approach can greatly enhance their ability to offer feedback in robot design [11, 50]. Prior research has highlighted how co-design can be enhanced through "mutual learning" [34, 48] and "scaffolding" [8, 58].

Older adults and researchers engage in mutual learning during the co-design process. For instance, as the researchers learn about robot design and how robots can fit into older adults' homes, the older adults can learn about existing robot capabilities [34] or how to program a robot's interaction [48]. Older adults and researchers can also learn mutually through sharing discussion material online, as demonstrated by the "Longevity Explorers" project pioneered by Richard Caro [17]. In this project, older adults participate in peer-based discussions about existing and emerging assistive technologies, while researchers and product developers gain valuable insights from the discussion data shared online [17].

Another method to enhance learning about technology is "scaffolding" (e.g., situated scaffolding [8, 58] or situated participatory design [54]), where researchers gradually reveal technology functions to participants during the design process. For example, Cerna et al. [8] used situated scaffolding to conduct several online workshops with a group of older adults, progressively building their knowledge and skills until they could work independently. Consequently, users enhance their design creativity [57] and no longer require research assistance [4].

However, most mutual learning studies emphasize what was learned about the robot but do not include in-depth investigation or documentation on the design learning process, while scaffolding studies typically discuss learning to evaluate an existing technology but not the design of emerging technologies. To explore the scaffolding of learning in robot co-design with older adults, we conducted a longitudinal panel and analyzed the design-learning process to understand how it unfolds and supports co-design.

3 THE LONGITUDINAL PANEL

3.1 The Panelists and the Research Team

A Ph.D. student and a community researcher led the panels, involving select research team members and 11 older adult panelists from the local community. The community researcher was a retired professional with experience in citizen participation in the aging community for 45 years. The research team included an industry-based researcher, two professors (one specializing in social HRI and one in computer science), and a diverse group of undergraduate, graduate, and postdoctoral researchers.

The research team recruited 11 older adult panelists (ages 62-85 years) from the local community based on word-of-mouth and snowball sampling methods (Table 1). To enhance the diversity of the group, we recruited participants with diverse prior robot experiences. Two panelists were people living with dementia recruited from a local memory care facility, where we plan to perform later evaluations of our designed system. Most panelists were white, aligning with Midwest U.S. demographics [29].

3.2 Robot and Setup

We implemented our ikigai robot design on LuxAI's QTrobot [39] platform, a humanoid robot with a monitor displaying facial expressions, and mobility in its neck and arms. Our panels took place in a university lab. The panelists, the community researcher, and the main Ph.D. student sat around a table with other faculty and student researchers surrounding them. The QTrobots were spaced around the room, in close proximity to the panelists (Fig. 1).

In the first six panels, the robot was Wizard-of-Oz (WoZ) operated with pre-scripted responses and gestures. The WoZ conversation flow improved with each session, progressing from general chatting to discussing a participant's photo at superficial and (later) deeper levels. In Panel 4, we created and added gestures during the WoZ interaction. In Panel 5, we added panel-made gestures with facial expressions created by the researchers. Panel 6 featured facial expressions contributed by both panelists and researchers. By Panel 7, our robot incorporated a Large Language Model and an automatic photo recognition function, making it fully autonomous (see 'technical process' in Fig. 2). The panels thus interacted with an improved prototype each time.

3.3 Data analysis

We analyzed the transcriptions of video, voice recordings, drawings, and written materials based on the principles of Clarke et al.'s thematic analysis [9]. The first and last authors began with an inductive analysis of the robot design outputs (i.e., communication, gestures). As we continued the panel and analysis, we observed that the panelists' gradual skill development matched the seven elements from the design-learning framework and used the framework to refine our codes and themes in deductive analysis. After all the codings were done, we calculated the number of panelists demonstrating design-learning outcomes per session (see Table 2). All the authors reviewed the quotes and codes for how well they matched the identified themes.

The seven characteristics, aligned with the design-learning framework [45], include: "capacity" for understanding robots and ikigai, "confidence" in designing and explaining robot features, "capability" to integrate design elements into the robot, "competence" in evaluating robot elements, "courage" to showcase the robot, "connection" with real-world applications, and "character," reflecting panelists' unique contributions like diverse roles in a sports team [15], identified through repeated behaviors like constructive criticism and summarizer. See supplementary materials for details.

3.4 The Study

The longitudinal panel for the photograph activity took place from December 2022 to May 2023, with 90 minute sessions occurring once or twice a month. Each panelist received a $40 gift card for each session. Each panel was facilitated by the community researcher and included interactions with the robot, co-design tasks, and a supplementary worksheet (available in the supporting materials). These co-design tasks differed for every session, as having a variety of methods could bring out different perspectives from the panelists [52]. Towards the end of each session, we often gave panelists a reflection or other task to do after the panel to inform participation in the upcoming panel (which they humorously called 'homework'). To ensure that each individual had the opportunity to express their ideas and to enhance diversity, we structured our activities to include rounds for sharing thoughts while explaining concepts (emphasized by giving each individual their own opportunity to speak as described below). We also facilitated smaller group discussions, creating a more comfortable setting for everyone to actively contribute.

The workshops were designed iteratively, not to repeat the same concept but to refine and adjust our procedures. More specifically, we started with an initial general plan of topics to cover, but adjusted the content of each ensuing session based on the panelists' understanding of the topic and the research team's progress with the robot implementation of the photo activity (see Fig. 2). The final co-design process consisted of seven panels. All the sessions were video-recorded using an Meeting Owl and an audio recorder.

Below, we describe each panel activity design, and highlight key design-learning outcomes and robot design outputs to demonstrate how the panelists' learning enhanced their design feedback.

3.4.1 Panel 1: Getting to know you, ikigai, and the robot. Panel 1 focused on introductions of the research team and goals to panelists, of panelists and the research team to each other, and of the robot and the ikigai concept to panelists. The introductions were meant to show that we prioritized the relationships within the panel and sought to build a sense of team camaraderie. To scaffold the panelists' learning about ikigai, we reviewed the concept, defining it as their meaning and purpose in life. We provided examples of ikigai sources and asked them to share: *"would anybody like to give an*

Table 1: Panelist demographics and background information

	Self-created pseudonym	Age	Gender	Race	Education	Robot experience	Living status	Living w/ dementia	# sessions
1	Catina	72	F	White	Doctorate	Never seen or used	Memory care facility	Y	7
2	Shelly	74	F	White	Some college	Never seen or used	With spouse	N	6
3	HAL-9000	76	M	White	Masters	Have programmed/built	Memory care facility	Y	7
4	Diane	62	F	White	Bachelors	Have seen in everyday life	With spouse	N	7
5	Big Daddy	65	M	White	Some college	Never seen or used	With spouse	Y	7
6	Laws	72	F	Pacific Islander	Associate	Never seen or used	With spouse	Y	6
7	John	73	M	White	Bachelors	Never seen or used	With spouse	N	6
8	Middle 52	70	F	African American	Bachelors	Have seen in everyday life	Alone	N	6
9	The Wise One	75	M	White	Masters	Never seen or used	With spouse	N	5
10	JJ	70	F	White	Masters	Have seen in everyday life	With family	N	7
11	Anna	85	F	White	Bachelors	Have seen in everyday life	With family	N	6

example of something you do for yourself?" To help the panelists develop a basic understanding of the robot, we introduced and conducted a demonstration of the QTrobot with three volunteer panelists. During the demonstration, the WoZ QTrobot greeted the volunteers and had a conversation about their day and interests. Building on this initial ikigai and robot knowledge, we asked panelists to divide into three groups to create a robot persona. We gave them a sheet to fill in the robot's name, personal attributes, role, and when it should talk to the user. Lastly, to reinforce the panelists' knowledge of ikigai, we asked them to find ten meaningful and purposeful personal photographs before the next session.

Design-learning outcomes: This first panel built the panelists' **capacity** for designing the ikigai robot by developing a basic understanding of ikigai and the robot, as evidenced by quotes from seven panelists. The panelists explored the ikigai concept through explaining their source of ikigai, such as their interests, hobbies, and even goals essential to their lives: *"art"* (Diane$_{62/F}$), *"musical activities"* (the Wise One$_{75/M}$), *"public speaking... I've spoken numerous times in front of large groups about my personal experience with dementia"* (John$_{73/M}$), or *"how about winning a Nobel Prize for doing this?"* (HAL-9000$_{76/M}$). Panelists also gained basic design and robot knowledge in crafting the ikigai robot's persona. For instance, Catina$_{72/F}$'s group created the Ami robot that is *"gender neutral, and multilingual, trying ... [to] help others... establish a life that is full and happy."* The Wise One$_{75/M}$'s team created Bobbi, who was "*empathetic, friendly, able to give a timely response,"* while Diane$_{62/F}$'s team made Jojo that was "*knowledgeable, gives quick but thoughtful responses, ... [and says] 'I don't know, but let me get back to you' or whatever instead of just giving us a bad response."* Here, the panelists brought their values of diversity and inclusion to the robot design, pointed out the robot's limitations, and recognized the robot's purpose of helping others by facilitating conversations.

Some panelists also gave comments not directly applicable to the robot's current capabilities. For instance, Big Daddy$_{65/M}$ suggested the robot could use a sense of smell: *"It notices that [we're cooking] because it has olfactory sensor... he (the robot) could comment on it: 'I smell something cooking. What are you doing?'"*

Robot design outputs: These introductory conversations, designed to build capacity among the panelists, provided valuable insights into their initial perceptions of the robot and what needs improvement. For example, when panelists described what their robot would do in situations where it did not know the answer, we recognized this as a feature we could implement. Moreover, the robot names chosen by panelists provided us with basic elements in creating the persona of the robot we presented back to them in Panel 3. Finally, the olfactory suggestion, even though technically outside our scope, told us that panelists want the robot to have situational awareness, be able to notice changes in the environment, and engage in relevant conversations.

3.4.2 Panel 2: Your ikigai and the robot. As a result of Panel 1's homework, the panelists each brought and introduced us to ten personal photographs. To build the panelists' understanding of their ikigai or sources of meaning in their lives, we asked each of them to discuss and categorize the photographs into related themes. To build their understanding of the robot, we asked panelist volunteers to interact with the robot (WoZ prototype) using their personal photographs to seed the conversation, and asked for their feedback. Lastly, to encourage them to connect their ideas with real-world experiences, we asked them to look out for any robot news or encounters in their lives as their homework.

Design-learning outcomes: While discussing how to categorize their own ikigai sources, all panelists built more **capacity** through recognizing shared narratives and creating categories such as social (family, friends), nature (gardening, galaxy), and activities and events (volunteer, work adventures). Moreover, compared to the first panel, where panelists offered brief answers, in this panel they shared more comprehensive narratives about their own ikigai photographs. For example, when Diane$_{62/F}$ described her background story as she showed her photograph in the 'work adventure' category: *"I am artistic and like to be creative, I made these big flowers out of paper for Mother's Day. I like to draw. I won grand champion at the fair for drawing with my Dad."*

Outside the co-design activities, the panelists' sense of fun and camaraderie created a safe space for them to build **confidence** to express their opinions and encouraged them to provide suggestions about the robot's design in a more constructive manner. For instance, when the robot raised its arms rapidly, resembling a "touchdown" gesture while saying "*Bye-bye*," the panelists responded with enthusiastic and humorous reactions, marked by laughter. As a result, Anna$_{85/F}$ showed her confidence in providing feedback: *"What is the purpose of the gestures?... [The robot was] getting a lot of laughs because... the gestures are nonsequiturs. They*

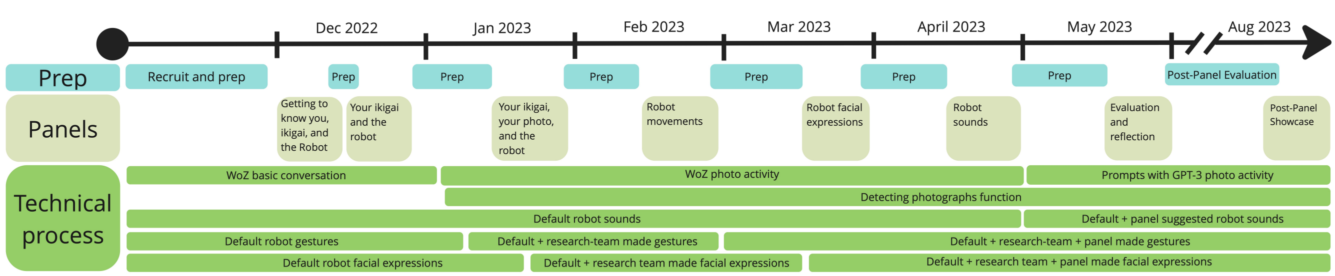

Figure 2: Timeline of the panel preparation (prep), the panels, and the technical progress

mean zero." Similarly, Middle 52$_{70/F}$ also commented on the robot's conversation topic and speed: *"will this thing get to know you, and then be faster?"* She was able to voice a thought she had kept quiet in the first session, and her comments showed that her confidence had increased. JJ$_{70/F}$ also demonstrated confidence as she shared how the robot could improve its conversational capabilities: *"get to know them (the user talking to the robot) their interest, how they talk..., their background."*

Robot design outputs: The panelists' photographs and their thematic categorizations helped us develop a computer vision model to detect important features of photos, and to develop robot conversations revolving around the photo themes. The panelists' stories about their photographs, which demonstrated capacity, offered ikigai-related topics that the robot can explore in its conversations (i.e., art tied to interpersonal relationships). From the questions showing confidence, we identified the importance of creating suitable robot gestures, increasing the speaking pace, and understanding users' backgrounds to enrich the conversation.

3.4.3 Panel 3: Your ikigai, your photo, and the robot. We realized that categorizing photographs only allowed for a surface-level understanding of ikigai for the panelists, instead of going deeper to the ikigai concepts. Adapting to this, we adjusted our pace from the initial single-panel plan to three panels (Panels 1 to 3) to address ikigai and photograph concepts to match the panelists' needs. Therefore, we continued the conversation about ikigai by narrowing it down from ten photos in Panel 2 to choosing one specific photo and reflecting on it in Panel 3. We asked each of the panelists to explain the details of their ikigai and think about how the robot could support this kind of conversation, aiming to enhance the robot's conversational flow and deepen the panelists' ikigai understanding. We ended the panel with a WoZ photo activity. In preparation for the next panel, we asked the panelists to develop a gesture for greeting others.

Design-learning outcomes: As the panelists completed their homework, seven panelists demonstrated their **connection** to the panel and the outside world, highlighting the robot's role in their everyday experiences. Catina$_{72/F}$ recognized the robot pet in their facility: "*One [robot] that is [already there] ... working is ... Sweetie, which is a cat... Lots of people want to hold it and pet it.*" HAL-9000$_{76/M}$ also mentioned a news article: "*somebody did an article... on autonomous cars and a program and it's not going well.*" While these connections were not directly related to the design, they empowered the panelists with the idea that they were contributing to research that intersects with their daily lives.

Eight panelists also demonstrated a deeper reflection on their ikigai while preparing their homework, showing a stronger **capacity** to identify and find links among their sources of ikigai. For example, Shelly$_{74/F}$ shared a picture of her and her husband on a yacht during sunset. She described her discussion with her husband: *"I was talking to my husband about it (the picture), and he looked at the picture, he says, 'Well, I'm here, [your] ikigai'... For me, [my ikigai was] all about being of service to family and friends and strangers, community... instead of throwing obstacles in my way, he'll say 'How can I help?' He brings out the best in me."* The Wise One$_{75/M}$ also provided personal examples that enriched the team's discussions. He mentioned how the robot could answer if his ikigai of playing music declined: *"How did you learn? How does it feel if you're not doing it?... [Does it not] give you satisfaction?"*

Four panelists also enhanced their **capability** for providing feedback on connected concepts, particularly the notion of an 'ikigai robot.' For instance, Big Daddy$_{65/M}$ summarized the panelists' ikigai and offered suggestions on the robot: *"The common denominator that I sense is that for everybody, their ikigai would be a combination of compassion, expression, and communication... I guess just asking more probing questions of meaning and trying to associate the meaning: 'What did that mean to you?'"*

At the same time, the panelists were also showing **confidence** in asking questions about things they did not know. For example, when we asked what is a better response from the robot, Anna$_{85/F}$ with the critical **character** said, "*I don't know how you tell a computer, which response is the best response?*"

Robot design outputs: The conversations about what the panelists learned from ikigai photos provided insights into how the robot could engage with this aspect (i.e., the robot could ask Shelly if her husband's role served as more than just an interpersonal relationship, potentially contributing to her sense of community as well). The capacity and character building from the Wise One also let us understand the importance of considering the negative aspects of ikigai, especially when older adults experience physical decline or other forms of loss relating to ikigai. In such situations, a robot's supportive response by asking how they felt and acknowledging the negative feelings could be helpful.

3.4.4 Panel 4: Robot movements. After making sure the panelists understood the ikigai concept, we moved on to focus on the design of robot gestures prompted by the panelists' observation of incongruity between the robot's gestures and speech in Panel 2. We started with panelists introducing themselves using a "Hi" gesture they designed as part of their homework and warm-up for this panel. Following this, we presented a backstory for the robot,

Table 2: Design-Learning Outcomes Per Session

Panel	Capacity	Confidence	Capability	Competence	Courage	Connection	Character
1	7	0	0	0	0	0	0
2	11	3	0	0	0	0	1
3	8	4	4	2	0	7	2
4	2	4	5	5	0	1	1
5	6	2	4	5	0	1	0
6	0	8	6	7	0	5	2
7	0	1	0	4	0	3	4
Showcase	0	0	0	0	3	0	0

synthesized from their personas (Panel 1). Both of these activities reinforced that panelists' voices were heard and incorporated into the robot design. Next, to provide the panelists with insights into the process of creating gestures for the robot, we introduced them to a predetermined script and worked with them in groups to record the robot's accompanying gestures by moving its arms. As a stepping stone for the next session, we asked the panelists to observe the facial expressions of those around them.

Design-learning outcomes: Despite still being uncertain about the development of the robot, the gesture design process demonstrated an increase in five panelists' **competence** in evaluating what is good or bad to have on a robot. For example, The Wise One$_{75/M}$, mentioned that the robot's head-nodding should be "*not too vigorous, just subtle enough to indicate that you are paying attention.*" Anna$_{85/F}$ also showed competence as she explained why it was not good to have too many gestures: *"[It] is better and more respectful if you quietly listen without movement... to have a movement for every sentence you say, it feels like it's way too much."* Middle 52$_{70/F}$'s group also made a judgment of the robot movement design activity by sharing why her group covered the robot's face: *"when it was a serious conversation, it was distracting to see him smiling. We covered the face, and that way it helped."* These detailed comments showed the increasing competence of the panelists.

Robot design outputs: The panelists came up with 24 gestures which we slightly modified and used in the photograph activity and other robot interactions later on. The panelists also emphasized the importance of subtle robot movements and suggested avoiding excessive gestures to maintain a smooth conversation flow.

3.4.5 Panel 5: Robot facial expressions. Inspired by the group covering the robot's face to avoid distraction, we shifted our focus to the integration of facial expressions. First, we asked panelists to individually fill out a survey about the appropriateness (yes/no) and one-word adjectives to describe the robot's 17 existing facial expressions. This allowed panelists to learn about the robot's face capabilities and allowed us to understand their impression of these faces. Next, we asked the panelists to break into groups to create specific facial expressions (i.e., listening or confusion). By drawing or using robot eyes and mouth cutouts, the panelists learned that the robot's face was a drawing displayed on a screen.

Design-learning outcomes: When the panelists discussed the survey results, five panelists showed **competence** through making judgments of the appropriateness of the faces. When presented with an image of a robot with open *"mouth with a look like fire coming out of it,"* Big Daddy$_{65/M}$ suggested that the face should express empathy instead of anger: *"[the picture] doesn't feel empathetic. It feels the opposite of empathy, and I think you'd want to be cultivating empathy with most of the expressions that QT has."*

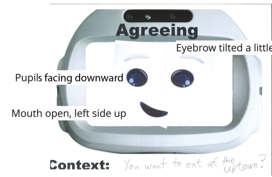

Figure 3: "Agreeing face" designed by the panelists: "*You want to eat at the Uptown?*" context, pupils facing downward, mouth open, left side up, and eyebrow tilted a little.

Two panelists showed their **confidence** as they designed the robot's facial expression and explained their design process. As Wise One$_{75/M}$ was showing the '*agree*' expression with pupils facing down, mouth open (Fig. 3), he described the details of the 'agreeing' face, such as "*people look out of the corner of their eye.*"

Robot design outputs: The panelists produced nine sets of faces, and we implemented some of them on the robot for use in the photograph activity. Their discussion helped us understand how certain faces were perceived as inappropriate for the ikigai-related interaction context: the ikigai-related conversation with the robot should be empathetic, and panelists found faces with aggressive elements to be incongruent with this empathetic context. Their detailed feedback after learning about each design further enriched our understanding of the subtleties in the robot's expressions (i.e., the pupil of the eyes).

3.4.6 Panel 6: Robot sounds. The panelists' emphasis on the subtlety in facial expressions during Panel 5 led us to explore the subtlety of sound during Panel 6. The panelists listened to human-like, machine-like, and environmental sounds, and provided feedback on whether these sounds aligned with the ikigai robot's participation in the photograph activity.

Design-learning outcomes: At the start of the session, five panelists spontaneously shared their experiences with robots in their daily lives in more depth and with more critical insight than before. These experiences showed their eagerness to **connect** the panel with the outside world. Big Daddy$_{65/M}$ expressed concern about AI development, stating, "*if we don't slow up and be careful, AI will take over our world and society.*" Anna$_{85/F}$ also shared "*I think AI is really involved in all of the phone systems... They're giving you ten choices... it's really not good for human beings.*"

Seven panelists also displayed their **competence** in Panel 6, especially when commenting what was good or bad on a demonstration of the robot. Diane$_{62/F}$ said: "*so much better than the first time.*" Big Daddy$_{65/M}$ complemented, "*I was tickled to see some of the facial expressions incorporated in it, it made a difference.*" Competence was also evident when they commented on what was appropriate and not for robot sounds. When the panelists listened to the sound of "*huh?,*" they commented the sound being *"a little judgy"* (Laws$_{72/F}$), and that it *"should be longer"* (Diane$_{62/F}$). Big Daddy$_{65/M}$ also noted how the current tone made it challenging to understand its intended meaning: *"if you're doing laughter, you go down with 'huh' (downward sound)... it's hard to tell what that was intended to be."*

Six panelists also demonstrated **capability** during the session. For example, the Wise One$_{75/M}$ suggested how to incorporate different sounds into the robot's design, such as applause (*"I interpreted applause for QT [as when] I had a very good day today"*) and nature sounds (*"if I've had a stressful day, I don't need to go outside or to log on to my computer. I can take QT ...play some background noise"*).

Robot design outputs: The panelists' connection between the robot and real-world experiences offered valuable insights into their concerns about current technology. For example, Anna's comment about the phone offering too many choices highlighted that our robot should not give too many choices at one time. We also removed sounds that the panelists found inappropriate (i.e., the 'huh?' sound) and incorporated suitable sounds (i.e., 'clapping' sound at the end of the activity) based on the panelists' recommendations.

3.4.7 Panel 7: Evaluation and reflection. In this final panel, we reflected on the panel process and presented the latest progress on the robot. The reflection included a robot demo of the photo activity, which included the gestures, facial expressions, and sound effects created or recommended by the panelists. The demo also featured robot dialogues generated using OpenAI's GPT3 (text-davinci-003) model [46]. This step allowed the panelists to see elements of their work in the latest iteration of the robot while providing additional feedback for the team.

Design-learning outcomes: As we reflected on our progress together, four panelists demonstrated their **competence** by providing insights into their thoughts about the design progress. For example, Big Daddy$_{65/M}$'s comment, "*That was a big improvement*," showed his ability to assess and appreciation in the design advancements.

Four panelists also demonstrated their **character** in Panel 7. For example, Anna$_{85/F}$ was critical when commenting that it was inappropriate for the robot to assume someone in the picture was dead: "*The assumption is that the robot seems to understand certain things, but doesn't ask you a question about it at all... we're talking about a brother. And suddenly, the robot is saying, 'Well, it's nice to have a memory of someone that we love.' And maybe it wasn't that at all.*" Big Daddy$_{65/M}$ reflected on how he adapted his character by learning patience and realizing the robot's purpose:

> *"Patience in the process. [When we] first started back in December, I was rather impatient to see... how little it could do at the beginning, and...as we contributed things, how slow that process was... Those other things are regurgitation...that's not what this is doing. This is finessing. This is taking the information and trying to assimilate it and trying to communicate it... give it time to spend time with somebody and interact with somebody and build a database of these stories and experiences. I think QT would be much more interesting."*

HAL-9000$_{76/M}$ also presented his reflective character as he highlighted the diversity and positive dynamic of the group that enhanced the panelists' participation: *"Everybody comes to the research project with the same frame of reference is going to fail. There are 11 minds [and] attitudes with different historical knowledge."*

Robot design outputs: Anna$_{85/F}$'s point on the robot making false assumptions during the photograph activity highlighted the need to improve the dialogue to prevent the robot from making assumptions. Big Daddy$_{65/M}$'s comment about patience implies the importance of ensuring the robot is intuitive to use since not all users will be patient.

3.5 Final Robot Design and Post-Panel Showcase

We ended with an autonomous robot that initiated interactions by introducing itself, asking the user to show a picture, detecting the content of the picture, and asking relevant questions. During interactions, the robot used gestures, sounds, and faces co-designed by the panel and research team.

We showcased the final result of the photograph activity to other end users on an individual basis. Three panelists extended their **courage** to share their newfound depth of knowledge about robots and ikigai with other potential users in their social circle. Anna$_{85/F}$ engaged three friends, and Catina$_{72/F}$ and HAL-9000$_{76/M}$ helped us find five other participants. Additionally, Catina also sat with us in one of the hour-long evaluations. She shared with us: "*It was fascinating to see and hear from the other side.*"

4 DISCUSSION

The longitudinal panel approach empowers older adults by scaffolding their learning outcomes and enabling them to provide valuable design feedback, even in a diverse group with varying technological backgrounds and cognitive levels. As shown in Table 2, the panelists' hierarchy of design-learning skills increased over time. The panelists initially were building capacity but gradually developed higher levels of design-learning skills. While previous literature has explored co-design sessions with multiple workshops [3, 34, 36, 48, 56], scaffolding [4, 58], and community-based research [38, 43, 44], this paper shows how the panelists' learning process provided nuanced feedback that informed our iterative robot prototype design. The panelists' and the robot's skill development lead to the question: *"How can we effectively conduct longitudinal panels for older adults to enhance their learning experience?"* In response, we offer the following guidelines:

1. Enhancing *capacity* and *confidence* by designing the panel iteratively: We iteratively designed our panels by shaping each panel's content based on the panelists' understanding of the topic and the research team's progress. This iterative process enhanced their comfort and **capacity** with the robot, ikigai, and co-design, and also enhanced their **confidence** in sharing thoughts. For example, the design of deeper ikigai discussions in Panels 2 and 3 demonstrated an enhance in reflection with capacity and confidence among the panelists (Panel 2: 11 capacity and 3 confidence; Panel 3: 8 capacity and 4 confidence). Our approach differed from traditional co-design 'curriculums' [57], allowing us to tailor session pace and content, align feedback with technical progress, and adapt to panelists' needs, which is crucial for older adults who sometimes need extra technological training [11, Ch. 8].

2. Building *capability* and *competence* by repeat interaction with the iterative robot: Providing panelists with regular opportunities to interact with the robot not only gave them consistent exposure to its technical evolution, but also showed that we valued their design suggestions. This interaction helped them become more familiar with the robot, building **capability**, and enhancing **competence**. For instance, following five panels of robot interaction, in Panel 6, we presented the panelists with an iterative robot featuring refined robot sounds, facial expressions, and gestures, some designed by the panelists. Thus, six panelists showed capability and competence, with specific mention on what they saw the first time. Repetition and scaffolding ensured regular exposure to the robot to panelists with varying technological knowledge, which promoted refinement of their thoughts [54] and created familiarity and understanding of the robot [1, 26, 58] and the ikigai. Furthermore, by seeing the development, the panelists came to understand the nuances of robot design and could imagine design opportunities beyond the current prototype, with "patience" for the time needed to make them a reality.

3. Strengthening *character* and *capacity* by embracing diversity in the team: As highlighted by HAL-9000$_{76/M}$, our design team included user panelists with varying backgrounds, technological expertise, and cognitive skills, and a research team of faculty, industry and community researchers, and graduate and undergraduate students with diverse knowledge of ikigai, robots, and aging. This approach transformed weaknesses into strengths, enhancing the design process [24] and identifying unknown weaknesses through varied perspectives [13], thus boosting team growth and effectiveness. The diversity fostered each panelist's unique **character**, enabling varied progress in developing **capacity**. For instance, panelists who lacked prior robot experience, such as Big Daddy, gave fresh perspectives that evolved from unrelated questions (i.e., the robot's olfactory features) in Panel 1 to offering profound insights and building "patience" in his character in Panel 7. With more insights, the research team, in turn, could provide timely feedback on the panelists' questions, aiding in their technology learning [22].

4. Amplifying *courage* and *connection* by homework and observations: Homework assignments and panelists' spontaneous observations of robots and ikigai outside the sessions led to more well-rounded feedback. These shared experiences played a crucial role in enhancing the robot design. This process not only empowered the panelists, fostering their **courage** to engage and share insights within their networks, but also encouraged them to **connect** their learnings with the wider world. We see such examples in Panel 3, where we encouraged panelists to observe real-world robot interactions, resulting in seven panelists showing connection as they shared technology insights they saw in their lives to the group, or in Post-panel Showcase, where they invited their friends to interact with the robot. Thus, their ability to articulate needs and offer constructive feedback and empowerment aligns with prior studies [14, 23] and signifies growth in design-learning skills.

5 FUTURE WORK AND LIMITATIONS

After this longitudinal panel, we plan to continue evaluating and iterating the robot and activity designs, with the goal of deploying the robots in elder care facilities, including the memory care facility in which two of our panelists live.

While our study primarily focused on design outcomes, we also observed indirect benefits to the many people involved in the study. For example, HAL-9000's daughter shared, "*Dad is really enjoying being part of a science project again... he worked at the [lab] at the [university] for many years... it has been hard on him not having that space since he moved to [town name]. It's great when research benefits the researchers and the community!*" This comment highlights the fulfillment panelists could gain from such projects, suggesting future research to explore co-design's benefits including enhanced well-being, purpose, active aging, and social engagement for older adults [12, 26]. Additionally, the panels provided a learning platform for both technical and social science/design students. Technical students, usually focused on engineering solutions, gained experience in a creative, iterative, human-centered design process [59], while social science/design students developed a deeper understanding of technical capabilities and challenges, leading to more practical design inputs. This suggests future research potential in exploring the impact of iterative panels on student development.

The limitations in our study also present opportunities for future research. First, our group exhibited positive and fun dynamics, such as bursting into laughter when the robot made a touchdown gesture, but this dynamic may vary in other groups and could impact their learning. We focused on older adults, both with and without dementia, yet didn't explore specific subsets of this group or populations beyond older adults. The longitudinal nature of the panel was time-consuming and required the physical co-presence of the group. All these limitations offer opportunities for future research, such as diversifying the panelists, accommodating participants with limited time, or conducting panels online.

6 CONCLUSION

We introduced the concept of a "longitudinal panel," which is distinct from prior participatory design methods or series of co-design workshops. Our design team was comprised of a panel of 11 older adults with varying levels of cognitive ability, a community researcher, a social sciences/design team, a technical team, and an industry researcher. We met regularly for six months to iteratively design and refine a robot-guided photograph-based conversational activity. During these meetings, older adult panelists engaged in carefully curated activities to mature this interaction design, and they learned about the robot including its abilities limitations as well as the concept of ikigai. We found evidence that our panelists demonstrated several design-learning outcomes — capacity, confidence, capability, competence, connection, and character — all of which enhanced the panelists' engagement and participation in the design process. Our longitudinal panel yielded detailed, nuanced feedback that would not have been possible in a compressed amount of time.

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REFERENCES

[1] Gopika Ajaykumar, Kaitlynn Taylor Pineda, and Chien-Ming Huang. 2023. Older adults' expectations, experiences, and preferences in programming physical robot assistance. *International Journal of Human-Computer Studies* 180 (2023), 103127.

[2] Patrícia Alves-Oliveira, Elin A Björling, Patriya Wiesmann, Heba Dwikat, Simran Bhatia, Kai Mihata, and Maya Cakmak. 2022. Robots for Connection: A Co-Design Study with Adolescents. In *2022 31st IEEE International Conference on Robot and Human Interactive Communication (RO-MAN)*. IEEE, 578–583.

[3] Victor Nikhil Antony, Sue Min Cho, and Chien-Ming Huang. 2023. Co-designing with older adults, for older adults: Robots to promote physical activity. In *Proceedings of the 2023 ACM/IEEE International Conference on Human-Robot Interaction (HRI)*. IEEE, 506–515.

[4] Edwin Blake, Uariaike Mbinge, Heike Winschiers-Theophilus, Donovan Maasz, Colin Stanley, Chris Paul Muashekele, and Gereon Koch Kapuire. 2021. Going beyond empowered design by scaffolding inter-community engagement. In *Proceedings of the 10th International Conference on Communities & Technologies-Wicked Problems in the Age of Tech*. 224–233.

[5] Edwin H Blake, William David Tucker, Meryl Glaser, and Adinda Freudenthal. 2011. Deaf telephony: Community-based co-design (case study). (2011).

[6] Lisa M Bouillion and Louis M Gomez. 2001. Connecting school and community with science learning: Real world problems and school–community partnerships as contextual scaffolds. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching* 38, 8 (2001), 878–898.

[7] Edward Joseph Caruana, Marius Roman, Jules Hernández-Sánchez, and Piergiorgio Solli. 2015. Longitudinal studies. *Journal of Thoracic Disease* 7, 11 (2015), E537.

[8] Katerina Cerna, Claudia Müller, Dave Randall, and Martin Hunker. 2022. Situated scaffolding for sustainable participatory design: Learning online with older adults. *Proceedings of the ACM on Human-Computer Interaction* 6, GROUP (2022), 1–25.

[9] Victoria Clarke, Virginia Braun, and Nikki Hayfield. 2015. Thematic analysis. *Qualitative psychology: A practical guide to research methods* 3 (2015), 222–248.

[10] Chris Conley. 2004. Leveraging design's core competencies. *Design Management Review* 15, 3 (2004), 45–51.

[11] Sara J Czaja, Walter R. Boot, Neil Charness, and Wendy A. Rogers. 2019. *Designing for older adults: Principles and creative human factors approaches*. CRC press.

[12] Neuciani Ferreira da Silva Sousa and Marilisa Berti de Azevedo Barros. 2020. Level of active aging: Influence of environmental, social and health-related factors. *Archives of Gerontology and Geriatrics* 90 (2020), 104094.

[13] Isha Datey, Hunter Soper, Khadeejah Hossain, Wing-Yue Geoffrey Louie, and Douglas Zytko. 2023. Ethical participatory design of social robots through co-construction of participatory design protocols. (2023), 2454 – 2461.

[14] Jennifer L. Davidson and Carlos Jensen. 2013. Participatory design with older adults: An analysis of creativity in the design of mobile healthcare applications. In *Proceedings of the 9th ACM Conference on Creativity & Cognition* (Sydney, Australia) *(C&C '13)*. Association for Computing Machinery, New York, NY, USA, 114–123. https://doi.org/10.1145/2466627.2466652

[15] Tripp Driskell, James E Driskell, C Shawn Burke, and Eduardo Salas. 2017. Team roles: A review and integration. *Small Group Research* 48, 4 (2017), 482–511.

[16] Jane Elliott, Janet Holland, and Rachel Thomson. 2008. Longitudinal and panel studies. *The SAGE handbook of social research methods* (2008), 228–248.

[17] Tech enhanced Life. 2023. Longevity Explorers: About. Retrieved 2023 from https://www.techenhancedlife.com/longevity-explorers

[18] Priska Flandorfer. 2012. Population ageing and socially assistive robots for elderly persons: The importance of sociodemographic factors for user acceptance. *International Journal of Population Research* 2012 (2012).

[19] Héctor García and Francesc Miralles. 2017. *Ikigai: The Japanese secret to a long and happy life*. Penguin.

[20] Amanda A Geppert. 2014. Co-design for community capacity building. In *Proceedings of the 13th Participatory Design Conference: Short Papers, Industry Cases, Workshop Descriptions, Doctoral Consortium papers, and Keynote abstracts-Volume 2*. 251–254.

[21] Maribeth Gettinger and Jill K Seibert. 2002. Contributions of study skills to academic competence. *School Psychology Review* 31, 3 (2002), 350–365.

[22] Philip J Guo. 2017. Older adults learning computer programming: Motivations, frustrations, and design opportunities. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*. 7070–7083.

[23] Christina N. Harrington, Katya Borgos-Rodriguez, and Anne Marie Piper. 2019. Engaging low-income African American older adults in health discussions through community-based design workshops. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (Glasgow, Scotland Uk) *(CHI '19)*. Association for Computing Machinery, New York, NY, USA, 1–15. https://doi.org/10.1145/3290605.3300823

[24] Diana Hicks. 2001. Mixed-ability classrooms: Turning weakness into strength. *Readings in Methodology* (2001), 79.

[25] Jocelyn A Hollander. 2004. The social contexts of focus groups. *Journal of Contemporary Ethnography* 33, 5 (2004), 602–637.

[26] Long-Jing Hsu, Janice K Bays, Katherine M Tsui, and Selma Sabanovic. 2023. Co-designing Social Robots with People Living with Dementia: Fostering Identity, Connectedness, Security, and Autonomy. In *Proceedings of the 2023 ACM Designing Interactive Systems Conference*. 2672–2688.

[27] Long-Jing Hsu, Waki Kamino, Weslie Khoo, Katherine Tsui, David Crandall, and Selma Šabanović. 2023. Working together toward ikigai: Co-designing robots that can help us achieve meaning and purpose in life. *XRDS: Crossroads, The ACM Magazine for Students* 30, 1 (2023), 38–45.

[28] Long-Jing Hsu, Weslie Khoo, Natasha Randall, Waki Kamino, Swapna Joshi, Hiroki Sato, David J Crandall, Katherine M Tsui, and Selma Šabanović. 2023. Finding its voice: The influence of robot voice on fit, social attributes, and willingness to use among older adults in the U.S. and Japan. In *2023 32nd IEEE International Conference on Robot and Human Interactive Communication (RO-MAN)*. 2072–2079. https://doi.org/10.1109/RO-MAN57019.2023.10309390

[29] Eric Jensen, Nicholas Jones, Megan Rabe, Beverly Pratt, Lauren Medina, Kimberly Orozco, and Lindsay Spell. 2021. The chance that two people chosen at random are of different race or ethnicity groups has increased since 2010. https://www.census.gov/library/stories/2021/08/2020-united-states-population-more-racially-ethnically-diverse-than-2010.html

[30] Birgit Jobst, Eva Köppen, Tilmann Lindberg, Josephine Moritz, Holger Rhinow, and Christoph Meinel. 2012. The faith-factor in design thinking: Creative confidence through education at the design thinking schools Potsdam and Stanford? *Design Thinking Research: Measuring Performance in Context* (2012), 35–46.

[31] Waki Kamino, Long-Jing Hsu, Swapna Joshi, Natasha Randall, Abhijeet Agnihotri, Katherine M Tsui, and Selma Šabanović. 2023. Making meaning together: Co-designing a social robot for older adults with Ikigai experts. *International Journal of Social Robotics* (2023), 1–16.

[32] Weslie Khoo, Long-Jing Hsu, Kyrie Jig Amon, Pranav Vijay Chakilam, Wei-Chu Chen, Zachary Kaufman, Agness Lungu, Hiroki Sato, Erin Seliger, Manasi Swaminathan, et al. 2023. Spill the tea: When robot conversation agents support well-being for older adults. In *Companion of the 2023 ACM/IEEE International Conference on Human-Robot Interaction*. 178–182.

[33] Amanda Lazar, Raymundo Cornejo, Caroline Edasis, and Anne Marie Piper. 2016. Designing for the third hand: Empowering older adults with cognitive impairment through creating and sharing. In *Proceedings of the 2016 ACM Conference on Designing Interactive Systems*. 1047–1058.

[34] Hee Rin Lee, Selma Šabanović, Wan-Ling Chang, Shinichi Nagata, Jennifer Piatt, Casey Bennett, and David Hakken. 2017. Steps toward participatory design of social robots: Mutual learning with older adults with depression. In *Proceedings of the 2017 ACM/IEEE International Conference on Human-Robot Interaction*. 244–253.

[35] Hee Rin Lee, Fei Sun, Tariq Iqbal, and Brenda Roberts. 2023. Reimagining robots for dementia: From robots for care-receivers/giver to robots for carepartners. In *Proceedings of the 2023 ACM/IEEE International Conference on Human-Robot Interaction*. 475–484.

[36] Tuck Wah Leong and Toni Robertson. 2016. Voicing values: Laying foundations for ageing people to participate in design. In *Proceedings of the 14th Participatory Design Conference: Full papers-Volume 1*. 31–40.

[37] Nathan A Lewis and Patrick L Hill. 2020. Does being active mean being purposeful in older adulthood? Examining the moderating role of retirement. *Psychology and Aging* 35, 7 (2020), 1050.

[38] Alex Jiahong Lu, Shruti Sannon, Cameron Moy, Savana Brewer, Jaye Green, Kisha N Jackson, Daivon Reeder, Camaria Wafer, Mark S Ackerman, and Tawanna R Dillahunt. 2023. Participatory Noticing through Photovoice: Engaging Arts-and Community-Based Approaches in Design Research. In *Proceedings of the 2023 ACM Designing Interactive Systems Conference*. 2489–2508.

[39] LuxAI. 2023. LuxAI - Award winning social robots for autism and special needs education. https://luxai.com Accessed Sept. 27, 2023.

[40] Michael Massimi, Ronald M Baecker, and Michael Wu. 2007. Using participatory activities with seniors to critique, build, and evaluate mobile phones. In *Proceedings of the 9th International ACM SIGACCESS Conference on Computers and Accessibility*. 155–162.

[41] Brenna McNally, Matthew Louis Mauriello, Mona Leigh Guha, and Allison Druin. 2017. Gains from participatory design team membership as perceived by child alumni and their parents. In *Proceedings of the 2017 CHI conference on Human Factors in Computing Systems*. 5730–5741.

[42] Meredith Minkler. 2005. Community-based research partnerships: Challenges and opportunities. *Journal of Urban Health* 82 (2005), ii3–ii12.

[43] Sanika Moharana, Alejandro E Panduro, Hee Rin Lee, and Laurel D Riek. 2019. Robots for joy, robots for sorrow: Community based robot design for dementia caregivers. In *2019 14th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*. IEEE, 458–467.

[44] Amal Nanavati, Patricia Alves-Oliveira, Tyler Schrenk, Ethan K Gordon, Maya Cakmak, and Siddhartha S Srinivasa. 2023. Design principles for robot-assisted feeding in social contexts. In *Proceedings of the 2023 ACM/IEEE International Conference on Human-Robot Interaction*. 24–33.

[45] Harold G Nelson and Erik Stolterman. 2014. *The design way: Intentional change in an unpredictable world*. MIT press.

[46] OpenAI. 2023. ChatGPT: Get instant answers, find inspiration, learn something new. https://chat.openai.com/ Accessed Sept. 27, 2023.

[47] Simon O'Rafferty, Hannah Curtis, and Frank O'Connor. 2014. Mainstreaming sustainability in design education–a capacity building framework. *International Journal of Sustainability in Higher Education* 15, 2 (2014), 169–187.

[48] Anastasia K Ostrowski, Cynthia Breazeal, and Hae Won Park. 2021. Long-term co-design guidelines: Empowering older adults as co-designers of social robots. In *2021 30th IEEE International Conference on Robot & Human Interactive Communication (RO-MAN)*. IEEE, 1165–1172.

[49] Natasha Randall, Swapna Joshi, Waki Kamino, Long-Jing Hsu, Abhijeet Agnihotri, Grace Li, Donald Williamson, Kate Tsui, and Selma Šabanović. 2022. Finding ikigai: How robots can support meaning in later life. *Frontiers in Robotics and AI* 9 (2022), 1011327.

[50] Natasha Randall, Selma Šabanović, and Wynnie Chang. 2018. Engaging older adults with depression as co-designers of assistive in-home robots. In *Proceedings of the 12th EAI International Conference on Pervasive Computing Technologies for Healthcare*. 304–309.

[51] JM Rocha, MJ Honorato, and E Costa. 2016. Assessment of expert panels. *IEEE Latin America Transactions* 14, 1 (2016), 303–308.

[52] Wendy A Rogers, Travis Kadylak, and Megan A Bayles. 2022. Maximizing the benefits of participatory design for human–robot interaction research with older adults. *Human Factors* 64, 3 (2022), 441–450.

[53] Dawn K Sakaguchi-Tang, Jay L Cunningham, Wendy Roldan, Jason Yip, and Julie A Kientz. 2021. Co-design with older adults: Examining and reflecting on collaboration with aging communities. *Proceedings of the ACM on Human-Computer Interaction* 5, CSCW2 (2021), 1–28.

[54] Laura Stegner, Emmanuel Senft, and Bilge Mutlu. 2023. Situated participatory design: A method for in situ design of robotic interaction with older adults. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*. 1–15.

[55] Anders W Tell. 2014. What capability is not. In *Perspectives in Business Informatics Research: 13th International Conference, BIR 2014, Lund, Sweden, September 22-24, 2014. Proceedings 13*. Springer, 128–142.

[56] Sofia Thunberg and Tom Ziemke. 2021. Social robots in care homes for older adults: Observations from participatory design workshops. In *Social Robotics: 13th International Conference, ICSR 2021, Singapore, Singapore, November 10–13, 2021, Proceedings 13*. Springer, 475–486.

[57] Sefora Tunc, Femke Nijboer, Angelica M Tinga, and Monique Tabak. 2023. "Hi, my mame is Robin"–Remotely co-designing an embodied conversational agent for empathy with older adults. In *International Conference on Human-Computer Interaction*. Springer, 376–391.

[58] Jenny Waycott, Sonja Pedell, Frank Vetere, Elizabeth Ozanne, Lars Kulik, Alan Gruner, and John Downs. 2012. Actively engaging older adults in the development and evaluation of tablet technology. In *Proceedings of the 24th Australian Computer-Human Interaction Conference*. 643–652.

[59] Lauren Wilcox, Betsy DiSalvo, Dick Henneman, and Qiaosi Wang. 2019. Design in the HCI classroom: Setting a research agenda. In *Proceedings of the 2019 on Designing Interactive Systems Conference*. 871–883.

[60] Charlotta Windahl. 2017. Market sense-making in design practice: Exploring curiosity, creativity and courage. *Journal of Marketing Management* 33, 3-4 (2017), 280–291.

[61] Ya-Huei Wu, Jérémy Wrobel, Mélanie Cornuet, Hélène Kerhervé, Souad Damnée, and Anne-Sophie Rigaud. 2014. Acceptance of an assistive robot in older adults: a mixed-method study of human–robot interaction over a 1-month period in the Living Lab setting. *Clinical Interventions in Aging* (2014), 801–811.